Net Effects:

A Model for the Evolution of Early and Middle Preclassic Socio-Political Complexity in the Upper Belize River Valley, Belize

by

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ABSTRACT

This dissertation examines how the interplay between regional socio-economic networks and local political strategies contributed to increases in ancient Maya socio-political complexity in the Upper Belize River Valley (UBRV) during the Early and Middle Preclassic periods (1200–300 BC). Drawing on theories of political economy, including dual-processual theory and collective action theory, this study evaluates the co-construction of village-level leadership strategies and regional socio-economic networks through a relational, diachronic framework. Using archaeological correlates of political organization alongside geochemical sourcing of ceramics, network analysis, and Exponential Random Graph Models (ERGMs), this project reconstructs patterns of inter-village interaction and evaluates how access to, and varied engagement with, socio-economic networks shaped emerging political institutions.

Results demonstrate that villages in the UBRV initially relied on predominantly corporate political strategies but increasingly adopted exclusionary leadership practices through time. Concurrently, regional socio-economic networks became denser and increasingly structured around bridging social capital, with localized coalitions emerging during the Late Middle Preclassic. Villages occupying brokerage positions within these networks were able to influence economic flows to consolidate political authority. These findings demonstrate that exclusionary leadership strategies were closely tied to exclusive network positions, providing early evidence that political strategies among the Maya were reinforced by a village's structural position within regional socio-economic networks. Additionally, the study identifies a consistent temporal lag between the emergence of exclusionary economic and ideological practices and their materialization in monumental architecture, suggesting that social and economic foundations preceded architectural expressions of political power.

This research demonstrates that socio-political complexity in the UBRV developed through multiple, non-linear pathways shaped by the interaction between local political strategies and regional network structures. Methodologically, the study introduces new quantitative approaches to evaluating political organization, including the use of valued ERGMs and large-scale geochemical ceramic datasets to reconstruct economic interaction. More broadly, this project contributes to comparative studies of socio-political complexity by illustrating how relational approaches integrating top-down political analysis with bottom-up network dynamics can provide new insights into the emergence of early complex societies.

DEDICATION

To my wife, Claire. Your encouragement, insight, and unwavering support made this work possible. Thank you for walking this path with me. I love you.

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This research would not have been possible without the generous support, guidance, and friendship of many mentors, collaborators, and colleagues. In a very real sense, it was only because of my position within several overlapping academic and personal networks that I was able to make the connections necessary to complete this study. While this dissertation examines ancient networks, it is equally a product of the networks that sustain scholarship today.

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May the merits of all involved in this research contribute to greater knowledge, compassion, and the happiness of all beings.

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RELATIONAL PERSPECTIVES AND DISSERTATION ORGANIZATION

Recent advances in Maya archaeology have transformed our understanding of this ancient civilization. In the last few decades, breakthroughs in epigraphy—the decipherment and analysis of ancient Maya texts—have revolutionized our knowledge of Classic period (AD 250-900) political and socioeconomic dynamics. These texts offer direct, if elite-centered, evidence of how Maya cities and villages negotiated complex webs of political alliance, social obligation, and economic exchange. Yet, as these advances have illuminated the Classic Maya world at its height, they have also sharpened a fundamental question that remains largely unanswered: how did such sophisticated urban centers, with their monumental architecture, elaborate writing systems, and intricate political hierarchies, emerge from the modest farming communities of earlier centuries?

To answer that question, we must look to the Early and Middle Preclassic periods (1200-300 BC), when the foundations of Maya complexity were first laid. But here we face a profound challenge. Writing did not yet exist. Centuries of village life, however, left the material traces of political, social, and economic activities. Until recently, archaeological methods lacked the fine-grained resolution needed to reconstruct how villages interacted with one another and organized themselves. This study seeks to bridge that gap by using new methods and large regional-scale datasets to illuminate the earliest networks of power and exchange that would eventually give rise to the great kingdoms of the Classic Maya world. But why would a focus on political and socio-economic spheres shed light on the development and evolution of socio-political complexity?

For centuries, scholars have examined the development of complexity from diverse perspectives, often framing it within the prevailing political, social, and economic theories of the time (e.g., Hobbes 2017 [1651]; Marx and Engels 1909 [1867]; Morgan 1985 [1877]; Service 1962, 1975; Fried 1967). Today it is not controversial to say that increasing scales of political, social, and economic interaction are central to the transition from small-scale to more complex societies. Given its deep-time perspective, the discipline of archaeology provides a powerful lens for exploring these processes across time and space, tracing specific trajectories of change that shaped ancient societies and continue to inform our own.

The specific research question this study addresses is: *how did the interaction between regional socio-economic networks and local political strategies restructure patterns of social, political, and economic differentiation through time in the Upper Belize River Valley?* This project investigates the evolution of socio-political complexity through an examination of socio-economic networks and local political strategies of the Early and Middle Preclassic Maya (1200–300 BC) in the Upper Belize River Valley (UBRV) of western Belize (Figure 1.1). The interplay between site-level and regional dynamics over time provides a framework for analyzing how shifting political strategies and network structures reorganized patterns of differentiation across communities.. By focusing on the evolution and interplay between these top-down and bottom-up processes, this project highlights how Early and Middle Preclassic trajectories culminated in the Chicanel and Classic period kingdoms of the Late Preclassic (300 BC–AD 250) and Classic (AD 250–900) periods.

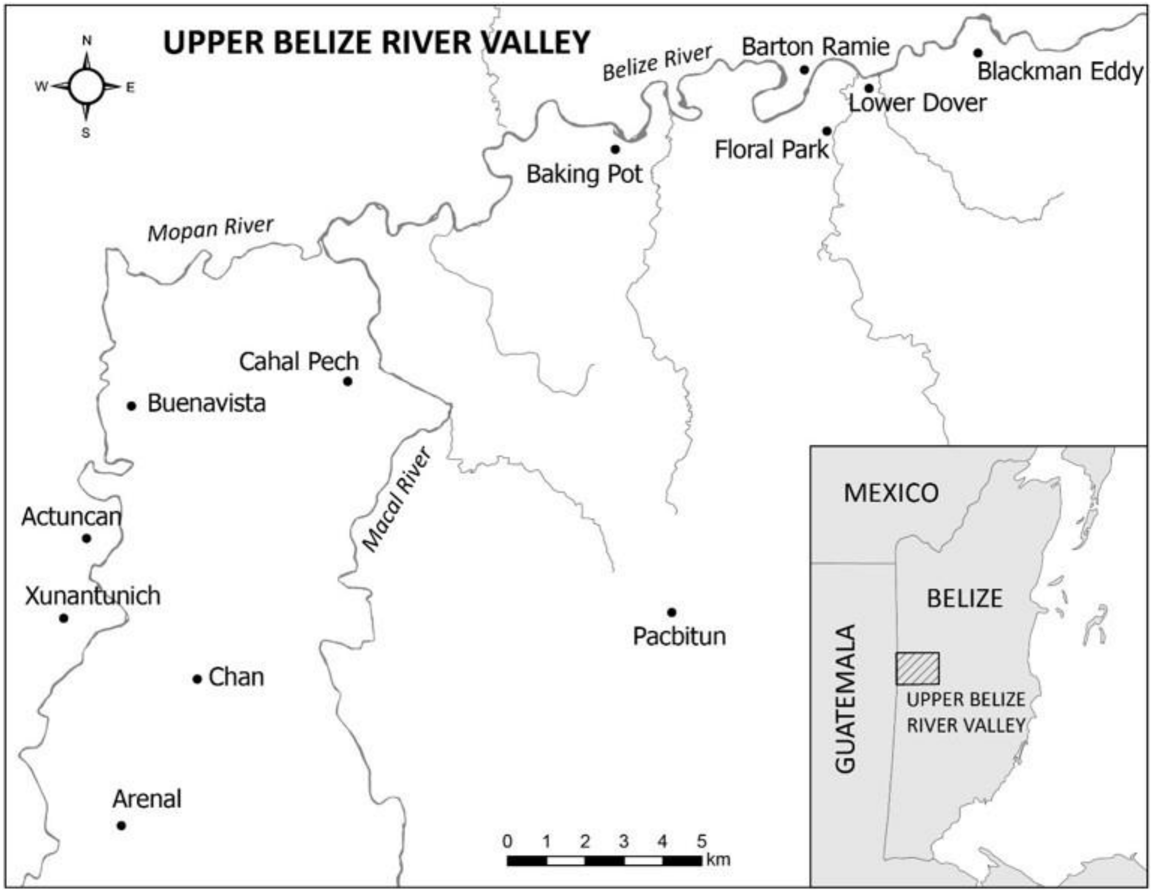

Figure 1.1. Map of the Upper Belize River Valley. Marked sites are mentioned in the text.

Current evidence, and new evidence presented in this study, point to considerable variability in political strategies and social networks across sites during the Preclassic, which produced significant differences in Classic period outcomes. This variability underscores that complexity did not evolve along a single, linear path. Instead, examining local variation within the midst of regional relationships provides a valuable perspective on the multiple ways through which complexity emerged. Importantly, villages did not evolve in a vacuum, rather the relationships between them created a structure which helped shape political and socio-economic actions at individual villages. This project is especially timely given recent calls for greater attention to local diversity in the development of Maya socio-political complexity (Horn et al. 2020; Pugh 2022). Additionally, this project answers a challenge presented by Sherman Horn (2015), who noted that scholars lack the data required for formal network analyses of Preclassic Maya villages in the UBRV.

A Relational Perspective

Scholars have long recognized that to understand an organizational system, one must examine how its parts interact. In the Western Intellectual Tradition this idea reaches back at least to the mid-4th century BC when Aristotle (1924:237) noted that "[a]ll wholes as opposed to mere aggregates must have a cause of unity, which in bodies is contact, viscidity, etc."[1] In social terms, the relationships between people generate a system greater than any one individual or group could create alone. To grasp the broader picture, then, we must focus on these relationships.

This does not mean that individual components are unimportant or unworthy of study. Rather, an exclusive focus on them risks obscuring the larger dynamics at play. As sociologist Mustafa Emirbayer (1997) observes, modern social scientists too often analyze social systems as though they consist of isolated, static units, which in turn exaggerates the prominence of the individual part. Such an approach effectively takes discrete elements and attempts to force them together to reconstruct a whole. Emirbayer instead argues that the key to understanding the whole lies in explicitly studying the dynamic relationships among parts, not simply inferring connections from the components themselves. The distinction is subtle but critical. While understanding the characteristics of individual parts

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[1] This is thought by some to be the origin of the phrase "the sum is greater than the whole of the parts." *Viscidity* means "to gel together," like a viscous liquid.

is necessary, it is the patterns of interaction between them that ultimately reveal how the system functions.

This project adopts a relational approach to examine how small-scale farming villages began the long transformation into complex kingdoms. The dynamic social and economic interactions among these villages, combined with internal political currents, set them on trajectories of increasing complexity, trajectories only fully visible in hindsight. Each trade relationship and political decision contributed to the connective "viscidity" of the networks binding these communities together.

Echoing Bourdieu's (1977) concept of *habitus*, every action became both the product of past conditions and the foundation for future ones, forming a flexible yet enduring structure within which villagers and leaders lived, adapted, and transmitted relationships across generations. By applying formal network analytical methods and models, this project investigates these evolving connections to illuminate the actions and consequences of a few villages of farmers and their descendants. In doing so, it seeks to foreground a dimension often overlooked in archaeology but central to the human experience: our relationships with one another.

Why Do We Connect?

If the relationships between human groups are important for understanding the overall structure of human systems, why is it that we form these relationships in the first place? Many would argue that we are evolutionarily driven to connect with one another. In a review of evolutionary anthropological literature, Curtis Marean (2015) points out that at least 150,000 years ago our species exhibited modern behavior, which is characterized by advanced cognition capable of symbolic thinking, *hyperprosociality* (i.e., a proclivity for cooperative behavior with unrelated persons), and a dependence on social learning. The anthropological data are backed up and enhanced by neurological data.

Matthew Lieberman, a social cognitive neuroscientist, has spent decades researching why humans are social. In his book *Social*, he makes a convincing argument that due to our species' evolutionary trajectory the default mode of our brains is focused on social interactions with other humans (Lieberman 2013). Indeed, the results of his research suggest that various parts of the human brain are hardwired to focus on connecting with others, anticipating or guessing their thoughts, and then harmonizing with them.

A surge of recent research has sought to answer this question from a wide range of perspectives and disciplines including anthropology, sociology, neuroscience, religion, and psychology. Despite their differences, these approaches share the fundamental insight that humans have an innate drive to connect with one another. The evidence surrounds us in the many institutions we create such as schools, clubs, religious organizations, sports teams, stock markets, nations, and countless others, all designed to foster cooperation, safety, and collective achievement Together, these perspectives highlight why examining the institutions that structured interaction, cooperation, and inequality in the Upper Belize River Valley is essential for understanding how socio-political complexity emerged and transformed through historically contingent social and economic relationships.

How Do We Connect?

One of the central themes of modern network science is understanding how people connect to one another and how those connections shape social structures. One well-known example is Stanley Milgram's (1967) Small-World Experiment, often summarized as "six degrees of separation." The premise is that no two people are more than six connections apart, linked through friends of friends and so on, creating what is essentially a "small world" network. For instance, my friend's ex-wife is the cousin of a woman who went to high school with the pop-Queen Taylor Swift, meaning I am only four degrees of separation away from Taylor Swift. Talk about a small-world! However, given the nature of these connections, it is highly unlikely that I will get free concert tickets. This lighthearted example illustrates that it is more than the ties that matter, rather it is the type of tie and the structure of those ties that present advantages and disadvantages in distinct scenarios.

Mark Granovetter's (1973) concept of "the strength of weak ties" is a prime example of how humans create and benefit from different types of social connections. Strong ties, such as those with close friends and family, provide social security, cooperation, and conflict resolution but often create an echo chamber of shared information. In contrast, weak ties, or connections with people outside one's immediate circle, can be more useful in specific contexts, such as finding a job. Granovetter found that people who relied on wider, weaker ties were more successful in job searches than those who depended solely on their close contacts. Decades later, Duncan Watts and Steven Strogatz (1998) used computational models to show that the strength of weak ties holds small-world networks together.

These and similar studies have led to the understanding that different types of social ties and network positions bring about different advantages and disadvantages. One of the classic studies to illustrate this concept is John Padgett and Christopher Ansell's (1993) investigation of the rise of the Medici family during the Renaissance in Florence, Italy.

Most of the prominent families in Florence tended to form dense clusters through business and marriage relations. The Medici, by contrast, frequently occupied intermediate positions within the broader social network, acting as bridges between otherwise disconnected clusters. This intermediary position generated social capital—defined by Ronald Burt (2005:4) as "the advantage created by a person's location in a structure of relationships." By leveraging this structural advantage, the Medici were able to exert disproportionate influence across the network and gradually consolidate political power within Florence.

These studies illustrate that the ways people connect to one another create social structures, and that positions within those structures can shape historical outcomes. Archaeology is particularly well suited to examine these dynamics because the time-depth investigated by the discipline allows researchers to observe how such processes unfold over long periods. This project builds on that advantage to explore how the Early and Middle Preclassic Maya connected with one another, and how those connections contributed to broader patterns of social and political change.

Outline of the Study

This study first establishes the theoretical and cultural foundations needed to understand the research and then systematically addresses each component of the overarching research question. Because the question engages both political and socio-economic domains, I treat them as two related but distinct lines of inquiry that are later woven together to inform one another.

Chapter 2 outlines the theoretical framework, focusing on the anthropological and archaeological concepts central to this study. I define socio-political complexity in a way that emphasizes its multidimensional nature, then explore archaeological approaches that address these dimensions. This project combines the dual-processual model (Blanton et al. 1996) and collective action theory (Blanton and Fargher 2008) to examine the political dimension of socio-political complexity through political strategies that range from corporate and collective to exclusionary and autocratic. The relational socio-economic dimension is approached through the lens of social capital. In this study, each village occupied a specific position within the regional network and leveraged that position for political and economic gain. The broader network itself falls along a continuum from close-knit bonding networks to more open bridging networks. These political and socio-economic spectra intersect and shape one another. The chapter concludes with a discussion of the archaeological correlates expected for different positions along these spectra, correlates that I test in later chapters.

Chapter 3 presents the cultural history of the UBRV Maya, emphasizing political and socio-economic developments. It begins with the earliest evidence of human presence in the region during the Paleoindian period (11,500–8000 BC) and continues through the Archaic period (8000–1200 BC), when the first indications of trade and agriculture appear. The chapter then focuses on the periods under study: the Early Preclassic (1200–900 BC), when permanent settlements, pottery production, and local trade were established; the Early Middle Preclassic (900–600 BC); and the Late Middle Preclassic (600–300 BC), when the first signs of political hierarchy and inequality emerged. It concludes with a brief overview of later periods including the Late Preclassic (300 BC–AD 250), Classic (AD 250–900), and Postclassic (AD 900–1519) to contextualize how developments in the Middle Preclassic shaped later trajectories.

Because several correlates of political strategies depend on local aspects of the network data, I first reconstruct the socio-economic networks. Chapter 4 details the methods and results of the largest Preclassic Maya Neutron Activation Analysis (NAA) study of ceramics conducted to date. A total of 539 potsherds from 10 sites across three time periods were analyzed. I use the Uniform Manifold Approximation and Projection (UMAP) algorithm, a relatively new method in archaeology, to identify preliminary groupings within the dataset. These groups are then evaluated using traditional approaches, including Principal Components Analysis, Canonical Discriminant Analysis, and group membership assessments. The results reveal several elementally distinct pottery recipes for each period, with some continuity between periods, which can be attributed to specific villages or production zones. These results provide the foundation for reconstructing interaction networks, which are examined in the following chapter.

Chapter 5 models the socio-economic networks for each period, based on the volume of ceramic exchange among sites. The chapter opens with a concise yet comprehensive review of geochemically based network studies and an explanation of my modeling approach. I then introduce Exponential Random Graph Models (ERGMs), a relatively new but powerful tool in archaeological research. ERGMs statistically assess the effects of local processes on global network structures, allowing researchers to test empirical data against theoretical expectations. In essence, ERGMs enable archaeologists to infer how local political and economic decisions led to an observed network. Using the NAA data, I develop a valued ERGM, which analyzes the intensity of goods flow rather than simply the presence or absence of ties. To my knowledge, this represents the first archaeological application of a valued ERGM. The chapter then examines the roles of individual sites through network metrics such as degree and betweenness centrality and brokerage potential. It concludes by situating these findings within the spectrum of socio-economic networks, addressing one half of the overarching research question. I use a walktrap algorithm to assist in community/factional detection and compare the distribution of strong and weak ties to assess bridging and bonding capital across periods. In brief, the results show a trend towards coalitional formation with an increasing emphasis on bridging capital across the networks.

Chapter 6 turns to the analysis of political strategies across sites and time periods. Using a modified Qualitative Comparative Analysis based on the correlates established in Chapter 2, I evaluate each site along a spectrum from fully corporate to fully exclusionary. This assessment draws upon three categories of evidence: architecture, artifacts, and network position. Importantly, network measures incorporated here are derived from independently constructed regional network models (Chapter 5) and are not used to define those models, ensuring analytical separation between network reconstruction and political classification. The chapter includes a literature review of architectural and artifactual data for the region and integrates the local aspects of the network data from Chapter 5 to build a comprehensive view of political strategies through time.

Finally, Chapter 7 synthesizes the political and socio-economic spectra to answer the overarching research question. The multi-temporal design of this project allows for an evaluation of how political strategies and regional network structures evolved together, providing both top-down and bottom-up perspectives on the emergence and development of socio-political complexity in the UBRV. In brief, exclusionary leadership strategies became more prominent as time advanced, and villages that engaged in exclusionary leadership strategies tended to occupy intermediate network positions. As the socio-economic network became denser, villages that were able to maintain these exclusive positions tended to exhibit further architectural and artifactual evidence of exclusionary strategies during the next period. These early exclusionary leaders were the precursors to the Classic period kings, and thus they set in motion the political and socio-economic processes that led to kingship. Although this study focuses specifically on the UBRV, these patterns resonate across the Maya world. A regional perspective thus offers valuable insights into broader processes relevant not only to the ancient Maya and Mesoamerica but also to the study of socio-political complexity within anthropology and more broadly within the social sciences.

CHAPTER 2

NETWORKS, POLITICS, AND SOCIO-POLITICAL COMPLEXITY IN PREHISTORY

This chapter establishes the theoretical and analytical framework for my investigation of the evolution of socio-political complexity in the Upper Belize River Valley (UBRV) during the Early and Middle Preclassic periods (1200–300 BC). First, I review recent archaeological debates on socio-political complexity, focusing on how research has moved from simple dichotomies of elites and commoners toward more nuanced spectra of political and social power and roles. I then introduce what I call "dimensional approaches" to leadership dynamics that parse distinct domains of political and economic variability into archaeologically measurable components. Drawing on the existing literature, I identify two intersecting, co-constructive domains as particularly important for this study: social capital, which varies along a spectrum of bridging and bonding ties, and political strategies, ranging from exclusionary to corporate forms. Finally, I outline the archaeological correlates that allow me to situate Preclassic villages within these spectra. Specifically, I link theories of socio-economic networks and political strategies with material evidence, providing a framework for the analyses presented in subsequent chapters.

Socio-Political Complexity

The concept of socio-political complexity lacks a single, universally accepted definition. Archaeologists have traditionally identified the emergence and evolution of complex societies through indicators such as hierarchical political structures and institutions, economic specialization, and monumental architectural programs (Daems 2021). These features are often associated with permanent settlements, increasing social stratification, political centralization, population growth, and the development of cooperative networks. More broadly, socio-political complexity involves repeated interactions at multiple scales and the institutionalization of diverse social and economic roles (Barton 2014; Daems 2021; Feinman 2013, 2017a).

Leonid Grinin and Andrey Korotayev (2011:282) highlight the intersection of politics and economics in the development of medium-complexity societies, such as the Preclassic Maya. They argue that complexity arises through interactions between different societal domains, such as political and socio-economic spheres. These interconnections shape both the pace and magnitude of change within each sphere, while also determining how transformations in one domain influence shifts in others. I other words, how these domains co-construct one another. This perspective emphasizes the dynamic, interconnected, and multilinear pathways through which complexity develops.

For the purposes of this study, I define socio-political complexity as *the degree and configuration of social, political, and economic differentiation within a social system, such as variation in social relationships among individuals and groups, diversity in political roles and authority structures, greater heterogeneity in network positions and forms of interaction, and disparities in access to resources and economic power*. The term serves as an umbrella concept capturing the combined structure and distribution of these interrelated forms of differentiation. I do not treat complexity as a binary condition. Even small-scale societies exhibit socio-political complexity. Rather, this study examines changes in the degree and configuration of complexity over time. While socio-political complexity is defined here in terms of differentiation across social, political, and economic domains, this study does not treat those dimensions as explanatory variables for complexity itself. Rather, it examines how interaction between analytically distinct dimensions (i.e., regional network structure and local political strategies) produces changing configurations of differentiation over time. Additionally, I do not equate complexity with hierarchy. While hierarchical organization is one possible expression of socio-political complexity, complex systems may also operate through heterarchical forms of governance.

In the UBRV, there is no question that socio-political complexity increased through the Preclassic and into the Classic periods. However, what remains unclear is the degree and configuration of social, political, and economic differentiation during the Preclassic that gave rise to the well-documented complexity of the Classic period. This study addresses that gap by examining how these forms of differentiation were structured and reorganized through time through the dynamic feedback between regional social and economic spheres and the local political sphere across multiple periods. Specifically, I analyze how these spheres are structured and interconnected within each period, and how their relationships transform over time, thereby reconstructing the trajectory of processes that reorganized and intensified patterns of differentiation across communities. Additionally, the focus on both regional and local trajectories allows for an investigation into possible diverse pathways to complexity. Archaeologists have historically assessed these processes of differentiation through a binary societal framework, classifying different segments of society into “elites” and “commoners.” Rooted in Marxist concepts of class, this perspective characterizes elites as leaders with privileged access to resources, such as surplus goods and labor, and commoners as those who lack such advantages.

Recent scholarship, however, challenges this rigid dichotomy. Many researchers argue instead for a more nuanced perspective, suggesting that prehistoric societies exhibited a spectrum of social positions rather than a strict elite–commoner divide (Furholt et al. 2020; Hutson 2020; McAnany 1995). Robert Sharer (1993), for instance, contends that the archaeological record of the Maya lowlands does not support a simplistic binary model. Instead, the evidence points to diverse political and social organizations that varied across spatial and temporal contexts. This variability reflects the multiple ways in which groups negotiated power that collectively shaped the expressions of socio-political complexity in the Maya world.

Despite these critiques, much of the archaeological literature continues to employ the terms "elite" and "commoner." Accordingly, this study engages with this terminology while recognizing its oversimplifications. As will become clear later in this study, evidence from the Preclassic UBRV suggests that some members of society and certain villages had differential access to goods, pointing to the existence of some level of social stratification. Yet rather than interpreting these differences as a strict dichotomy, they are better understood as part of a broader spectrum of social roles, a spectrum that became increasingly pronounced during the Late Preclassic and Classic periods with the rise of the *Kuhul Ajaw* divine kingship institution.

Anthropological theories of socio-political complexity, often rooted in the political economy literature, have traditionally framed regional socio-economic change as the product of unidirectional hierarchical growth, emphasizing elite control over economic processes (Brumfiel and Earle 1987; Clark and Blake 1994; Earle 1997; Sahlins 1972; Service 1975). Terence D'Altroy and Timothy Earle (1985) argue that elites financed political activities through two primary systems: *staple finance* and *wealth finance*. In staple finance systems, elites collected local goods, often in the form of taxation, while wealth finance systems relied on the acquisition of exotic items, sometimes used as primitive currency, to build political influence. Both systems frequently coexisted within societies in varying proportions.

In the case of Mesoamerica, John Clark and Michael Blake (1994) suggest that early elites drew on both systems to consolidate their authority. They acquired social capital by tapping into prestige goods networks (wealth finance) and by hosting feasts with accumulated surpluses (staple finance). Over time, what began as temporary or situational forms of privilege hardened into hereditary positions, with access to resources and networks increasingly restricted to specific kinship lineages. Comparative global research further supports this model, showing that elites often maintained political control by monopolizing trade routes (Hirth 1978; Junker 1999; Sáenz 1991; Schortman and Urban 2011) and employing political intimidation to suppress rivals (Junker 1990), thus maintaining control over economic networks. This further highlights the interconnected nature of political and economic spheres. For good reason, this model remains the prevailing framework in Mesoamerican archaeology for explaining the emergence and consolidation of elite power, and this study contributes further evidence to support this model.

Dimensional Approaches

Scholars have developed multiple frameworks to examine the evolution of social, political, and economic organizations by breaking them into distinct dimensions. By "dimensional approaches," I refer to models that deconstruct complex social, economic, and political processes into archaeologically measurable components. Researchers typically analyze these components separately, allowing them to track specific aspects of cultural change across time and space. This section outlines several prominent models that have inspired my approach to analyzing variability in political strategies and socio-economic structures in prehistoric societies. I do not specifically use all parts of these approaches, except the dual-processual model, but they do influence the theoretical framework that I present below.

Richard Blanton and colleagues (1996) created the dual-processual model to address multiple, intersecting dimensions of political organization, particularly economic strategies, governance structures, and expressions of power. It contrasts exclusionary strategies centered on wealth finance, prestige goods, and competitive elite differentiation with corporate strategies emphasizing staple finance, group decision making, and community cohesion. These dimensions are not treated as a rigid binary but as a flexible spectrum, allowing societies—or even neighboring communities within the same region (Beekman 2016)—to adopt different configurations of leadership and economic management. The model also captures temporal variability, showing how political strategies can shift over time in response to social and material conditions. Together, these dimensions link economic practices, political authority, and material patterns in the archaeological record, providing a comparative framework for analyzing political variability.

Richard Blanton and Lane Fargher (2008) investigate ruler–subject relationships through dimensions such as revenue sources, access to public goods, bureaucratic scale, and constraints on rulers' power. They find that autocratic governance relies on external wealth sources, provides fewer public goods, operates with fewer bureaucratic levels, and places minimal restrictions on rulers. Collective governance, by contrast, depends on internal wealth sources, ensures greater access to public goods, maintains more extensive bureaucratic structures, and places stronger constraints on rulers' decision-making.

Seeking to integrate top-down and bottom-up perspectives, Martin Furholt and colleagues (2020) combine hierarchical frameworks with theories of anarchy (Bakunin 1950; Clastres 1989; Graeber 2004; Kropotkin 1972; Scott 1976, 1985, 2017), heterarchy (Crumley 1995; DeMarrais 2013; Scarborough et al. 2003), and collective action (Blanton and Fargher 2008; Levi 1981, 1988, 1997). Their model emphasizes that political agency is distributed across overlapping collectives, such as neighborhoods, guilds, and political coalitions, each with its own agenda and capacity to negotiate power. These intersecting networks of interaction create tensions that shape governance and economic structures (see McGuire and Saitta 1996; Saitta and McGuire 1998). In archaeological contexts, detecting collaboration, resistance, or negotiation requires material proxies. Furholt and colleagues (2020:164) identify six key elements for reconstructing political economies: aspiring power, property rights, collaboration and power balancing, resistance, overlapping layers of action, and historical embeddedness. Each element has associated material correlates, from the control of wealth objects and bottlenecked economic positions, to patterns of property rights evident in spatial organization and land use, to monumental projects that materialize power. By analyzing these dimensions, archaeologists can identify collaboration, resistance, and power dynamics without reducing them to an elite/commoner binary. This long-term, historically embedded approach highlights the dynamic nature of political economies.

Jennifer Birch (2016) applies a dimensional approach to historic Wendat societies, examining migration, coalescence, and political institutions as mechanisms shaping differentiation. She argues that while migration created political asymmetries, inter-settlement ties mitigated inequalities. Social network analysis by John Hart and colleagues (2016) supports this, showing increasingly dense networks from prehistoric to historic times. Birch (2016), echoing David Braun (1986), suggests that bridging ties (i.e., weak ties) often evolve into bonding ties (i.e., strong ties) as populations grow, helping villages mediate conflict.

Adrian Chase (2021) develops a dimensional model tailored to the Maya region by integrating Blanton and Fargher's (2008, 2011, 2012) autocratic/collective spectrum with Michael Mann's (1984, 2008, 2019) despotic/infrastructural power spectrum. Mann defines despotic power as rulers' ability to command without consent, while infrastructural power refers to the state's capacity to embed itself in daily life through institutions and services. Chase's analysis of the site of Caracol's architecture and spatial organization at multiple scales suggests governance that combined autocratic and collective elements, while exercising limited despotic power.

Taken together, these models demonstrate the value of dimensional approaches for analyzing political and socio-economic variability. While I lack the data to apply any one of them directly, except for the dual-processual model, they provide theoretical inspiration and material correlates that I can investigate. In particular, I build around the dual processual approach and follow Chase (2021) by drawing heavily from Blanton and Fargher's spectrum of governance, I integrate Furholt and colleagues' (2020) emphasis on economic bottlenecks and monumental construction, and I use the models by Birch (2016) and Hart and colleagues (2016, 2025) to conceptualize social capital as a spectrum. I now turn to my specific approach for understanding these two interconnected domains, socio-economic networks and political strategies, as key mechanisms for differentiation.

Socio-Economic Networks

The relationships between villages and broader regions plays a critical role in shaping socio-economic and political structures. Anthropological and sociological research suggests that social capital, or the advantages of specific network positions, is an important emergent property of dynamic inter-personal and inter-institutional relationships that allow individuals and groups to influence those around them (Bourdieu and Wacquant 1992; Burt 2005; Emirbayer 1997; Foucault 1979:29). Archaeologists can analyze these relationships using formal, statistical methods to explore how ancient networks were structured and how they influenced the trajectory of ancient societies, thus giving us a pathway to explore the evolution of social capital and its effect on socio-political complexity. Archaeological network analysis, as applied today, primarily derives from graph theory, social network analysis, and complexity science.

Graph theory, which mathematically reconstructs relationships using algebraic matrices, saw archaeological applications as early as the 1970s in regions such as Oceania

(Terrell 1976, 1977; Irwin 1978), the Pacific (Hage 1977; Hage and Harary 1983, 1991; Hunt 1988), Mesoamerica (Santley 1991), South America (Jenkins 1991), and the United States (Peregrine 1991). Social network analysis, on the other hand, has been widely used by archaeologists, historians, and sociologists since the 1970s to examine complex social relationships (Golitko and Feinman 2015; Irwin-Williams 1977; Mills et al. 2013; Padgett and Ansell 1993; Peeples 2018; Wasserman and Faust 1994; among many others). Complexity science, which integrates physics and computer science to explore organizational features such as small-world networks (Watts and Strogatz 1998), has primarily been applied by archaeologists to Bronze Age Aegean networks (Knappett et al. 2008; Rivers et al. 2013). This research primarily employs a combined approach derived from graph theory and social network analysis which uses formal network methods and models to reconstruct ancient socio-economic networks.

Formal network methods and models provide a bottom-up perspective on social and economic organization, allowing archaeologists to move beyond rigid socio-political models (e.g. bands, tribes, chieftains, states) that often obscure variability within complex cultural systems. At the same time, it can complement and refine existing frameworks rather than completely replacing them (Holland-Lulewicz 2023). By analyzing previously collected attribute data, formal network methods help archaeologists examine relational processes within and between communities (Brughmans and Peeples 2023; Peeples 2019). Researchers can then integrate these network models with existing interaction models, such as central place theory (Smith 1974) and site-size hierarchies (Earle 1987; Johnson 1977; Parsons 1971), providing a multi-layered understanding of regional dynamics. Recent archaeological research has emphasized that network positions themselves are a type of resource, granting varying degrees of social capital that rulers and collective groups can leverage to achieve their goals (Lin 2004). This approach reveals the underlying relational structures in which leadership and economic strategies were embedded, and the deep-time perspective of archaeology allows for an investigation into the trajectory of change within these domains (Holland-Lulewicz 2023).

One of the most significant insights from network analysis is its ability to demonstrate how interaction networks themselves function as mechanisms of differentiation. Archaeologists have explored this idea in various contexts, showing that different network configurations influence the spread of goods, ideas, and social innovations in distinct ways (Mills et al. 2013; Mizoguchi 2009; Munson and Macri 2009; Munson et al. 2014; Scholnick et al. 2013). In archaeological approaches to network analysis, a network consists of nodes (e.g., individuals, sites, artifacts, etc.) and the formally defined connections or "ties" between them (e.g., trade relationships, kinship connections, etc.). In this study, archaeological sites serve as nodes, while ties between them represent socio-economic interactions.

To characterize ancient network structures, analytical methods typically involve network visualizations and descriptive statistics. By analyzing network-level metrics and configurations, researchers can study large-scale regional processes, while node-level metrics shed light on a village's influence, dominance, subordination, isolation, and centrality within the broader regional network. This dual approach enables a nuanced investigation into the interaction between local and regional scales. A relational perspective, therefore, provides a bottom-up complement to traditional top-down models, adding additional depth to studies of political and socio-economic strategies.

A particularly relevant feature in archaeological network analysis is the distinction between bridging and bonding ties, different forms of social capital, and how they relate to network positions. Archaeologists have successfully adapted these concepts, originally used in sociological and ethnographic research, to archaeological contexts to investigate the evolving nature of intercommunity interactions (Hart et al. 2019, 2025; Peeples and Haas 2013; Lulewicz 2019). Bonding ties represent strong, cohesive connections, often linked to kinship or ethnic affiliations, while bridging ties represent weaker, cross-cutting connections facilitated by institutions such as long-distance trade partners, religious organizations, or diverse coalitions (Burt 2001; Adger 2003; Granovetter 1985; van Staveren and Knorringa 2007). Both types of ties were likely used and maintained by prehistoric villages, but their relative prevalence creates a spectrum of social capital that granted them specific structural positions within the network. Sites that maintained many bridging ties, such as Kenneth Hirth's (1978) "gateway communities" or Peeples and Haas's (2013) broker communities, held strategic positions that allowed them to control resource flows, creating economic bottlenecks. This form of social capital was critical for exclusionary, network-oriented leaders who relied on economic centralization and monopolization (Earle 2017; Furholt et al. 2020; Junker 1990, 1999; Schortman and Urban 2011). Conversely, bonding ties were often associated with cross-village collective groups, such as kinship networks, secret societies, and artisan guilds, aligning more closely with corporate strategies (Lulewicz 2019). However, these associations are not absolute. Exclusionary leaders may form bonding ties to consolidate power, and corporate groups may create bridging ties to secure food supplies during periods of environmental stress (Rautman 1993).

Importantly, bridging and bonding social capital operate at both the network and node levels. Their distribution across the network reveals global structural properties, while the number and intensity of bridging and bonding ties maintained by individual villages shaped local political dynamics. I leverage both perspectives in complementary ways: global patterns of social capital are used to characterize the regional network as a whole, whereas node-level measures of social capital serve as correlates of village-level political strategies. I elaborate on this distinction below.

The cultural significance of bridging and bonding ties varied across societies (Pachucki and Breiger 2010). Several prominent examples illustrate this point. Peeples and Haas (2013) show how bridging ties in the prehistoric U.S. Southwest were often unstable, as brokerage positions were frequently bypassed when networks closed, making them disadvantageous in the long run. Further evidence of disadvantageous bridging ties can be seen in the decline of Oc-Eo, possibly the capital of Funan, a key intermediary trading port in Southeast Asia between China and Indonesia. As China began bypassing Oc-Eo in its trade routes, the network closed, likely prompting a shift away from the Southeast Asian coast and setting the stage for the rise of the Angkor Empire in the interior (Vickery 1998). These findings align with ethnographic studies, where individuals or groups in brokerage positions often lose influence once direct ties replace them (Xiao and Tsui 2007). However, this is not always the case. James Coleman (1988), in a study of Jewish merchants in New York, found that brokerage positions remained beneficial even when network closure occurred. These examples highlight how different forms of social capital influenced organizational structures in culturally specific ways. Due to the time depth of archaeological research, it is possible to examine the trajectory of network positions alongside cultural trajectories, allowing us to gain insight into how different cultures responded to specific network positions.

Political Strategies

Recently, Mesoamerican archaeologists have relied primarily on two models to examine prehistoric political strategies: the dual-processual model (Blanton et al. 1996) and collective action theory (Blanton and Fargher 2008). These models explore similar aspects of political and economic organization and share many archaeological correlates, yet they do not fully overlap. However, addressing collective action models with archaeological data alone presents challenges, as direct evidence of negotiated governance is often difficult to detect in the archaeological record (Beekman 2016; Blanton et al. 2021; Stark and Stoner 2022). Nevertheless, the degree of overlap between the two approaches justifies considering them together for analytical purposes (Feinman 2018; Stark and Stoner 2022). Therefore, for the purposes of this study, I treat them as a single dimension of governance. The following sections outline the key aspects of each model, and, later in the chapter, I will discuss their expected archaeological correlates and how they manifest in the material record.

Dual-Processual Model

The dual-processual model is one of the foundational frameworks for understanding political systems and social change in Mesoamerica. This model explains the evolution of elite power as a dynamic interplay between two political strategies: exclusionary and corporate (Blanton et al. 1996). Exclusionary strategies emphasize acquiring prestige goods through wealth finance systems, which prioritizes access to exotic or high-status items to finance alliances and followers. In contrast, corporate strategies focus on managing and distributing local goods through staple finance systems, often fostering community cohesion (Blanton et al. 1996; D'Altroy and Earle 1985). These economic strategies reflect distinct approaches to governance and political structure which manifest different material patterns in the archaeological record (Earle 2016, 2017; Feinman and Nichols 2016).

Blanton and colleagues (1996) stress that all societies exhibit characteristics of both strategies, positioning the dual-processual model as a spectrum rather than a binary opposition. Initially, they proposed that societies within large cultural areas shift between these strategies over time, with one strategy predominating at different points (Blanton et al. 1996). Adding nuance to this model, Christopher Beekman (2000) provides evidence from west Mexico demonstrating that contemporary villages within the same region could occupy opposite ends of this spectrum. This suggests that neighboring villages can employ different political strategies, highlighting the flexibility and adaptability of leadership within a shared cultural and geographical context.

Developed specifically for archaeological research, the dual-processual model remains a widely used framework for analyzing political variability (Beekman 2016). Over time, scholars have expanded its applications by incorporating insights from global studies on inequality and collective action theory (Bard 2017; Englehardt and Nagle 2011; Fargher and Heredia Espinoza 2016; Peregrine and Ember 2016; Prufer et al. 2011; Wang and Marwick 2020, 2021). While the model effectively captures elite-driven strategies, it primarily addresses one dimension of political variation, leaving other aspects of governance less explored.

One major critique of the dual-processual model is its limited focus on commoners, their agency, and their role in shaping political and social evolution (Blanton and Fargher 2008). Many scholars argue that commoners were not passive subjects under elite control but active participants who negotiated power and resources within their societies (Cowgill 2000; Joyce 2000; Levi 1988; Lohse 2013; McGuire and Saitta 1996; Ostrom 1990, 2009; Pauketat 2001; Robin 2012; Scott 2009; Wolf 1955).

In the Maya world, Cynthia Robin (2012) and Jon Lohse (2013) emphasize the role of non-elite farming households and community decision-making in long-term societal transformations. Their research in Belize demonstrates how commoners influenced political and economic structures through labor contributions and resource management. Since some aspects of elite power depended on agricultural surplus, commoner households played a crucial role in shaping political negotiations. Similarly, Earle (2017) compares global data to highlight the ability of commoner collectives to leverage their contributions, influencing the balance of power within their societies.

Collective Action Theory

Collective action theory, as applied in archaeology, emerged as an extension of the dual-processual model and the foundational political philosophy of Margaret Levi (1981, 1988, 1997). This framework conceptualizes political power as a reciprocal relationship between rulers and the ruled, positioning governance along a spectrum from fully autocratic to fully collective systems. At one extreme, autocratic rulers exert near-total control over society, while at the other, various collectives within society possess the social power to impose strict restrictions on rulers and negotiate for policies that benefit the broader community (Blanton and Fargher 2008, 2016; Carballo 2013; Fargher and Heredia Espinoza 2016).

Blanton and Fargher (2008) introduced collective action theory to archaeological audiences by analyzing historic and ethnographic data, emphasizing the relationship between revenue sources and political structures. Their findings demonstrate that governments relying primarily on external revenue sources (i.e., wealth finance) tend to be more autocratic, while those dependent on internal revenue (i.e., staple finance) exhibit more collective governance. Although their study relied on historical tax records to assess revenue sources, archaeological data support this correlation. For instance, in Mesoamerica, Gary Feinman (2018) observes that societies characterized by exclusionary strategies, as described in the dual-processual model, tend to exhibit more autocratic tendencies, whereas those employing corporate strategies are more often associated with collective governance.

From an archaeological perspective, Beekman (2016) cautions against overgeneralizing or attempting to address all the collective action theory correlates without sufficient data. He argues that archaeological research often lacks the fine-grained evidence necessary to fully reconstruct power structures and negotiations in past societies. As a result, he advocates prioritizing the dual-processual model as a more practical and accessible framework for archaeological analysis. Other scholars emphasize the benefits of integrating aspects of both models to provide a more comprehensive understanding of governance (Feinman 2018; Stark and Stoner 2022).

Despite these challenges and differences in approach, developing archaeological proxies for studying power dynamics and collective action remains a crucial task for archaeologists. Therefore, I use both the dual-processual model and collective action theory to build a spectrum of governance. As Feinman (2018) has noted, in much of Mesoamerica the two models overlap. For assessing Preclassic Maya politics, the integration of the two does not pose an issue, as will become evident in later chapters.

Intersection of Political Strategies and Socio-Economic Networks

As I hope is clear, theories of political power consistently highlight the intrinsic relationship between socio-economics and politics. Within the dual-processual and collective action models, scholars note a strong tendency for exclusionary and autocratic rulers to rely on external revenue sources, while corporate and collective societies typically depend on internal revenue. Importantly, external revenue inherently implies the existence of socio-economic networks, which may be composed of numerous configurations of bridging and bonding ties. In low-density regions, such as the Maya lowlands during the Early and Middle Preclassic periods, external resources may have come from within the same region rather than more geographically distant places. Likewise, collective villages probably did not function in isolation; they likely interacted with neighboring villages through kinship ties, festivals, markets, and mechanisms designed to mitigate food scarcity.

The structure of socio-economic networks helps to shape the nature of these interactions. Networks dominated by weak bridging ties, which tend to link more distant communities, operate differently than dense networks characterized by strong bonding ties, which reinforce cohesion within closely allied groups. When both types of ties coexist, coalitions play a critical role in structuring relationships. From a network perspective, coalitions consist of multiple villages internally connected by strong bonding ties while maintaining weak bridging ties to other coalitions of similarly bonded settlements. The ways in which exclusionary and corporate leaders engage with their networks depend on their structural positions within their networks, the balance of bridging and bonding ties, and their coalition affiliations. These factors create a diverse range of political and socio-economic configurations along two intersecting spectra: exclusionary/corporate leadership and bridging/bonding social capital (Figure 2.1). For convenience throughout the remainder of this study, I will refer to the exclusionary/autocratic side of the spectrum as "exclusionary," and I will refer to the corporate/collective side as "corporate."

I present these spectra as intersecting dimensions for two reasons: 1) the preceding discussion shows that politics and economics are intertwined, and 2) because ethnographic and archaeological research suggests that regional socio-economic interactions can act as a leveling mechanism to restrain aspiring exclusionary rulers while also making corporate groups more resilient during periods of stress (Blanton and Fargher 2008). This second point has a strong influence on both the political and economic trajectory of individual villages, which impacts the pace and shape of socio-political complexity within the region. Furthermore, exclusionary leaders could potentially exploit their structural position in the network, thereby gaining more political and economic power. Thus, the spectra are not absolutely correlated, as they may intersect at differing points. Several examples illustrate this point.

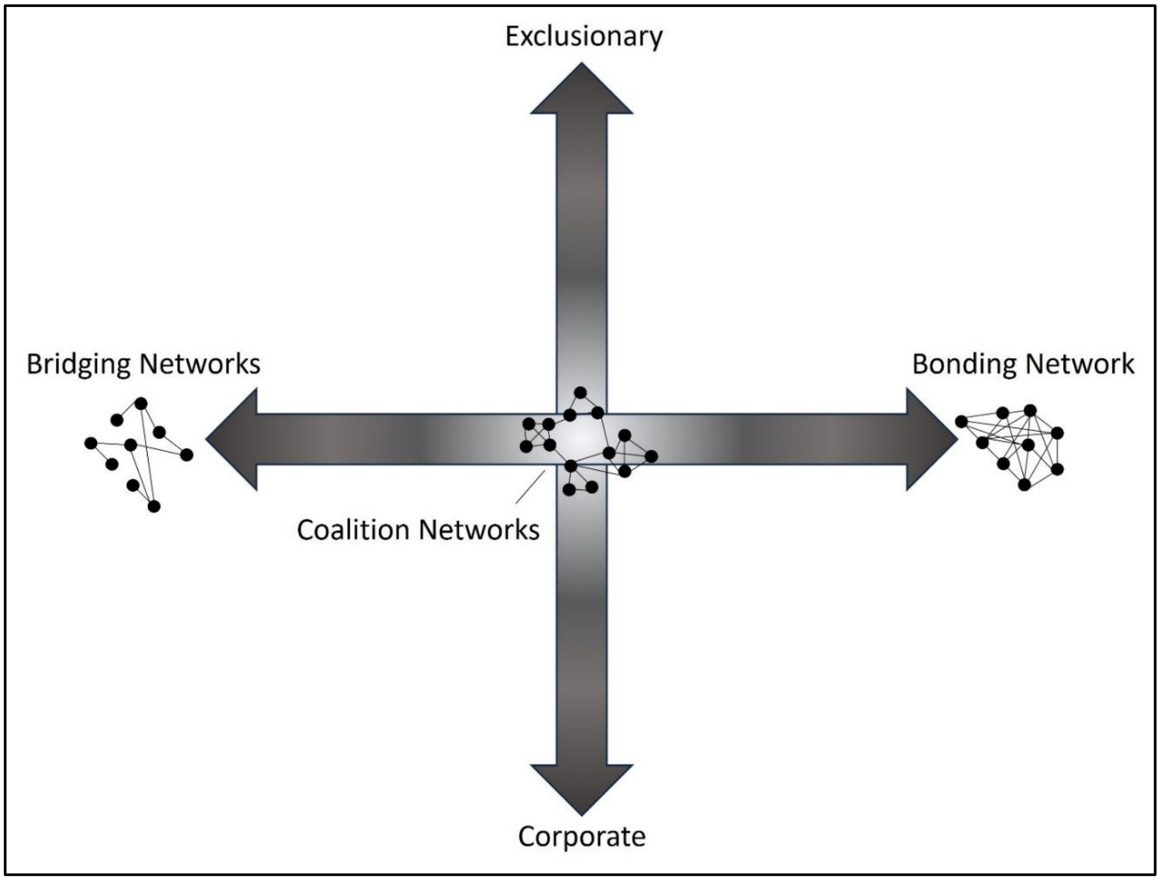

Figure 2.1. Intersecting Spectra of Political Strategies and Socio-Economic Networks. The vertical dimension represents the exclusionary/corporate political spectrum, and the horizontal dimension represents the bridging/bonding socio-economic network spectrum.

We would expect exclusionary rulers who relied on wealth finance to establish bridging ties to facilitate long-distance economic exchanges. This is evident among Classic Maya elites, who maintained extensive long-distance trade networks, emphasizing bridging social capital, connecting them to other distant elites (Feinman 2017b). Teotihuacan, on the other hand, exemplifies a corporate/bridging society where leadership was largely corporate, yet they maintained extensive material connections across Mesoamerica demonstrating a preference for bridging ties (Feinman and Carballo 2018). In contrast, the Northwest Coast Salish provide an example of a corporate society where political power was closely tied to coalitional social capital. To prevent any single chief from accumulating excessive authority, rival leaders formed coalitions to limit political centralization (Ames 1995, 2008; Angelbeck and Grier 2012). Conversely, modern China presents an example of an exclusionary political system where economic opportunities are primarily composed of nucleated bonding ties (Bian 1997, 2019), a pattern reflected across other political institutions which covered large geographic areas such as the Roman Empire.

The position and trajectory of settlements within these intersecting spectra provides valuable insights into the motivations behind political strategies and socio-economic engagement, furthering the broader goals of anthropological archaeology and Maya studies. Therefore, archaeologists should examine local governance structures alongside regional socio-economic network dynamics to develop a more comprehensive understanding of the emergence and development of complex organizational systems.

Top-down theories predict specific patterns in the archaeological record that indicate whether a village leaned toward exclusionary or corporate governance. In contrast, formal network methods offer a bottom-up approach, reconstructing the local and regional relationships within which these top-down strategies were embedded. Additionally, these formal methods provide key correlates for identifying sites that functioned as bridges, maintained strong bonds, or belonged to coalitions, helping to pinpoint the primary movers within these networks. The remainder of this chapter explores the archaeological correlates associated with leadership and social capital in the Early and Middle Preclassic periods of the UBRV.

Archaeological Correlates of the Spectra

This section outlines the archaeological correlates used to assess where prehistoric villages fall along the spectra of socio-economic networks and political strategies. I also introduce the formal analytical methods used to evaluate these correlates, with more detailed methodological discussions presented in later chapters. I begin with socio-economic network correlates to establish the regional context within which political strategies operated. Political strategies are then addressed as village-level responses embedded within these broader economic and relational structures.

Socio-Economic Network Correlates

Socio-economic networks provide the regional context in which political strategies emerged, operated, and evolved. I characterize the structure of these networks by examining the distribution of strong ties associated with bonding social capital and weak ties associated with bridging social capital across villages in each time period, allowing regional socio-economic systems to be described as predominantly bonding, coalitional, or bridging networks. To do this, I employ formal network methods to reconstruct site-to-site economic interactions using Neutron Activation Analysis (NAA)–derived pottery groups as a proxy for material movement across the Upper Belize River Valley (UBRV). This approach captures both patterns of resource flow and the broader network structures that shaped economic opportunity and constraint.

Archaeological data suggest that villages that maintain ties to non-local sites – not within their own sub-region – tended to participate in weaker bridging relationships, while those embedded primarily within nearby settlement clusters exhibit stronger bonding ties;

communities positioned between these extremes combine elements of both, reflecting sub-regional coalitions that balanced local integration with broader connectivity (Birch and Hart 2018; Crowe 2007; Mills and Peeples 2023; Ramirez-Sanchez and Pinkerton 2009). These patterns of connectivity structure access to resources, information, and exchange partners, forming the basis of regional social capital.

At the graph level, I use formal network measures to evaluate overarching properties of the socio-economic system, including density, clustering, and the prevalence of bridging versus bonding configurations. Triad censuses are used to identify common interaction patterns among groups of three sites, with particular attention to intransitive triads that signal economic bottlenecks within the regional network. Community detection algorithms, such as the walktrap algorithm, further identify clusters of villages that interacted more frequently with one another, highlighting potential coalitions or subregional economic groupings. Importantly, several of these network analyses provide both graph-level (i.e., regional socio-economic network) and node-level (i.e., local political strategies) information. The regional network data are used to access the correlates associated with the socio-economic networks, and the village level metrics are addressed below in the political strategies correlates.

As a further step, I explore the processes that likely generated these observed network structures by employing Exponential Random Graph Models (ERGMs), a relatively recent addition to archaeological research (Amati 2020; Brughmans and Peeples 2023; Wang and Marwick 2021). ERGMs statistically evaluate how specific structural tendencies and covariates—such as geographic distance or shared architectural features—shape the probability of tie formation by comparing observed networks to simulated, hypothetical alternatives (Lusher et al. 2013). These models provide insight into how regional exchange systems evolved over time and establish the socio-economic conditions within which villages developed and deployed political strategies. Together, these analyses clarify how social capital was distributed across the regional network and how participation in different network configurations created varying opportunities for economic leverage, cooperation, and control.

Political Strategies Correlates

Political strategies did not operate independently of regional socio-economic networks; rather, they represent village-level responses to structural opportunities and constraints created by those networks. Groups rarely adhere strictly to either exclusionary or corporate political strategies, instead combining elements of both to varying degrees (Blanton et al. 1996; Stark and Stoner 2022). Although preservation challenges in the tropics and the absence of writing during the Preclassic period limit direct evidence for political organization, village-level patterns in architecture, artifacts, and network position provide valuable archaeological proxies.

This study builds on Nancy Peniche May's (2016:48–52) operationalization of dual-processual correlates in the UBRV, drawing on broader theoretical frameworks including dual-processual theory, collective action theory, and political economy approaches (Blake et al. 2006; Blanton et al. 1996; Feinman 1995, 2000; Hayden 2001; Helms 1993; McAnany 1995; Renfrew 1974; Blanton and Fargher 2008; Carballo and Feinman 2016; DeMarrais and Earle 2017). These perspectives link political strategies to distinctive architectural forms, material distributions, and patterns of economic engagement and control (Table 2.1).

Table 2.1. Archaeological Correlates for the Political Strategies Spectrum.

Category	Correlate	Exclusionary	Corporate	Source
Architecture	Domestic structures	Diversity in residence sizes with elaborate, centrally-located, large residences	Limited diversity in residence size with modest, similarly-sized residences	Blake et al. 2006; Blanton et al. 1996; Feinman 2000; Renfrew 1974
	Monumental architecture	Dynastic temples such as E-Groups or Eastern Triadic Shrines	Community structures such as round and keyhole shaped structures and low communal platforms	Blanton and Fargher 2008; Carballo and Feinman 2016; Feinman 1995; Peniche-May 2016
	Access to spaces	Private spaces with restricted access	Public spaces with open access	Feinman 1995; Peniche-May 2016
Artifacts	Ritual symbolism	Ancestor-centered	Fertility or cosmology related	Blanton et al. 1996; Feinman 1995; Hayden 2001; McAnany 1995; Peniche-May 2016
	Portable wealth	Concentrated	Dispersed	Goldstein 2000; Helms 1993
	Access to non-subregion pottery	More access	Less access	Blanton et al. 1996; Peniche-May 2016
	Obsidian	Access to many sources (3+)	Access to fewer sources (1-2)	Blanton et al. 1996; Peniche-May 2016
Networks	Strength of ties to distant sites	Strong	Weak	Blanton et al. 1996
	Strength of incoming ties	Strong	Weak	Blanton et al. 1996
	Betweenness centrality	High	Low	Blanton et al. 1996
	Economic bottlenecks (Brokerage potential)	High brokerage potential	Low brokerage potential	Earle 2017; Earle and Spriggs 2015; Furholt et al. 2020

Villages leaning toward exclusionary leadership tend to exhibit centrally located elite residences, restricted spaces, and ancestor-focused monumental architecture such as E-Groups and Eastern Triadic Shrines. Ritual symbolism emphasizes lineage and ancestry, often expressed through figurines and the placement of human remains in central or temple contexts with distinctive grave goods. Portable wealth items—such as jade, slate, and worked shell ornaments—are unevenly distributed across households, and these villages frequently accessed non-local materials, including multiple obsidian sources and non-local pottery.

Corporate-oriented communities, by contrast, emphasize inclusivity and collective participation. These sites typically display greater uniformity in domestic architecture, monumental spaces designed for communal use, including round or keyhole-shaped structures and low non-domestic platforms, and open, unrestricted plazas. Ritual symbolism tends to focus on fertility and cosmology rather than ancestry, with objects conveying plant and animal imagery and offerings such as shells and jade—often symbolizing maize—placed beneath building posts or in public contexts. Portable wealth is more evenly distributed across households, and these communities relied primarily on locally produced pottery with limited participation in long-distance exchange networks.

Household plan maps and artifact inventories provide a direct means of assessing variation in household size and access to wealth (Smith 1987). Extensive household data are available for sites such as Barton Ramie in the Lower Dover area, with additional datasets from Blackman Eddy, Buenavista del Cayo, Cahal Pech, Chan, Pacbitun, and Xunantunich, although coverage remains uneven due to prehistoric and modern disturbances.

Although network-derived measures are used as one line of evidence for assessing political strategies, the regional socio-economic networks and village-level political strategies are constructed independently. Network structure is first reconstructed from NAA-derived ceramic flows and analyzed at both graph and node levels. Political strategies are then evaluated separately using architectural and artifactual correlates, with network position incorporated as only one component among several. The relationship between network position and political strategies is assessed only after these independent analytical steps, allowing for comparison rather than circular definition.

Corporate-oriented villages, in contrast, generally occupied more peripheral or locally embedded network positions, with lower inflows of non-local goods, limited control over regional exchange routes, and reduced brokerage potential. Even so, some peripheral sites likely played important roles by linking local communities into broader coalitions, demonstrating that political strategies were shaped not only by access to resources but by how villages navigated their specific network positions (Peeples and Haas 2013; Lulewicz 2019). Detailed discussions of these network measures are presented in Chapter 5.

To operationalize political strategies as a continuum from exclusionary to corporate, I employ a modified Qualitative Comparative Analysis (QCA) that translates qualitative archaeological indicators into a quantitative dataset. A series of structured questions based on the correlates outlined in Table 2.1 are used to assign scores to each village in each period, allowing villages to be positioned along the political spectrum. Full methodological details are provided in Chapter 6.

Although this study focuses on the relationship between political strategies and socio-economic networks, these methods also offer broader applications. They can be extended to investigate open marketplace systems (Cap 2020; Hirth 1998; Masson and Freidel 2012; Ossa 2013) as well as more restricted exchange mechanisms such as gift-giving, patron–client relationships, and kin-based reciprocity (Ossa 2013; Stark and Garraty 2010; Triadan and Inomata 2020; Tsukamoto 2020).

Conclusion

In conclusion, this study examines the evolution of socio-political complexity in the UBRV by analyzing regional socio-economic networks and local political strategies. Drawing on formal network methods and several models of governance, this study evaluates how sites varied along a spectrum of socio-economic network types and a spectrum of exclusionary–corporate governance. By integrating architectural, artifactual, and network evidence, this research reconstructs how the socio-economic and political dimensions co-constructed one another over time.

Ceramic NAA data provide the foundation for tracing the movement and volume of goods across the regional network. These data, when combined with formal network methods, make it possible to measure each site’s ability to receive resources, control their flow, and shape broader patterns of interaction. At the regional scale, ERGMs simulate network dynamics and test which political strategies influenced the structure and evolution of the network, shedding light on both top-down and bottom-up dynamics. To situate sites along the exclusionary–corporate spectrum, I compare architectural, artifactual, and network data through a modified Qualitative Comparative Analysis. Taken together, these approaches illuminate the creation of social capital and the strategies through which communities negotiated power. By mapping economic and political processes through time, this study also identifies the mechanisms through which patterns of differentiation were reorganized and intensified over time in the UBRV. I now turn to a culture-historical overview of the UBRV, the stage upon which the processes examined in this study took shape.

CHAPTER 3

A CULTURE HISTORY OF THE UPPER BELIZE RIVER VALLEY MAYA

Deep within the jungles of western Belize, the ancient Maya built and sustained vibrant settlements that grew, thrived, and adapted to changing social and climatic conditions before eventually declining. Today, a mixture of English, Spanish, Yucatec Mayan, and Creole are spoken by Afro-Caribbean and Mestizo populations, along with Yucatec Maya groups who migrated to the area during the Mexican Caste Wars of the late 19th century.

The Upper Belize River Valley (UBRV) spans approximately 125 square kilometers in the Central Maya lowlands of west-central Belize (Figure 1.1). This subtropical forest receives an average annual rainfall of 1,300 to 2,000 millimeters (Jolly and McRae 2008:68). In the western UBRV, the Mopan and Macal rivers converge to form the Belize River, which flows eastward across the country before emptying into the Atlantic Ocean. This river system has played a crucial role in shaping the region’s ecology and supporting both ancient Maya populations and contemporary communities.

The UBRV’s landscape features rolling hills and river valleys shaped by three primary landforms: the main river valleys, the southern uplands, and the escarpments and plains (Jenkin et al. 1976). Most archaeological sites in this study are in the main river valleys, except for Arenal, Chan, and Pacbitun, which lie in the southern uplands. These landforms closely reflect the region's underlying geology, which consists primarily of marine limestones of varying ages and textures. In contrast, the nearby Mountain Pine Ridge region of the Maya Mountains contains batholithic granite, shales, and quartzites.

Researchers have conducted numerous geological and soil classification studies in the UBRV, offering essential insights into its composition (Baillie et al. 1993; Birchall and Jenkin 1979; Cornec 2015; Flores 1952; Jenkin et al. 1976; King et al. 2004; Wright 1959). While these studies vary slightly in scope and classification, recent archaeological research (Jordan et al. 2020; Villarreal 2024) generally follows the simplified classification system proposed by Baillie and colleagues (1993). Further geological considerations relevant to ceramic sourcing are discussed in Chapter 4, and a complete assessment of the local geology and soils is presented in Appendix A.

The culture history of the ancient Maya, including those who inhabited the UBRV, is broadly divided into five major periods: Paleoindian (11,500–8000 BC), Archaic (8000–c.1200 BC), Preclassic (c.1200 BC–AD 250), Classic (AD 250–900), and Postclassic (AD 900–1519). This study only addresses a portion of the Preclassic, but I include information on periods before and after to situate this research into the broader trajectory of Maya society. I do not address events following the arrival of Europeans during the Colonial, Historic, and Modern periods (AD 1519–present), as these later periods, nearly two millennia removed from the focus period of this study, brought significant disruptions to traditional lifeways, political strategies, and socio-economic networks, which are the primary foci of this research.

Each period is further divided into smaller phases based on shifts in subsistence practices, political organization, and material culture. The Preclassic period, for instance, consists of the Early (1200–900 BC), Middle (900–300 BC), and Late (300 BC–AD 250) phases, which are defined by developments in monumental architecture, population growth, and pottery traditions. In some cases, including this study, archaeologists distinguish finer chronological divisions, such as the Early Middle Preclassic (900–600 BC) and Late Middle Preclassic (600–300 BC) (Table 3.1).

This study focuses on political and socio-economic processes during the Early and Middle Preclassic periods to examine the evolution of socio-political complexity in the region. To contextualize this study within broader cultural trajectories, the remainder of the chapter provides a brief overview of the periods of study and those preceding and following the Early and Middle Preclassic. Rather than offering an exhaustive account of ancient Maya culture, this summary emphasizes key themes in politics, economics, and social organization. For more comprehensive culture histories, readers are encouraged to consult works such as Coe and Houston (2022) and McKillop (2006). Throughout this discussion, I will highlight political developments and socio-economic interactions to establish the cultural framework for this study.

Table 3.1. Timeline of Major Political, Economic, and Societal Trends in the UBRV

Period	**Architecture**	**Pottery**	**Settlement**	**Regional Demographic Trends**	**Regional Networks**
Postclassic AD 900-1519 Settlement Hiatus from ~AD 900-~1250	No monumental structures; Some domestic structures post-AD 1250	New Town complex (Late Postclassic). New forms, limited distribution	Cities remain abandoned, inhabitants primarily in agricultural flood plains	Some villages may have had ~500+ inhabitants in Late Postclassic, other sites were abandoned	Ceramic influence seems to shift north; Obsidian and jade from Guatemala; Marine shell from coast

Late Classic AD 600-900	Monumental palace complexes; Domestic houses in clusters	Tiger Run and Spanish Lookout complexes. Ash temper returns. Polychromes at height of production	Cities and house mounds dot the majority of the UBRV landscape	Cities with 5000+ inhabitants in periphery	Large scale elite gifting networks (primarily with the Petén); Obsidian and jade from Guatemala; Marine shell from coast
Early Classic AD 250-600	Monumental palace complexes; Domestic houses in clusters	Hermitage complex. Polychrome vessels, some with writing, as well as black monochromes	Cities primarily on hilltops, periphery in agricultural flood plains	Cities with 1000+ inhabitants in periphery	Petén pottery increases; Obsidian and jade from Guatemala; Marine shell from coast
Late Preclassic 300 BC–AD 250	Round public structures; Monumental structures at most sites; Domestic houses	Barton Creek, Mount Hope, and Floral Park complexes. Assemblages dominated by Sierra Red type. Orange wares & polychromes in late part of period	Wealthy villages on hilltops, periphery in agricultural flood plains (increased population in flood plains)	Villages with perhaps 100+ inhabitants in early part of period, Large centers in latter part of period with 500+ inhabitants	Pan-Maya Chicanel ceramic sphere; Obsidian and jade from Guatemala; Marine shell from coast.
Late Middle Preclassic 600-300 BC	Public and monumental Structures at most sites; Eastern Shrines; Domestic houses	Late Jenney Creek complex. No ash temper. Primarily Savana Orange and Jocote Orange-brown types	Wealthy villages on hilltops, periphery in agricultural flood plains	Larger villages with perhaps 50-100 inhabitants	Multi-region Mamom ceramic sphere; Obsidian and jade from Guatemala; Marine shell from coast (presumed trade with Petén)

Early Middle Preclassic 900-600 BC	Public structures (Platforms); Some monumental structures (E-Groups, Low Pyramidal structures); Domestic Houses	Early Jenney Creek complex. Some ash temper in early part of period. Primarily Savana Orange and Jocote Orange-brown types	Small hilltop villages, some habitation in agricultural flood plains	Larger villages with perhaps 50 inhabitants	Obsidian and jade from Guatemala; Marine shell from coast (presumed trade with Petén)
Early Preclassic 1200-900 BC	Domestic houses	Cunil and Kanocha complexes. Ash temper	Small hilltop villages	Small villages with a few dozen inhabitants	Obsidian and jade from Guatemala; Marine shell from coast
Archaic 8000–1200 BC	None	None	Utilizing hilltops	Unknown. Probably low	Chert from Northern Belize
Paleoindian 11,500–8000 BC	None	None	None	Unknown. Probably low	Unknown

Paleoindian (11,500 – 8000 BC)

The Paleoindian period in Mesoamerica is traditionally defined by the presence of Clovis-like and Fishtail-like projectile points, which mobile hunter-gatherer groups crafted and used for hunting (Pearson 2017; Stemp et al. 2021). However, due to the limited archaeological evidence from this time, much remains unknown about these early inhabitants. Recent discoveries of Paleoindian human remains are beginning to shed light on their presence and activities. The earliest skeletal evidence for humans in the Maya region dates to approximately 11,500 BC in the Yucatán Peninsula of Mexico (Arroyo-Cabrales et al. 2015; González 2013; González González et al. 2008; Wrobel et al. 2021).

As research in the region continues, this date may be pushed back, as has been the case in other parts of the Americas (see Waters 2019 for a review).

By approximately 9750 BC, marking the end of the Younger Dryas, warming temperatures and increased precipitation gradually transformed the region's savanna landscape into the tropical forest ecosystem commonly associated with the Maya world today (Hodell et al. 2008; Prufer et al. 2021; Winter et al. 2020). Despite these environmental changes, evidence for Paleoindian populations in Belize remains sparse, with only a few significant finds. These include three Clovis-like points (MacNeish and Nelken-Terner 1983; Hester et al. 1981; Valdez and Aylesworth 2005) and four Fishtail-like points (MacNeish and Nelken-Terner 1983; MacNeish et al. 1980; Pearson and Bostrom 1998; Weintraub 1994). It is likely that the human population was generally low, and the sparsity of data limit any political or economic interpretations for this period.

More recently, excavations at the Mayahak Cab Pek and Tzibte Yux rock shelters in the Maya Mountains of southern Belize uncovered a single alternately beveled biface fragment dating to 10,450–10,085 cal BC, as well as three additional alternately beveled bifaces with transitional dates ranging from 8275 to 6650 cal BC (Prufer et al. 2021). While these discoveries remain limited, they provide crucial insights into the early human occupation of the region. They also underscore the importance of continued archaeological investigations in Belize and the broader Maya lowlands to refine our understanding of Paleoindian presence and adaptation in this tropical setting.

Archaic (8000 – c.1200 BC)

Dating the beginning of the Archaic period remains challenging. If large-scale human-environment interactions, such as widespread anthropogenic forest burning, serve as a marker, the period likely began around 9000 BC (Anderson and Wahl 2016). This date coincides with the disappearance of Clovis-like and Fishtail-like lithic technologies from the archaeological record and the potential early emergence of stemmed bifaces (Prufer et al. 2021; Stemp et al. 2021). However, archaeologists traditionally place the start of the Archaic period around 8000 BC, based on the unequivocal appearance of stemmed, barbed, and beveled projectile points in the Maya lowlands (Lohse et al. 2006; Stemp et al. 2021).

Ancient DNA studies suggest that multiple migration episodes contributed to the settlement of the Maya lowlands, with groups from North and South America arriving at different times (Chatters et al. 2014; Kennett et al. 2022; Prufer et al. 2019; Wrobel et al. 2021). Although not all early inhabitants were direct ancestors of the Maya, genetic evidence indicates that ancient and modern Maya share ancestry with Paleoindian and Archaic migrants from northern South America and southern Central America (Chatters et al. 2014; Posth et al. 2018; Prufer et al. 2021; Roca-Rada et al. 2020; Wrobel et al. 2021).

Archaic material remains in the Maya lowlands primarily appear in rock shelters, caves, and hilltops overlooking rivers (Awe et al. 2021). Hilltops likely served as logistical viewpoints for hunters and provided access to nearby aquatic resources. While little evidence exists for Archaic ritual and religion, rock shelters appear to have been used for burials (Prufer et al. 2021).

The domestication and spread of maize played a pivotal role in shaping Mesoamerican cultures. By 7000 BC, inhabitants of the Balsas River Valley in Central

Mexico had begun experimenting with teosinte, the wild ancestor of maize (Piperno et al. 2009). By 6200 BC, maize had spread to South America, where it underwent selection processes that contributed to traits associated with modern maize (Kistler et al. 2018, 2020). Pollen analyses from lake cores and starch residues on stone tools indicate that domesticated maize and manioc were consumed in the Maya lowlands by 4500 BC, with squash, beans, and chili peppers added by 3000 BC (Blake 2015; Cagnato 2021; Lohse 2010, 2020; Lohse et al. 2006; Pohl et al. 1996; Rosenswig 2021; Rosenswig et al. 2014). The spread of maize horticulture aligns with northward migrations, as suggested by the DNA evidence, indicating a pattern of south-to-north cultural and biological transmission during the Archaic period (Kennett et al. 2022; Kistler et al. 2020; Prufer et al. 2021).

By 6000 BC, formal bifacial tools disappear from the archaeological record, replaced by expedient blades and unifacial technologies, reflecting a shift from hunting to horticulture (Acosta Ochoa et al. 2019; Prufer et al. 2021; Stemp et al. 2021). Between 4500 and 3500 BC, climatic conditions in the region became drier than earlier in the Archaic period (Mueller et al. 2019; Winter et al. 2020). During the Late Archaic period (3400–1200 BC), formal blades and pointed unifaces appear in northern Belize but remain absent in central Belize, where expedient lithic technologies persist throughout the period (Brown et al. 2011; Horowitz 2017; Stemp et al. 2021). Around 2200 BC, constricted adzes emerge as forest clearance tools, coinciding with increased deforestation in northern Belize (Gibson 1991; Iceland 1997; Stemp and Awe 2013; Stemp and Harrison-Buck 2019; Stemp et al. 2021; Jacob 1995; Pohl et al. 1996) and the Petén region of Guatemala (Rosenmeier et al. 2002; Wahl et al. 2006). Isotopic research on human remains suggests that maize became a dietary staple by 2750 BC, with some Late Archaic populations consuming maize in quantities comparable to the Classic Maya by 2050 BC (Kennett et al. 2020; Prufer et al. 2021).

The transition to sedentism, farming, and pottery production marks the end of the Archaic period in the Maya lowlands. Rosenswig (2015, 2021) argues that drier conditions toward the end of the period pushed semi-mobile groups to establish permanent settlements near reliable water sources to support expanded agriculture. However, this transition occurred gradually rather than as a singular event. Inomata and colleagues (2015) propose that while some groups settled permanently, others remained semi-mobile, facilitating trade, communication, and innovation among scattered villages. Rosenswig (2023) acknowledges that this scenario is plausible but notes that no definitive evidence currently supports it.

In the UBRV, evidence of Archaic populations includes diagnostic projectile points and constricted adzes (Solmo 2017; Stemp and Awe 2013; Stemp et al. 2021), lithic deposits in Actun Halal cave (Lohse et al. 2007; Lohse 2010, 2020), and expedient lithic tools beneath Maya sites along the Mopan River (Brown et al. 2011; Horowitz 2017). Stemp and colleagues (2018) observe that lithic materials in the UBRV include both local chert and high-quality chert from northern Belize’s Chert-Bearing Zone. Whether this high-quality chert was intentionally imported or transported by mobile groups remains uncertain. As research continues, additional evidence of Archaic populations in the UBRV is likely to emerge.

Early Preclassic (1200-900 BC)

This study focuses on developments beginning in the Early Preclassic period, also referred to as the "Formative" period, which in much of Mesoamerica begins around 2000 BC with the onset of sedentism, agriculture, and pottery production. However, in the Maya lowlands, these innovations emerged later, around 1200 BC. As a result, Belize does not have an “early” Early Preclassic period (2000–1200 BC) (Awe et al. 2021; Lohse et al. 2006). Traditionally called the "Late Early Preclassic" or the “Terminal Early Preclassic,” this period will be referred to here simply as the "Early Preclassic" (EPC) for clarity. Archaeological evidence indicates a significant increase in settlement activity across the Maya lowlands during this time. The following discussion focuses specifically on processes unique to the UBRV, unless notable deviations from broader Maya lowland patterns are observed.

The first permanent settlements in the UBRV date to the EPC, around 1200 BC, marking the establishment of small-scale farming villages. These communities produced ceramics but lacked several hallmarks of heightened socio-political complexity, such as pronounced inequality, monumental architecture, or multi-level political institutions. It is important to emphasize that farming and ceramic production were not intrinsically linked, as these innovations appeared at different times throughout Mesoamerica (Rosenswig 2023). Excavations in the UBRV suggest that EPC settlements housed only a few dozen individuals per site, as indicated by the limited number of domestic architectural remains (Brown 2003; Cheetham 1996; Crow and Powis 2023; LeCount et al. 2019; Peniche May 2016). Clark and Cheetham (2002:298), using a neo-evolutionary framework, describe these early settlers as "tribal units." While EPC populations continued to favor hilltops and elevated areas near the Mopan, Macal, and Belize Rivers, following Archaic settlement patterns, rock shelters transitioned from habitation sites to ritual spaces (Awe et al. 2021; Moyes et al. 2009, 2017). A key distinction from the Archaic period is the introduction of permanent architecture during the EPC.

Early domestic architecture in the UBRV follows a pattern similar to other early Maya lowland structures, featuring ovoid or apsidal shapes built directly on leveled bedrock (Andrews V 1981; Gerhardt and Hammond 1991; Hansen 1998; Powis 1996; Rice 1976; Ringle and Andrews V 1988; Smith 1972; Willey et al. 1965). Evidence of discreet EPC habitation has been identified at several UBRV sites, including Actuncan (LeCount et al. 2017; Simova 2024), Blackman Eddy (Brown 2003; Brown and Garber 2003, 2005; Garber et al. 2004a), Cahal Pech (Awe 1992; Cheetham 1996; Ebert et al. 2017; Peniche May 2016), and Xunantunich (Brown et al. 2011; Rawski 2020).

While domestic structures appeared between 1200 and 1000 BC, monumental construction in the UBRV did not begin until approximately 800 BC, apart from a single public-oriented mound feature at Actuncan dating between 1125 and 1015 cal BC (LeCount et al. 2017; Simova 2023). This general delay contrasts with the nearby Pasión and Usumacinta regions, where monumental architecture emerged earlier. At Ceibal in the Pasión region, Inomata and colleagues (2013) documented one of the earliest E Group complexes and a large platform structure, dating to around 1000 BC. E Groups, which typically feature a western pyramid and a north-south range structure to the east, became key architectural elements in major Maya centers. At Ceibal, an initial low square western structure and a low eastern range structure were later modified into a pyramid between 850 and 800 BC. Similarly, in the Usumacinta region, Inomata and colleagues (2020) uncovered the Aguada Fénix earthwork, a massive 1,400-meter-long artificial plateau with nine causeways, dated to 1000–800 BC. The scale of Aguada Fénix indicates significant labor investment and organizational capacity at this early stage, the likes of which were not seen in the UBRV for several more centuries.

The emergence of ceramics is another defining feature of the Preclassic transition. The earliest pottery in Mesoamerica appears around 1900 BC in the Coastal Chiapas region of Mexico and northern Honduras, followed by ceramic innovations near San Lorenzo by 1700 BC and in the Isthmus of Tehuantepec by 1600 BC (Rosenswig 2023). The Maya lowlands were among the last regions to adopt pottery, with ceramic complexes emerging between 1200 and 900 BC. Rather than developing independently, pottery likely spread into the lowlands through expanding trade networks and the continued mobility of semi-nomadic groups. In the UBRV, the Cunil and Kanocha pottery complexes are associated with the earliest settled sites by at least 1200 BC (Awe 1992; Garber et al. 2004b; Sullivan and Awe 2013; Sullivan et al. 2009, 2018). Other examples of EPC ceramics include the K'as and Chich complexes at Nixtun-Ch'ich' in the Petén (Rice 2019), Real 1 at Ceibal (Inomata 2023; Inomata et al. 2020), Ek and Ch'oh Ek in the Yucatán (Andrews V and Bey 2023; Andrews V et al. 2018), and Swasey in northern Belize (Kosakowsky 1987; Kosakowsky and Pring 1998; Kosakowsky et al. 2018; Pring 1977; Valdez 1987, 1994; Valdez et al. 2021).

This project examines the similar and contemporaneous Cunil and Kanocha ceramic complexes, which have been identified in discreet contexts at Actuncan (LeCount et al. 2017, 2019), Blackman Eddy (Brown 2003; Garber et al. 2004b), Cahal Pech (Awe 1992; Ebert et al. 2019; Sullivan and Awe 2013; Sullivan et al. 2018), and Xunantunich

(Brown et al. 2011; LeCount and Jaeger 2010). Although EPC ceramics appear in Middle Preclassic fill deposits at Arenal (Brown et al. 2025), Chan (Kosakowsky 2012), Floral Park (Garber et al. 2004b), and Pacbitun (Powis et al. 2009) no EPC architecture has been identified at these sites, suggesting that earlier structures may remain undiscovered. In the UBRV, these ceramics are divided into two broad groups: Belize Valley Dull Ware, characterized by ash-tempered pastes and red, white, or black dull slips, and Belize Valley Coarse Ware, which is composed of calcite- and quartz-rich pastes (Figure 3.1).

Figure 3.1. Early Preclassic Ceramics. Top left is a Zotz Zoned-Incised bowl, top right is a Cocoyol Cream bowl, bottom left is an Uck Red dish rim, bottom center is a Sikiya Unslipped jar rim, and bottom right is an Ardagh Orange-brown jar rim. The first three are Belize Valley Dull Ware types, and the last two are Belize Valley Coarse Ware types.

Dietary shifts during the EPC included the adoption of maize agriculture and an increased reliance on aquatic and small mammal resources (Stanchly and Awe 2015; Stanchly and Burke 2018). River snails (*Pachychilus* spp.), often prepared by removing their ends, became a dietary staple alongside small mammals, including domesticated dogs. Interestingly, the modern Maya community near Pacbitun in San Antonio, Belize still prepare river snails in a cornmeal and tomato stew for festivals (personal observation).

Technological innovations during the EPC include the use of chert microdrills for crafting marine shell beads (Awe et al. 2021; Hohmann 2002), polished jade sourced from the Motagua River Valley (Awe et al. 2021; Powis et al. 2016), and limited obsidian use, suggesting emerging connections to Mesoamerican trade networks (Golitko et al. 2019; Golitko and Feinman 2015). Evidence of cotton textile production also appears during this period, including cotton pollen (Lohse 2010; Wiesen and Lentz 1997), textile impressions in plaster (Lawlor et al. 1995), bone needles (Brown 2003; Garber et al. 2004a, 2004b), and ceramic spindle whorls (Awe 1992).

It has been implicitly hypothesized that EPC villages within the UBRV were interacting with one another based on shared traditions, but as of the time of this study, no data exist to definitively support this hypothesis. This study will not only show that these villages were indeed interacting with one another, but also the relative extent of those interactions.

Middle Preclassic (900 – 300 BC)

Early Middle Preclassic (900 – 600 BC)

The transition into the Early Middle Preclassic (EMPC) in the UBRV, as in much of the Maya lowlands, is marked by significant developments including the widespread appearance of monumental architecture (Brown and Bey 2018; Doyle 2017; Ebert et al. 2021; Garber et al. 2004a), large platform construction on leveled hilltops (Reese-Taylor 2023), rising populations (Willey et al. 1965), and an expansion in obsidian tools and new lithic forms (Ebert 2017; Kersey 2006; Stemp et al. 2018; Suarez et al. 2024). The period also saw a marked increase in marine shell bead production (Healy et al. 2004; Hohmann 2002; Hohmann et al. 2018; Lee and Awe 1995), the emergence of a new pottery complex (Gifford 1976), long-distance ceramic trade (Callaghan et al. 2018), and increased evidence of centralized religious and ritual activities (Awe et al. 2021; Brown et al. 2018; Lohse 2010). However, this transition was neither immediate nor uniform; its impact varied across different regions of the Maya lowlands over several centuries.

One of the most visible changes during the EMPC was the introduction of monumental architecture (Doyle 2017). Between 1000 and 600 BC, single-tier rectangular and rounded platforms and low pyramidal structures appeared throughout the Maya lowlands (Figures 3.2 and 3.3; Ebert et al. 2021; Inomata et al. 2013, 2020). Many of these early structures were E Group complexes (Figure 3.4), initially thought to align with equinoxes and solstices (Blom 1924). However, more recent research suggests that most E Groups were not astronomically aligned (Aimers and Rice 2006). Instead, they likely served as ceremonial spaces for community gatherings, feasts, and dances (Brown and Garber 2005; Estrada- Belli 2011; Garber et al. 2004a; Inomata 2014; Rice 2008).

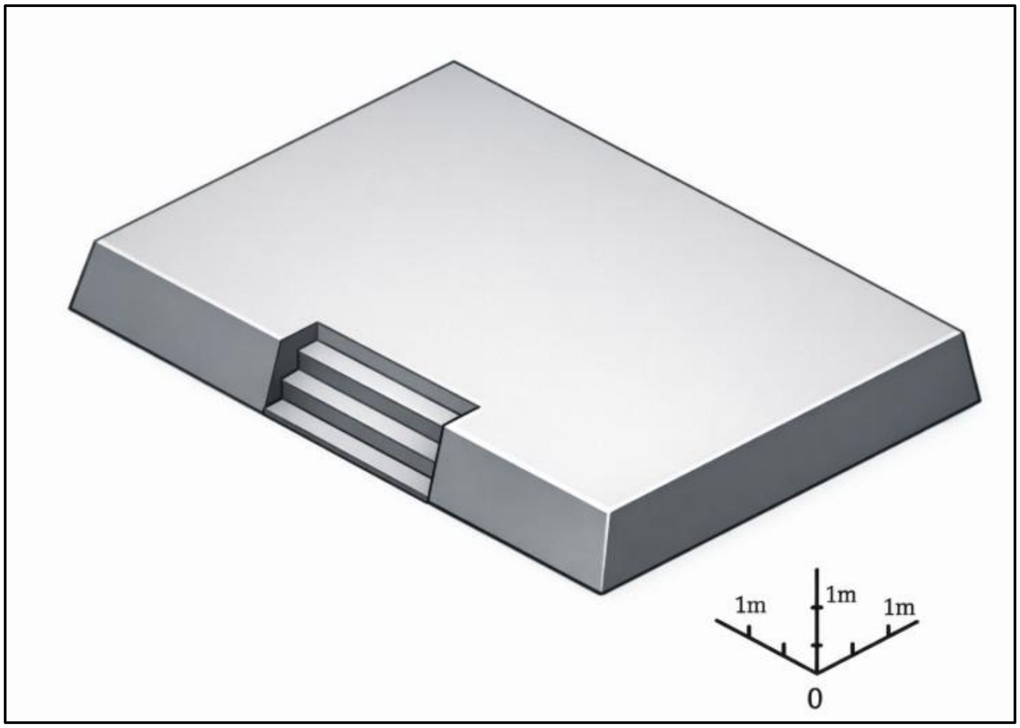

Figure 3.2. Early Middle Preclassic Low Platform Structure. Adapted from Garber et al. 2004a.

Figure 3.3. Early Middle Preclassic Round Structure.

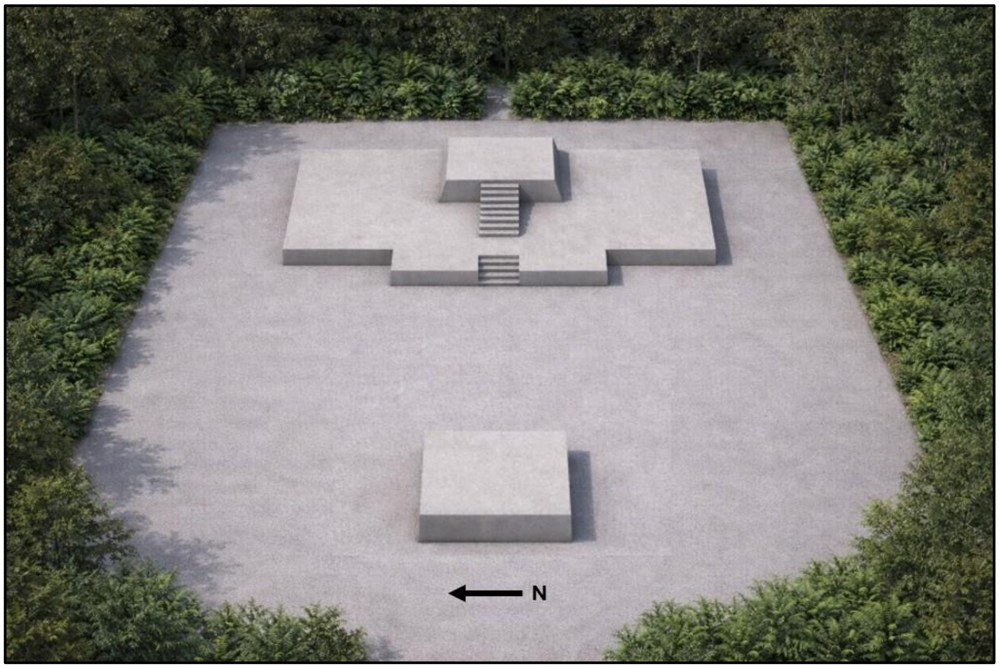

Figure 3.4. Early E-Group Representation. Modeled after "Early Xunantunich" E-Group presented by Brown 2017:395.

Differences in the built environment of pyramidal structures, round structures, low platforms, and public plazas have been identified at multiple UBRV villages dating to this period including Blackman Eddy (Brown and Garber 2005; Garber et al. 2004a), Cahal Pech (Awe 1992), and Xunantunich (Brown et al. 2018). As mentioned in the previous chapter, researchers generally interpret these features to suggest different political strategies ranging from the exclusionary, pyramidal style structures, to the corporate, public-oriented low platforms and round structures. Thus we begin to see clear evidence of differing political strategies forming in the region.

Population growth during the EMPC is evident in increased settlement activity and artifact densities at sites such as Barton Ramie (Willey et al. 1965), Blackman Eddy (Garber et al. 2004a), Cahal Pech (Awe 1992; Powis 1996), Chan (Robin 2012), Lower Dover (Walden et al. 2017), and Pacbitun (Healy et al. 2007). At Barton Ramie, for example, 18 of 65 excavated house mounds contained pottery from this period. Most houses were arranged in small clusters across the site, likely reflecting multiple extended family groups (Willey et al. 1965:562). As populations expanded, increased territorialization likely required new political mechanisms to manage growing social networks (Braun 1986).

By this time, a robust pan-Mesoamerican obsidian trade network had fully developed, linking Western Belize to larger exchange systems (Golitko et al. 2019; Golitko and Feinman 2015). X-ray fluorescence analyses indicate that most obsidian artifacts in the UBRV came from the Guatemala Highlands (Ebert 2017; Kersey 2006; Suarez et al. 2024). Interestingly, different UBRV sites show distinct preferences for obsidian sources. For example, El Chayal obsidian dominates at Cahal Pech (Ebert 2017), whereas San Martin Jilotepeque obsidian is more common at Blackman Eddy (Kersey 2006).

New lithic forms, including unifacial scrapers, celts, and a resurgence of bifacial tools, also emerged during the EMPC (Stemp et al. 2018). Chert microdrills, commonly used for marine shell bead production, became increasingly prevalent (Hohmann 2002). The expanded reliance on local chert sources suggests either a decline in trade with the Chert-Bearing Zone of northern Belize or a shift in material preferences.

Marine shell bead production, which began in the Early Preclassic, intensified during the EMPC (Hohmann 2002; Hohmann et al. 2018; Lee and Awe 1995). Large quantities of shell debitage, finished beads, and chert drills have been recovered from Cahal Pech, Blackman Eddy, and Pacbitun (Hohmann 2002; Hohmann et al. 2018; Horn 2015; Lee and Awe 1995; Messinger et al. 2023; Powis et al. 2009). In the nearby Petén region of Guatemala, archaeologists have found complete shell adornments but little evidence of shell working, suggesting that the UBRV may have been a center for finished shell bead production, possibly exporting goods further inland (Hansen et al. 2018; Reese-Taylor 2023).

Pottery production in the UBRV during the EMPC underwent significant changes. The Cunil and Kanocha pottery types disappeared, replaced by the Jenney Creek ceramic complex. At Barton Ramie, Gifford (1976:61-62) identified an early phase of this complex, now recognized as corresponding to the EMPC, which he defined by interior lip thickening on bowls, flaring-walled dishes with flat bases, and slipping on the interior of bowls and plates and on the exterior of jars. This new ceramic tradition, known by different names at various sites, is dominated by Mars Orange Ware and Uaxactun Unslipped Ware (Figure 3.5.), both of which became widespread across UBRV settlements (Gifford 1976; Kosakowsky 2012; Peniche May 2016; Powis 2009; Walden 2021; Willey et al. 1965).

Figure 3.5. Middle Preclassic Ceramics. On the left is a Jocote Orange-brown jar rim, and on the left is a Savana Orange bowl rim.

A notable technological shift during this period was the decline of ash tempering in ceramics. Gifford (1976) found ash-tempered Mars Orange Ware sherds at Barton Ramie but lacked stratigraphic evidence to support an early phase date. Decades later, Peniche May (2016) documented a stratigraphic sequence at Cahal Pech showing a gradual transition from ash-tempered Cunil pottery to early-phase Kanluk pottery, which initially retained some ash tempering before it was phased out entirely. A similar pattern has been observed in early pottery at Blackman Eddy (Garber et al. 2004b).

Other pottery complexes, including Eb in the Petén (Culbert 1993; Culbert and Kosakowsky 2019), Real 2 and 3 and Escoba 1 at Ceibal (Inomata 2023; Inomata et al. 2020), and Xe in the Pasión region (Adams 1971; Inomata et al. 2020; Willey 1970; Willey et al. 1967), also emerged during this period. Notably, Mars Orange Ware has been identified in the Petén, marking it as one of the earliest known trade wares in the Maya region (Callaghan et al. 2018). Although there is evidence (i.e., ceramic, obsidian, and shell) of trade with villages outside of the UBRV, prior to this study there was no definitive evidence of trade networks within the region.

Late Middle Preclassic (600 – 300 BC)

During the Late Middle Preclassic (LMPC), the Maya lowlands experienced significant transformations, including the spread of monumental architecture, road construction, increasing wealth disparities, and expanded trade networks (Pugh 2022). These changes reflect growing political centralization, as rulers mobilized labor on a larger scale, and an intensification of socio-economic interactions, both key indicators of increasing socio-political complexity. In the UBRV, all major sites show evidence of occupation during this period.

Previous studies in the UBRV have often grouped the Early and Late Middle Preclassic together due to challenges with relative dating methods. This difficulty is further compounded by the Hallstatt plateau, which significantly affects radiocarbon calibration for dates between approximately 800 and 400 BC (Pearson et al. 1983; Stuiver and Becker 1986). Despite these limitations, Bayesian radiocarbon modeling (Bayliss 2009; Ebert et al. 2017) and subtle ceramic attribute changes provide tools to differentiate these phases.

At Barton Ramie, Gifford (1976) identified a late phase of the Jenney Creek ceramic complex, which corresponds to the Mamom complex in the Petén. This phase is distinguished by the increase of Joventud Red and Sayab Daub pottery types, as well as the use of incision, punctation, and smooth-slipping on Jocote Orange-brown jars. Similar distinctions have been documented at other UBRV sites (Awe 1992; Brown 2007; Garber et al. 2004b; Peniche May 2016; Ebert et al. 2019; Walden 2021). Throughout the LMPC, Mars Orange Ware and Uaxactun Unslipped Ware remained dominant in the UBRV, mirroring their prevalence across the Maya lowlands. This widespread distribution suggests increased interaction among settled populations.

Other notable ceramic complexes from this period include the Mamom and Tzec complexes in the Petén (Culbert and Kosakowsky 2019; Smith and Gifford 1966), Escoba 2 and 3 at Ceibal (Inomata 2023), and Bladen and Lopez in northern Belize (Kosakowsky 1987; Kosakowsky and Pring 1998; Kosakowsky et al. 2018; Valdez 1987, 1994; Valdez et al. 2021). Scholars often use "Mamom" as an overarching term to describe this ceramic phase across the Maya lowlands due to shared vessel forms, decorations, and slip colors (see Walker 2023 for a full discussion). The transition from local pre-Mamom ceramics to the more standardized ceramics of the Mamom sphere appears to have been gradual and seamless across much of the lowlands, including the UBRV (Walker 2023).

Architectural developments during the LMPC included the continued construction of large platforms and double-tier pyramidal structures (Figure 3.6), signaling an expansion of monumental architecture throughout the region. Population growth also continued, as reflected in increasing artifact densities and settlement expansion. While material culture from the LMPC shows continuity with the EMPC, its proliferation suggests not only larger populations but also an increase in long-distance trade. These developments likely gave certain sites greater access to resources, strengthening their political influence. How these

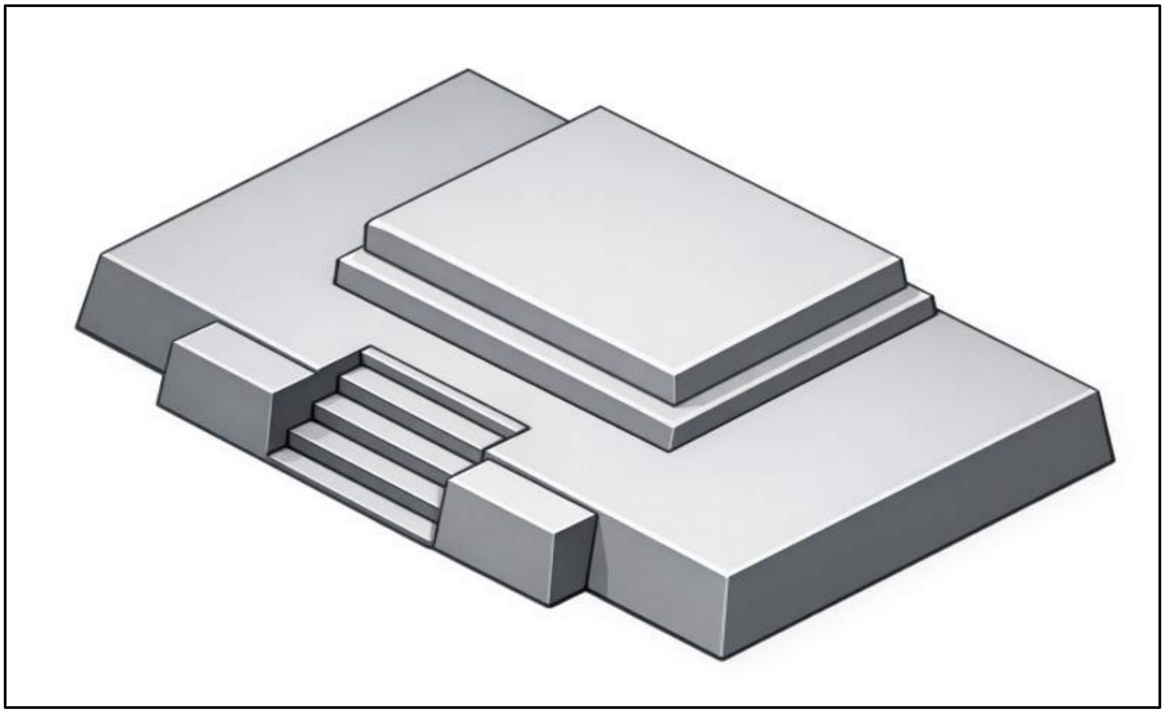

Figure 3.6. Late Middle Preclassic Pyramidal Structure. Adapted from Garber et al. 2004a.

sites interacted with one another, and the extent to which these features associated with differing political strategies influenced the regional trajectory towards complexity has remained a mystery. This trajectory, which is the focus of this study, laid the foundation for the emergence of Maya kingdoms in the Late Preclassic period.

Late Preclassic (300 BC – AD 250)

The Late Preclassic period is often associated with the emergence of kingship in the Maya world (Estrada-Belli 2011; Freidel and Schele 1988), significant population increase (Willey et al. 1965), the widespread expansion and elaboration of large-scale monumental architecture, rising social inequality, and the development of settlement hierarchies. During this time, the pan-Maya Chicanel pottery sphere also became dominant (Gifford 1976). Scholars previously believed that Maya writing did not emerge until around AD 250, marking the start of the Classic period. However, recent discoveries have revealed numerous examples of writing dating to the Late Preclassic (Hansen 1991; Saturno et al. 2006).

Some researchers recognize a "Terminal Preclassic" or "Proto-Classic" period (AD 150–250), defined by the collapse of El Mirador as the dominant lowland Maya polity (Dahlin 1984) and agricultural difficulties likely caused by drought (Ebert et al. 2017). While this sub-period falls outside the scope of this study, readers can refer to Brady and colleagues (1998) for a more detailed discussion.

In the UBRV, the Late Preclassic saw the emergence of three or more tiered pyramidal structures at multiple sites, including Actuncan (McGovern 2004), Blackman Eddy (Brown 2003, 2005; Garber et al. 2004a), Cahal Pech (Awe 1992; Conlon 2013), and

Pacbitun (Powis et al. 2019b). Among these, Structure 1 at Actuncan, which reached a height of 28 meters, stood as the tallest structure in the UBRV until the Late Classic period, more than five centuries later. Interestingly, sites such as Baking Pot, Barton Ramie, Lower Dover, and Floral Park do not exhibit these larger architectural forms until much later. Shifts in the design of E Groups, along with associated material culture, suggest that these structures became even more restricted and elite-controlled areas (Aimers and Rice 2006; Chase and Chase 1995; Laporte and Fialko 1990). The widespread use of masks on pyramidal structures further indicates exclusionary ideologies and connections with northern Belize and the Petén, where similar masks appeared on major temples. These features were presaged during the EMPC at both Blackman Eddy (Brown 2003, 2005; Garber 2004) and Pacbitun (Davis and Powis 2015; Powis et al. 2019a, 2019b).

This period also marks the earliest evidence of burials within the eastern structures of E Group complexes in the UBRV (Awe 2013; Awe et al. 2017). Awe and colleagues (2017) argue that these structures should be referred to as "Eastern Triadic Shrines," as they differ substantially from traditional E Groups in the Petén. Burials within these shrines represent a form of exclusionary ancestor veneration, suggesting that elite lineages were using these spaces to establish political legitimacy. This practice foreshadows the divine kingship that would define the Classic period.

The expansion of the Chicanel ceramic sphere, defined by the widespread use of Sierra Red pottery, is another hallmark of this period. Gifford (1976:84) describes the Chicanel Horizon as “massive in bulk of deposit and in the character of its pottery. Sierra Red is its diagnostic pottery type and the geographic range of this single pottery is enormous, covering more square kilometers in quantity of deposition than any pottery type

I know of in Middle America." Sierra Red pottery is particularly notable for its lustrous, waxy red slip and its extensive distribution across the Maya lowlands. While Sierra Red is dominant, Willey and colleagues (1965) observed a mutually exclusive relationship between Sierra Red and Hillbank Red pottery types within domestic house mounds at Barton Ramie. This pattern suggests differences in access to materials or social divisions within the community.

Toward the end of the Late Preclassic, two new ceramic complexes emerged in the UBRV. At Barton Ramie, the Mount Hope phase closely resembles the preceding Barton Creek phase, while the Floral Park phase, which is largely contemporaneous, displays distinct forms and styles that align more closely with ceramics from the Petén. Willey and colleagues (1965:349-350) proposed that this shift resulted from a large-scale migration from the Petén into the UBRV. Population growth had been steady since the Middle Preclassic, but the increase during this time appears more dramatic, as evidenced by rapid settlement expansion across the region (Healy et al. 2007; Willey et al. 1965; Walden 2021). At Barton Ramie, the number of occupied house mounds doubled, and many new domestic constructions contained Floral Park phase ceramics in their foundational levels, further supporting the idea of a major migration event.

Classic Period (AD 250 – 900)

The Classic period of Maya civilization, traditionally divided into the Early Classic (AD 250–600) and Late Classic (AD 600–900), represents a pivotal era in Maya history. Early scholarship focused heavily on this period, as it produced most of the monumental architecture seen on the ground today and supported a very large population, resulting in an extensive archaeological record. More recently, scholars have turned their attention to the Terminal Classic period (AD 750–900), which marks the latter half of the Late Classic. This period is characterized by a decline in monumental construction, reduced elite activity, and significant demographic shifts. Scholars often refer to this transition as the "Maya Collapse" (Culbert 1973; Diamond 2005).

Early Classic Period (AD 250–600)

The Early Classic period (beginning around AD 250) is marked by the widespread adoption of writing across the Maya world and the emergence of the *K'uhul Ajaw* (divine kingship) political structure. This period also saw significant population growth and the expansion of extensive trade networks, as evidenced by both archaeological and epigraphic records (Martin 2020; Martin and Grube 2000; Munson and Macri 2009). Urbanization became well-developed in the Maya lowlands, making the term "city" appropriate for many major centers.

At Barton Ramie, 50 of the 65 excavated house mounds show evidence of occupation during this period, reflecting substantial demographic expansion (Willey et al. 1965:350). The political landscape of the Early Classic was shaped by far-reaching alliances and rivalries among Maya city-states, as recorded in hieroglyphic texts. This period was highlighted as a prime example of exclusionary leadership within the original framework of the dual-processual model (Blanton et al. 1996). While all the sites in this study continued to grow during this period, the major centers of the Preclassic including Blackman Eddy, Cahal Pech, and Pacbitun retained their prominence. Meanwhile, Xunantunich and Buenavista del Cayo began developing into large political centers, but they did not fully emerge as dominant players on the political landscape until the Late Classic.

Ceramic production during the Early Classic saw an increase in monochrome black pottery and polychrome types. Gifford (1976) notes that ceramics from the Petén and the UBRV during this period are strikingly similar, suggesting strong interconnections between these ceramic spheres. Patron-client relationships developed to support the production of polychrome pottery vessels, indicating new economic forms such as attached specialization (Inomata 2001).

Late Classic Period (AD 600–750)

The Late Classic period marked the apex of complexity for Pre-Columbian Maya civilization, with many cities reaching their peak population (Culbert and Rice 1990) and settlements clustering into dense neighborhood groups (Thompson et al. 2022; Walden 2021). At Barton Ramie, for example, all 65 of the excavated house mounds show evidence of occupation during this period, reflecting the region's demographic expansion (Willey et al. 1965:371). As a means of comparison, there are more Late Classic prehistoric house mounds in the region than modern houses.

The elite gift economy flourished during this time, as indicated by the widespread exchange of polychrome pottery, which was likely of central importance to ceremonial feasts (Reents-Budet 1994; Reents-Budet et al. 2000). Pottery production also underwent technological shifts, including a resurgence of ash tempering. Belize Red pottery, primarily in dish form, was extensively distributed throughout Belize. Its prevalence in the UBRV suggests that it was likely produced locally, underscoring the existence of interregional trade networks and the exchange of goods within the region.

This period also saw a proliferation of monumental architecture and public art, further highlighting the role of elite-sponsored activities in maintaining urban life and consolidating political power. Large-scale construction projects and artistic displays reinforced elite authority, demonstrating their ability to mobilize labor and resources on an unprecedented scale.

Terminal Classic Period (AD 750–900)

The Terminal Classic period, beginning around AD 750, brought significant changes to Maya society. This era saw the widespread breakdown of the *K'uhul Ajaw* political system, population decline, and the cessation of both monumental construction and the inscription of carved monuments (Ebert et al. 2014; Demarest et al. 2005; Hoggarth et al. 2021; Premo 2004). Scholars have proposed multiple explanations for these shifts, with recent research emphasizing the impact of an extended, multi-decadal drought that likely eroded faith in divine kingship and prompted migrations to more fertile regions (Brenner et al. 2002; Dahlin 2002; Hoggarth et al. 2017).

Over the last decade, researchers in the UBRV have worked to better understand this transitional period by analyzing peri-abandonment deposits, remnants of the final uses of monumental site cores (Alvarado 2019; Davis 2018; Koenig 2014; Romih 2019; Rovito 2021; Stricklin 2019; Tappan 2020). These studies suggest that even as cities were abandoned, people returned to these sacred sites to leave offerings, bury their dead, and petition their gods and ancestors. At Baking Pot, for example, analyses of artifact assemblages and associated iconography indicate that peri-abandonment deposits were linked to ancestor veneration and rituals aimed at alleviating societal stress primarily through petitioning the gods for water through water-related symbolism (Davis 2018). Similar deposits found across the UBRV, and broader Maya lowlands suggest that these practices were widespread during this period of upheaval (Awe et al. 2020).

It is important to note that societal decline was not uniform across the Maya lowlands. Some areas, including portions of the UBRV, retained ritual activity in monumental cores well into the mid-9th century (Hoggarth et al. 2020). This variability underscores the complexity of the so-called “Maya Collapse” and highlights regional differences in how communities responded to changing political and environmental conditions. High-resolution radiocarbon dating and demographic modeling suggest that this "collapse" was a gradual process rather than an abrupt event (Hoggarth et al. 2020, 2021). These findings support the concept of a prolonged “crumble” (Aimers 2007a) rather than a sudden and total societal breakdown. Regardless, the established political strategies and social networks, which had been forming and evolving since the Early Preclassic period, faced irreversible changes, which served as a pivot point for Maya civilization as a whole.

Postclassic Period (AD 900 – 1519) and Beyond

The Postclassic period is primarily known for its major centers in the Yucatán region of Mexico, including Chichén Itzá, Tulum, and Mayapán. Much of what is known about the later Postclassic comes from Spanish accounts, written after contact, and indigenous Maya documents, such as the four surviving codices, the *Popol Vuh*, and the

Books of Chilam Balam. One of the most significant political changes during this period was the reorganization of leadership structures. Instead of centralized rule by kings and queens, many centers adopted governance by the *Multepal*, a council of elders. This style of leadership is more corporate than in previous periods, which relied heavily on hierarchies and genealogical dynasties. This cycling between leadership styles was predicted by the dual processual model (Blanton et al. 1996).

Further south, in the UBRV and nearby Petén region, archaeological evidence suggests large-scale depopulation at the start of the Postclassic period. Pottery production and other material culture sharply declined, indicating reduced occupation. While archaeologists once believed that the UBRV experienced continuous occupation from the Terminal Classic into the Postclassic, recent radiocarbon assays from the Baking Pot epicenter and surrounding settlement suggest a hiatus between the end of the Classic period and resettlement, which likely occurred in the middle of the Postclassic (Hoggarth 2014). No monumental architecture from this period has been identified in the UBRV, and Postclassic settlement remains are sparse (Aimers 2002; Hoggarth 2014; Willey et al. 1965). This pattern contrasts sharply with sites further north in Belize, such as Lamanai, which saw population increases during the Postclassic, likely due to migration from depopulated regions in the south (Aimers 2007b; Pendergast 1991).

Due to the region's low population levels and restricted settlement areas during the Postclassic, little is known about pottery production and interaction in the UBRV. The New Town pottery phase, which corresponds to the Late Postclassic, introduced new ceramic forms with ties to both the Petén and northern Belize (Aimers 2002). Continued research may provide greater insight into Postclassic exchange networks and settlement patterns.

Significant reoccupation of the UBRV did not occur until the historic period, when environmental conditions once again became favorable for agriculture. During this time, large groups, likely migrating from the Petén, resettled the region. Today, the area is home to a diverse population, primarily composed of Afro-Caribbean and Mestizo communities, as well as some Yucatec Maya communities that migrated to the region during the 19th century as a result of the Mexican Caste Wars.

Conclusion

This chapter examined the changes in artifacts and architecture as they relate to political and economic transformations, as they apply to advances in socio-political complexity, throughout the Pre-Columbian history of the UBRV. The focus of this study is on the Early Preclassic and Middle Preclassic periods, a time when archaeologists observe the emergence of permanent settlements, monumental architecture, pottery production, and first signs of social differentiation in the Maya world. The emergence of different types of monumental features during these periods points towards different leadership style preferences. Additionally, the excavations of households provide the means of observing when and where differences in portable wealth and social status first emerged. Several assumptions about these early periods permeate the literature. First, it is assumed that sites were primarily corporate earlier in time and more exclusionary as time progressed. Second, there is an assumption that most, if not all, of these sites were in communication with one another. Both are suggested by the prevailing theories on the advancement of socio-political complexity in Mesoamerica, but few studies have explicitly assessed political strategies in this region, and no studies have addressed the evidence for direct interaction among early sites. This study does both, a step which is crucial to evaluate these prevailing assumptions.

Understanding the origins of political and economic diversity, which became defining characteristics of later periods, requires close examination of these early developmental phases. Key questions arise: How did local political power manifest at the major centers in the UBRV during these early periods? How did economic networks within the region and beyond influence the evolution of socio-political complexity? It is to these questions that we turn to in the next few chapters.

CHAPTER 4

INVESTIGATING SOCIO-ECONOMIC RELATIONSHIPS WITH NEUTRON ACTIVATION ANALYSIS OF POTTERY

This chapter lays the foundation for tracking socio-economic interaction networks between sites within the project area using ceramic circulation as a proxy for interaction. To evaluate pottery exchange within the region, I use Neutron Activation Analysis (NAA) on a sample of pottery from sites across the Upper Belize River Valley (UBRV) region divided between the Early Preclassic (EPC), Early Middle Preclassic (EMPC), and Late Middle Preclassic (LMPC) periods.

Pottery is particularly well suited for exploring past network flow patterns for several reasons. First, it is ubiquitous. Once pottery appears, it is produced in large quantities and its use increases over time, giving us a consistently abundant dataset. Second, pottery is used across many domains of daily and social life. It appears in utilitarian contexts such as cooking, eating, storage, and transport, but also in ritual settings including architectural offerings, burials, and feasting deposits. Pots, and often their contents, also played roles in social, political, and economic interactions, including gifting and exchange. Third, pottery is distributed differently in staple finance and wealth finance systems, making it sensitive to multiple forms of economic organization. Because it is discarded regularly, it also provides strong temporal resolution, helping track change through time. Importantly for provenance analysis, specific types of pottery can often be tied to a geographic locus of production.

In this chapter, first I will discuss the social and functional role of pots in the region followed by an explanation of my sampling strategy, and then briefly explain the laboratory methods used in NAA. I then present the statistical approach, as well as the data, that I use to establish core groups which are likely related to specific production locations. Finally, I will discuss the distribution of NAA-derived pottery groups amongst the sites. In the following chapter I build on this study to reconstruct site-to-site interaction networks.

Pots and People in the Upper Belize River Valley

Preclassic pottery in the UBRV served a range of both social and utilitarian roles. Broadly, the ceramic assemblages can be divided into two functional categories: utilitarian jars and serving vessels, including bowls, plates, and dishes. Utilitarian jars were likely used for water transport and storage, as well as the storage of dry goods and fermented products. In contrast, bowls, plates, and dishes were primarily associated with food consumption in both daily household contexts and communal feasting events. These functional distinctions likely map onto different social arenas, with utilitarian jars embedded in household economies and serving vessels playing a more visible role in social interaction, including feasting and the negotiation of status.

This distinction also has implications for understanding patterns of exchange and social relationships. Drawing on the spheres of exchange framework (e.g., Bohannon 1955; Sahlins 1972), several studies have shown that different categories of goods tend to circulate within different social networks, corresponding to different forms of social capital. For example, in the Southwest U.S., David Abbott (2000:139) demonstrates that the distribution of different types of Hohokam pottery reflected degrees of social closeness.

Finer, more desirable red wares tended to circulate across greater social distances due to their higher exchange value, whereas plain utilitarian wares were more commonly exchanged within close-knit kin groups. Similarly, Andrew Duff (2002) argues for the Western Pueblo region of the U.S. Southwest that low-value, utilitarian vessels typically circulated among kin groups, while decorated or fine wares moved through broader regional networks.

Importantly, both studies also note that utilitarian wares can constitute a substantial proportion of exchanged goods, over 50 percent in Abbott's case, suggesting that everyday exchange can be embedded in kin-based or otherwise socially proximate relationships. If this can be applied to the UBRV, these insights suggest that the exchange of utilitarian pottery may primarily reflect bonding ties, while serving vessels, especially those that are decorated or stylistically distinctive, may have played a greater role in bridging ties that connected villages across the regional network.

In the UBRV, these functional distinctions correspond closely with ceramic groups. The Jocote, Sayab, and Sikiya groups are most commonly found in jar forms, whereas the Chi, Chunhinta, Cocoyol, Joventud, Savana, Pital, and Uck groups are typically represented by bowls, dishes, and plates. One noteworthy mention is the Savana group, which occasionally includes spouted vessels, and has also been called "the first Maya trade ware" due to its distribution into the Petén (Callaghan et al. 2018). Additionally, residue analysis of spouted vessels at the site of Colha in northern Belize suggests that some, though not all, spouted vessels contained cacao-based beverages (Powis et al. 2002). Despite these functional distinctions, most pottery groups are recovered from architectural fill contexts across all periods under study. Due to the relative scarcity of burials and formal ritual deposits dating to the Early and Middle Preclassic, securely contextualized assemblages remain limited, constraining interpretations of pottery use in specific social settings.

Even so, several lines of evidence point to the participation of pottery in ritual and architectural practices. The earliest known ceramic cache in the UBRV comes from Actuncan, where a utilitarian jar was deposited as an architectural offering. At Blackman Eddy, multiple Early and Middle Preclassic features have been interpreted as construction-related deposits, including spouted vessels, jars, and bowls placed on the surfaces of buried architecture (Brown and Freiwald 2020; Hartman 2003). At Pacbitun, a spouted Savana vessel was deposited as a termination offering during the burial of the El Quemado structure in the Late Middle Preclassic, suggesting continuity in the use of ceramics in architectural ritual (Figure 4.1). While no clear correlation exists between specific pottery groups and these offerings, the repeated inclusion of spouted vessels may indicate a specialized or symbolically charged role. These deposits suggest that ceramics were not merely utilitarian objects but were actively incorporated into practices that materialized relationships between people, architecture, and cosmological beliefs.

Iconographic evidence further highlights the social and ideological significance of Preclassic pottery. Several Early Preclassic serving vessels from Cahal Pech, though recovered from fill contexts, display incised motifs interpreted as cosmological symbols (Garber and Awe 2008, 2009; Garber et al. 2004a). These include the kan cross, a widespread Mesoamerican symbol often associated with the ordering of the cosmos; representations of the harpy eagle, an apex predator with potential elite or cosmological associations; and the "flame brow" motif, which shows affinities with contemporaneous

Figure 4.1. Spouted Pot Cache. Pacbitun, El Quemado, Cache 2. Photograph by J.B. Davis

Olmec iconography. Together, these motifs point to the integration of local ceramic traditions within broader pan-Mesoamerican ideological systems.

Sampling Strategy

The goal of this NAA study is to track the relative volume of flows of pottery among sites through time across the UBRV and potentially beyond, to reconstruct patterns and changes in economic interaction within the region during its formative period of organizational complexity. Charles Perreault (2019) points out that economic processes can change within a matter of days, weeks, months, and years, well below the temporal resolution which archaeologists generally have access to. While it is true that archaeological resolution is generally confined to decades at best, and usually centuries, it is possible to evaluate longer periods of time using the accumulation of materials. This study is not trying to reconstruct the exact volume of flow between sites. Instead it uses the accumulation of materials to reconstruct the strongest continuous vectors of interaction over the long-term which likely represent consistent relationships.

Since I am interested in tracking flows directly, I needed to sample such that the NAA sample was proportional to site assemblages in terms of both time period and ceramic categories. Thus, I employed a proportional sampling strategy based on both site and period, modified where necessary based on the available pottery sample. My goal was to collect 25 sherds per site per period, but practical field conditions resulted in sample sizes generally ranging from 10 to 30 sherds per site per period. For instance, at Blackman Eddy, I sampled 23 EMPC sherds. Of the total EMPC site assemblage, 48% was classified to the Jocote ceramic group, so I selected 11 Jocote group sherds for NAA, maintaining proportional representation (11/23 ≈ 48%). Table 4.1 summarizes the total NAA sample. These sampling percentages were informed by published analyses, consultation with Principal Investigators, and personal observations during lab visits. The Cahal Pech sample comes from Ebert and colleagues (2019) prior NAA study which was similarly designed to proportionally represent the materials available. Rim sherds with differing diameters were preferentially selected to avoid sampling multiple pieces of the same vessel, and sherds from unmixed contexts were sampled when available. Additionally, to ensure temporal accuracy, radiocarbon dated contexts were chosen where those data were available, or with guidance form the Principal Investigator of the site. This proportional sampling strategy allows me to make a better model and compare the relative volumes of flow of ceramics among sites.

The ceramic categories used to define this sample were based on Smith and Gifford's (1965; see also Gifford 1976:17) definition of the ceramic group level, which they describe as "a set of closely related and very similar pottery types that demonstrate a distinctive homogeneity in range of variation concerning form, base color, technological, and other allied attributes… A ceramic group is in a sense more or less a 'super-type.'" I chose the group level rather than the type level because regional ceramicists who use the type-variety classification system tend to reach greater consensus at the group level. This is equivalent to how the ceramic ware concept has been used in the U.S. Southwest and many other regions as the basis of tracking networks of interaction across time and space (see Mills et al. 2013). Moreover, within a given period, the group level likely reflects a distinct category of pottery vessels that was meaningful within the original cultural context (see also Mills et al. 2016).

Table 4.1. Pottery Sherds Sampled by Site, Period, and Ceramic Group.

Site	Period	Pottery Group	Sample Size
Actuncan	EPC (n=12)	Cocoyol	1
		Jocote	1
		Savana	2
		Sikiya	4
		Uck	3
		Unknown	1
	EMPC (n=18)	Jocote	6
		Joventud	2
		Savana	9
		Sayab	1
Arenal	LMPC (n=31)	Jocote	15
		Joventud	4
		Savana	12

Baking Pot	LMPC (n=60)	Jocote	27
		Pital	2
		Savana	26
		Sikiya	1
		Uck	1
		Unknown	3
Blackman Eddy	EPC (n=17)	Jocote	5
		Savana	3
		Sayab	1
		Unknown	8
		Jocote	11
	EMPC (n=23)	Joventud	3
		Savana	7
		Unknown	2
		Jocote	12
	LMPC (n=20)	Savana	8
		Chunhinta	4
Buenavista del Cayo	LMPC (n=21)	Joventud	7
		Savana	9
		Sayab	1
		Cocoyol	2
Cahal Pech	EPC (n=32)	Sikiya	17
		Sikiya/Jocote Transitional	3
		Uck	8
		Unknown	2
		Cocoyol	1
	EMPC (n=50)	Jocote	14
		Joventud	2
		Savana	18
		Sikiya	6
		Uck	9
		Jocote	13
	LMPC (n=57)	Joventud	4
		Savana	31
		Sayab	3
		Unknown	6
		Chunhinta	1
Chan	EMPC (n=51)	Jocote	19
		Joventud	2
		Pital	1
		Savana	22
		Unknown	6
		Jocote	6
Lower Dover	EMPC (n=15)	Joventud	1
		Savana	2
		Sayab	1
		Unknown	5
		Jocote	14
	LMPC (n=27)	Savana	11
		Sayab	2
		Jocote	15

Pacbitun	EMPC (n=44)	Joventud	3
		Pital	1
		Savana	17
		Uck	2
		Unknown	6
		Jocote	9
	LMPC (n=16)	Pital	1
		Savana	5
		Uck	1
		Calam	1
Xunantunich	EPC (n=10)	Chi	1
		Cocoyol	1
		Cu	1
		Sikiya	2
		Uck	4
		Jocote	6
	EMPC (n=10)	Savana	2
		Unknown	2
		Jocote	12
	LMPC (n=26)	Savana	14

Neutron Activation Analysis Methods

The following information is derived from NAA preparation protocols used at the University of Missouri Research Reactor (MURR) Archaeometry Laboratory, which I conducted during a six-month internship at MURR. The first few steps for NAA preparation are to clip a small sample from a potsherd, burr off the exterior of the sample with a Dremel grinder using a tungsten bit to remove all slips and exterior contaminants, rinse the burred sample with deionized water, and then allow it to dry. Then each sherd is crushed in an agate mortar and pestle to homogenize the sample. The powdered sherd is placed into a glass vial and left to sit in an oven for 24 hours to ensure that all moisture is removed. After the manual preparation is complete, 100 mg of sherd powder is placed into a polyethylene vial and 200 mg is placed into a quartz vial that is then hermetically sealed with a torch. Any remaining sample powder is retained for archival purposes, and the remainder of the sherd is retained for further analysis and eventual repatriation to Belize.

At MURR, the NAA process for ceramics involves a series of three gamma radiation counts, supported by two separate irradiations, making it a comprehensive and comparable method also used by other NAA labs (Glascock 1992; Neff 1992, 2000). The procedure begins with a short irradiation, where the ceramic samples in polyethylene vials are exposed to neutrons in a pneumatic tube system for five seconds at a neutron flux of 8×10^{13} n cm^{-2} s^{-1}. This irradiation is followed by a 720-second gamma ray count, which identifies nine short-lived elements: aluminum (Al), barium (Ba), calcium (Ca), dysprosium (Dy), potassium (K), manganese (Mn), sodium (Na), titanium (Ti), and vanadium (V).

Following the short irradiation, the samples in quartz vials undergo a 24-hour long irradiation at a flux of 5×10^{13} n cm^{-2} s^{-1}. After this, the samples are allowed to decay for a week before undergoing a middle count for 1,800 seconds using a high-resolution germanium detector. This count assesses seven medium half-life elements: arsenic (As), lanthanum (La), lutetium (Lu), neodymium (Nd), samarium (Sm), uranium (U), and ytterbium (Yb).

The final step involves a longer decay period of three to four weeks, followed by an 8,500-second final count, which measures 17 long half-life elements: cerium (Ce), cobalt (Co), chromium (Cr), cesium (Cs), europium (Eu), iron (Fe), hafnium (Hf), nickel (Ni), rubidium (Rb), antimony (Sb), scandium (Sc), strontium (Sr), tantalum (Ta), terbium (Tb), thorium (Th), zinc (Zn), and zirconium (Zr). The concentration data for each element from these three counts are captured in parts per million (PPM).

Additionally, while the unknown samples are being irradiated, known standard samples developed by the National Institute of Standards and Technology (NIST) are also included in the irradiations to serve as a baseline. These standards include SRM-1633b (coal fly ash), SRM-688 (basalt rock), SRM-278 (obsidian rock), and New Ohio Red Clay.

Neutron Activation Analysis Statistical Approach

This section provides an overview of the statistical techniques I used to create and evaluate group membership. In brief: 1) chemical compositional data were pretreated and transformed, 2) groups were defined using several clustering and ordination methods, 3) groups were assessed and core groups (i.e., well defined discrete groups) were created, 4) unassigned samples were projected into core groups, and 5) remaining samples were assessed for provisional groups too small to statistically evaluate. For an in-depth explanation of the mathematics, I refer the reader to Appendix B. Note that each temporal period was analyzed separately, and results were later compared to better capture change through time.

Once the PPM elemental data are collected and tabulated, an elemental ‘recipe’ for each sample is analyzed using compositional data analysis tools. The MURR Archaeometry Laboratory uses a program called GAUSS, which was specifically developed to examine NAA data and evaluate the validity of groups based on chemical compositions. I use both GAUSS and the ArchaeoDash platform as developed for archaeological purposes by ASU’s Center for Archaeological Sciences for both initial group assignment and comparative purposes (Bischoff and Peeples 2025). All compositional datasets are unique and require different approaches to analysis. For this project, initial groupings of ceramics were developed using methods of ordination including Uniform Manifold Approximation and Projection (UMAP), Principal Components Analysis (PCA), and Canonical Discriminant Analysis (CDA) along with clustering algorithms including both assessments of the raw data and the ordinations. I follow Duff (2002) Neff (2002), and Peeples (2011) who use similar statistical approaches to determine "core groups," which are here interpreted as sets of ceramics which represent distinct paste recipes that can consistently be identified and differentiated from other groups using multiple statistical approaches. These recipes are dependent upon both natural resources and production methods. For instance, potters are likely to use nearby clays and tempering materials (Arnold 2011), and different pots call for different proportions and types of temper. Thus, these factors come together to create a distinct elemental profile that NAA can capture.

Before analysis can occur, some pre-processing is required to standardize the elemental data. All data are base-10 log transformed, which helps to approximate a normal distribution for many elements to meet the general requirements of most statistical evaluations subsequently used. This also means that both rare and common elements are equally able to influence groupings and similarity statistics. Furthermore, any element which is missing from more than 20% of the samples is removed from future analysis to avoid skewing the results. In this analysis, strontium (Sr) and nickel (Ni) are removed for this reason. Finally, any missing data, which is likely missing due to being below the threshold of detection by NAA is imputed. Here I use the random forest imputation, which iteratively splits the dataset into two subsets: one containing observed data for training and the other consisting of missing values to be predicted (Pantanowitz and Marwala 2009).

The random forest model was trained on the observed data and then used to estimate the missing values, which were reintroduced into the dataset. This completed a single iteration of imputation. The process was repeated five times, with each cycle enhancing the dataset's quality. Now the data are ready for analysis.

To establish core groups, I first used the Uniform Manifold Approximation and Projection (UMAP) algorithm to visually project the samples by period. UMAP is a procedure for reducing the dimensionality of high dimensional datasets while attempting to simultaneously capture local and global structure (McInnes et al. 2020). The UMAP algorithm evaluates both local and global structures of the dataset through two primary phases: (1) construction of a fuzzy topological representation and (2) optimization in a low-dimensional graph. In the first phase, the algorithm represents the data as a fuzzy graph, where closeness reflects the similarities between points. To streamline computations, these strengths are determined only for each point's five nearest neighbors, as they diminish quickly for more distant points. The Nearest-Neighbor-Descent algorithm efficiently identifies these neighbors, even in high-dimensional spaces. Finally, the data are projected into a two-dimensional space, where points are presented as clusters with 90% confidence ellipses (Figures 4.2, 4.3, and 4.4). Note that this method is based on the intra-point distances between samples and although this approach sometimes creates relatively discrete clusters of points, those clusters are not influenced by or predetermined by the researcher in the process, unlike canonical discriminant analysis which attempts to create maximally separated groups based on a researcher supplied group definition.

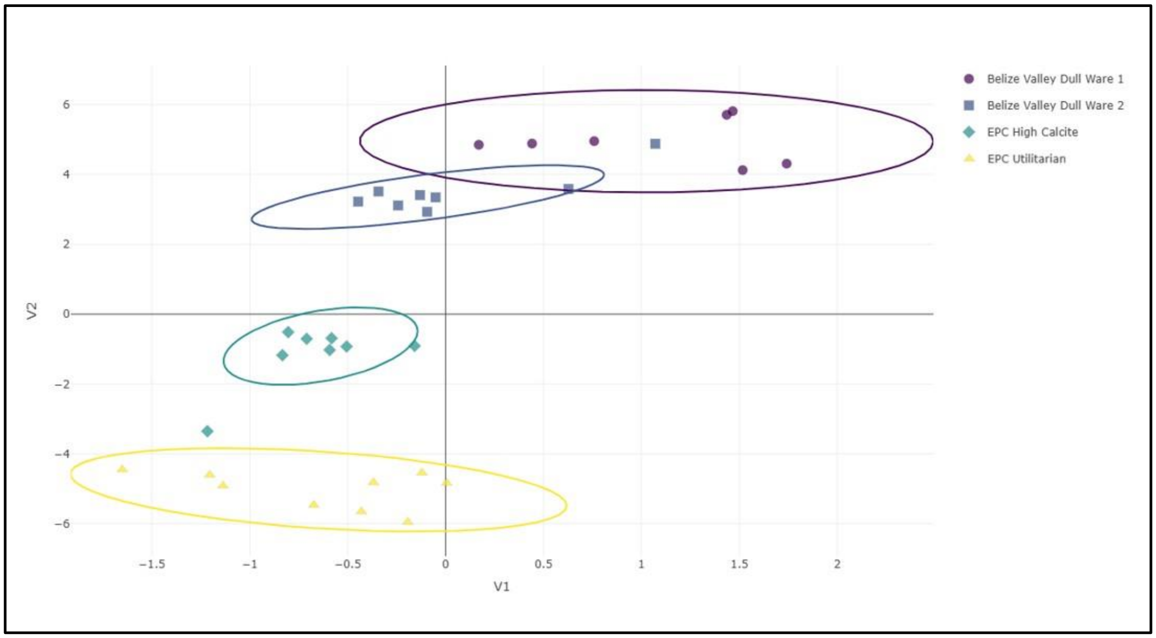

Figure 4.2. UMAP Projection of Early Preclassic Core Groups

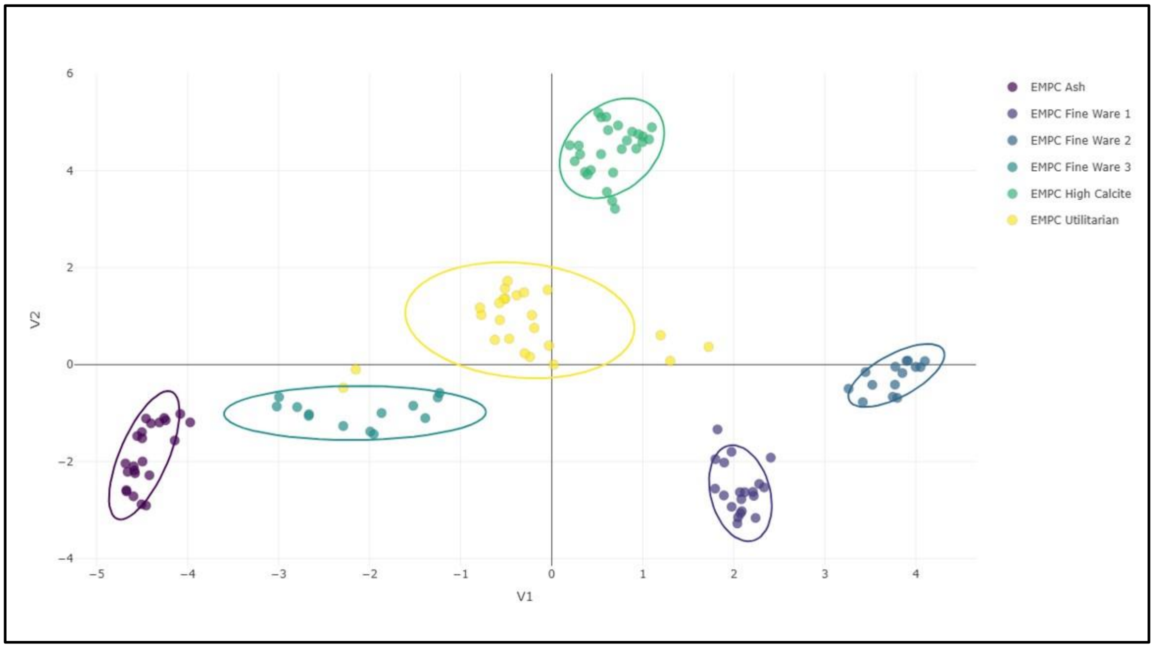

Figure 4.3. UMAP Projection of Early Middle Preclassic Core Groups

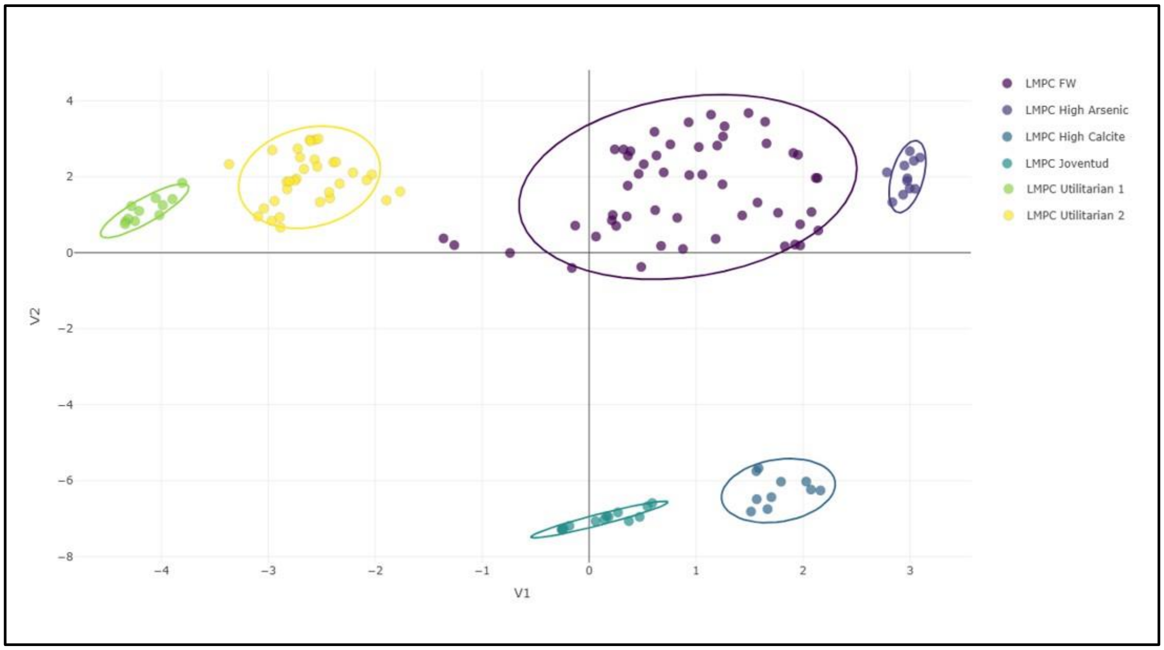

Figure 4.4. UMAP Projection of Late Middle Preclassic Core Groups

Initial group membership was then evaluated using a back-and-forth combination of the UMAP algorithm and traditional Principal Component Analysis (PCA). Figures 4.5-4.10 show the PCAs with the best evidence for group structure. Researchers across various scientific fields have compared UMAP and PCA, including studies in petrography (Mpaka and von der Heyden 2024), whole rock chemistry (Lukmanov et al. 2021, 2022), ecology (Milošević et al. 2022), and archaeology (Qiu et al. 2025). These studies consistently find UMAP to be an effective dimensionality reduction method, with outputs that are especially well-suited for chemical data. Once the UMAP groups concurred with PCA groups, each sample was temporarily assigned to an initial group.

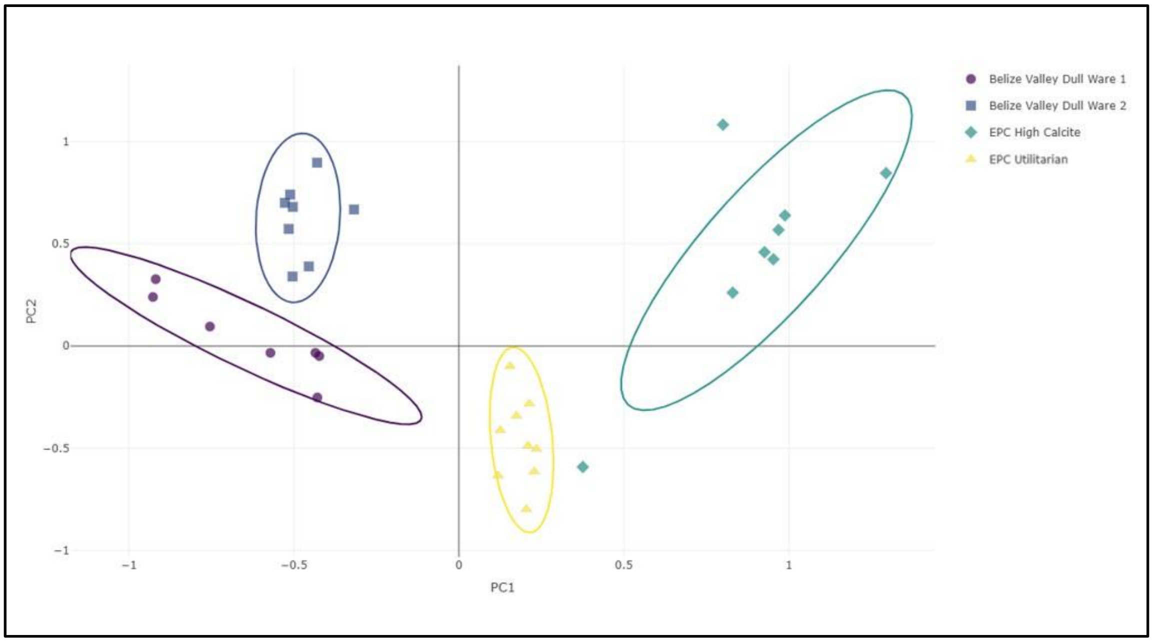

Figure 4.5. PCA plot of PCs 1 and 2 of Early Preclassic Core Groups.

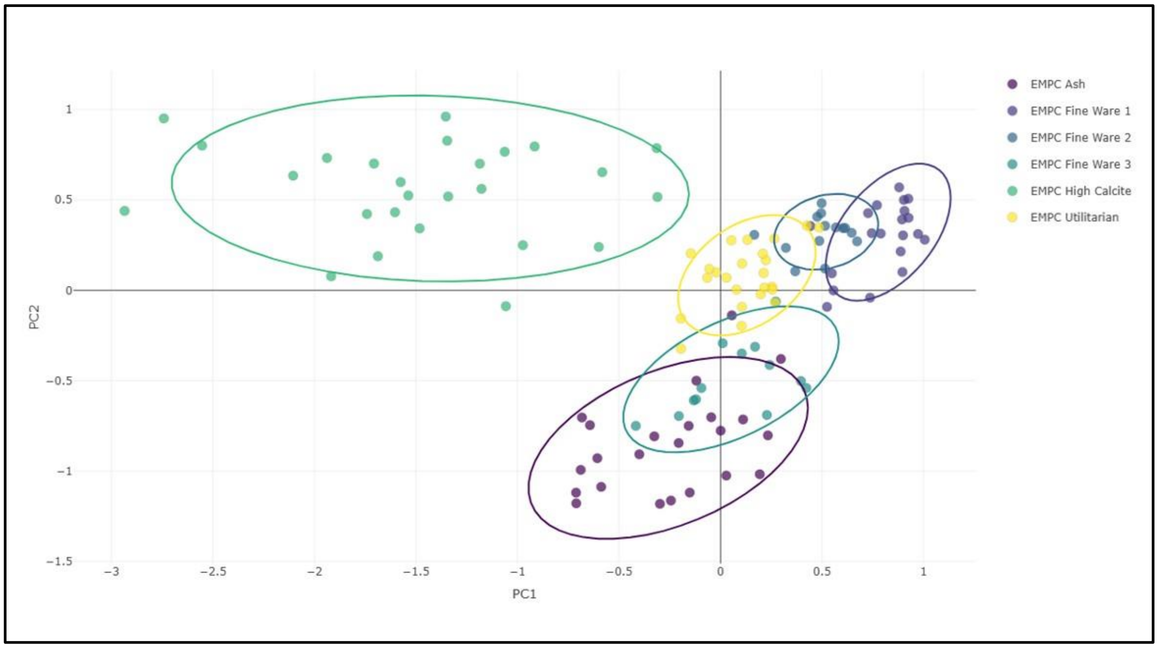

Figure 4.6. PCA plot of PCs 1 and 2 of Early Middle Preclassic Core Groups.

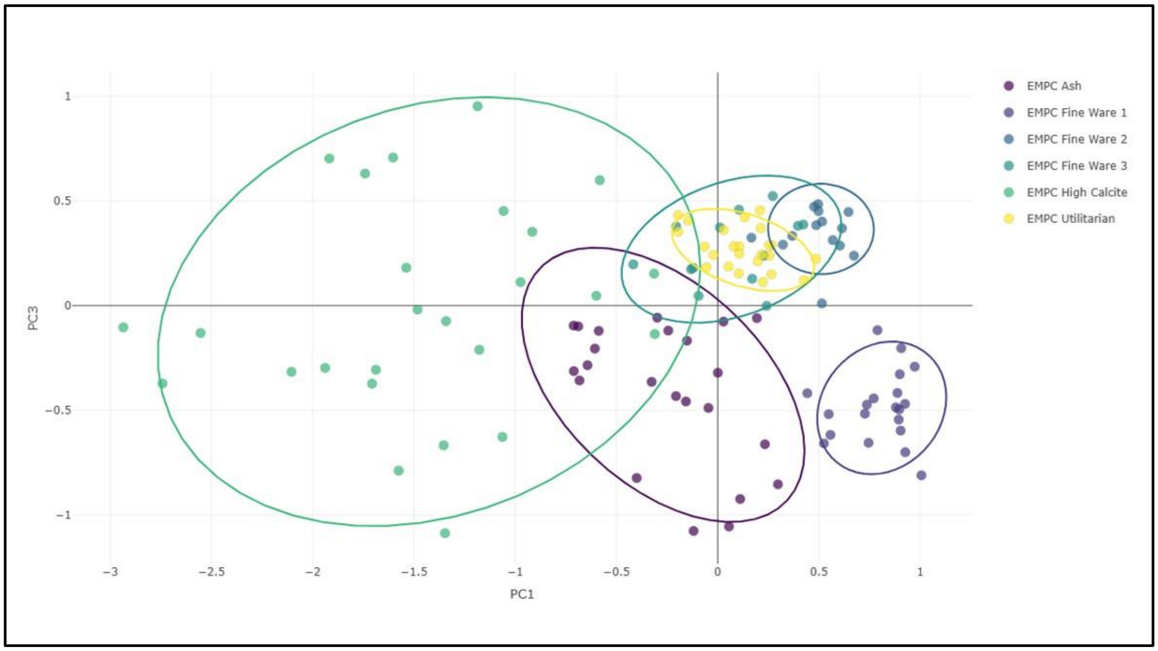

Figure 4.7. PCA plot of PCs 1 and 3 of Early Middle Preclassic Core Groups.

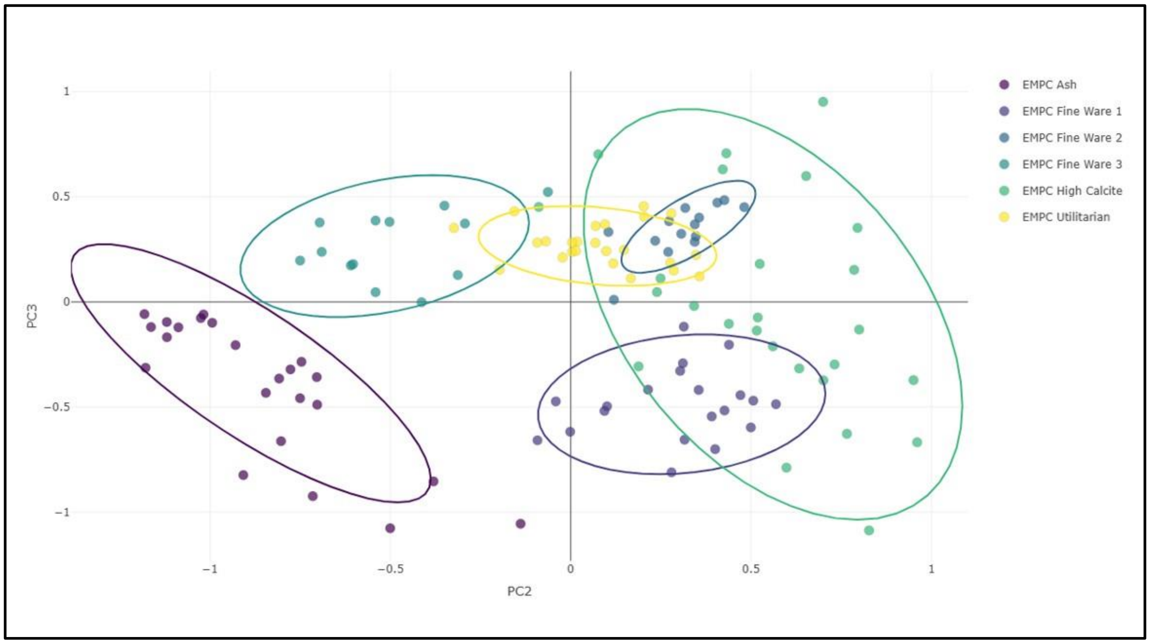

Figure 4.8. PCA plot of PCs 2 and 3 of Early Middle Preclassic Core Groups.

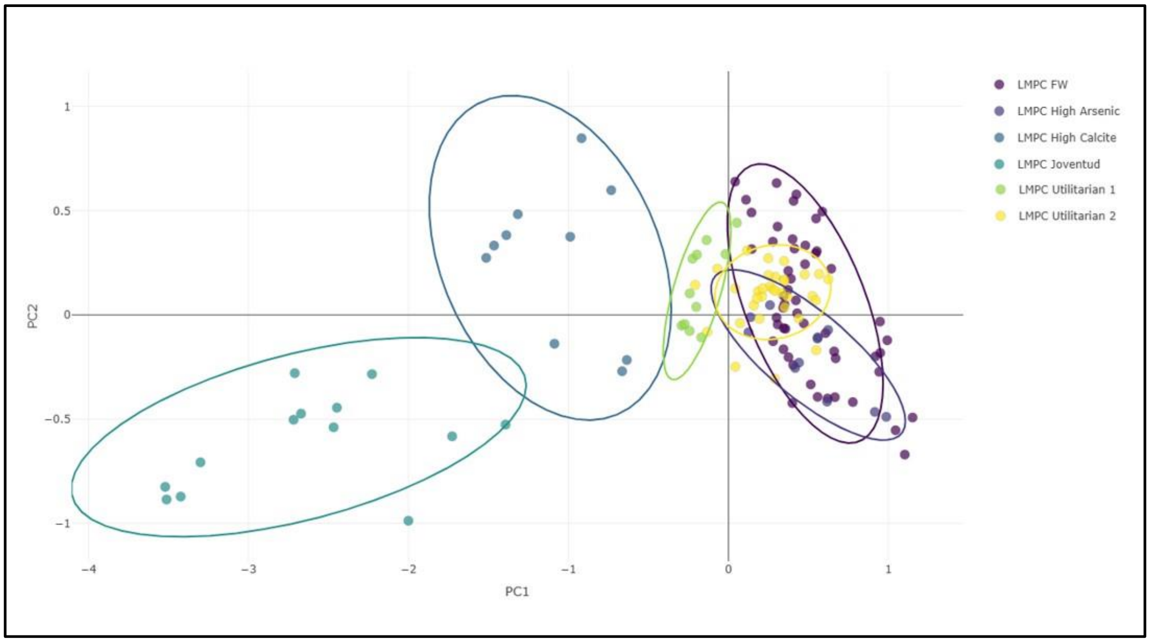

Figure 4.9. PCA plot of PCs 1 and 2 of Late Middle Preclassic Core Groups.

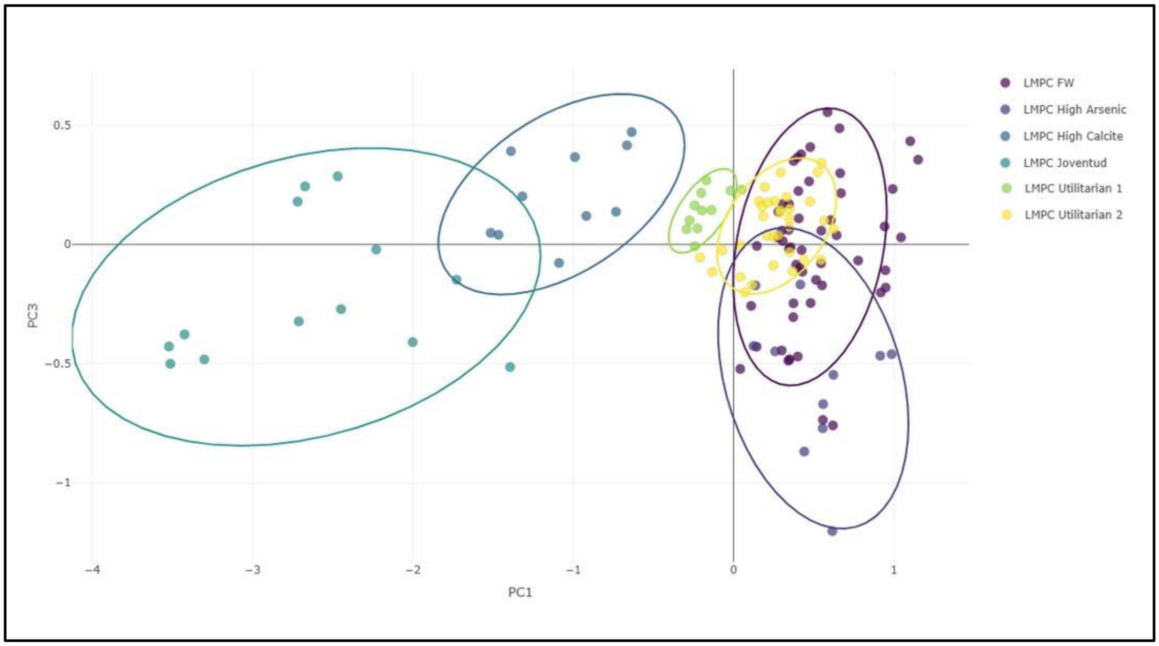

Figure 4.10. PCA plot of PCs 1 and 3 of Late Middle Preclassic Core Groups.

Once initial groups were assigned, I evaluated membership probabilities using MURR's GAUSS software. This analysis applies a combination of Mahalanobis distance and Hotelling's T^2 statistic to determine the likelihood that a sample belongs to a given group, after temporarily removing it from that group (Bishop and Neff 1989; Glascock 1992; Neff 2002). For this method to be valid, each group must contain at least two more samples than the number of variables used in the analysis. Technically a group must include one sample more than the variables considered but an additional sample is required in order to use the jackknife procedure described below. For example, if 31 elements are considered in the membership analysis, the group must contain at least 33 samples. When groups are smaller, Principal Components (PCs) derived from a PCA are used instead, selecting the few that collectively account for the majority of the variance in the dataset. In many cases, a small number of PCs capture 90% or more of the total variation, enabling statistical evaluation of much smaller groups.

This combined approach introduces a level of statistical rigor that supports the identification of core groups. It also incorporates a jackknife method, in which a sample is removed from the group to which it is assigned before probabilities and distances are assessed so that the sample's probability of group membership is assessed without its own influence on group composition. This is a conservative cross-validation based approach which tends to produce robust groupings as samples are iterative included and removed and probabilities are assessed. Probabilities are calculated based on the sample's multivariate distance from the centroid of the group in question. These probabilities range from 0% to 100%, with higher values indicating a stronger likelihood of membership. When a sample is compared to multiple groups, each probability is calculated independently, so the total does not sum to 100%.

There is no externally defined rule for determining an appropriate membership threshold, but others have used a number between 2.5%-5% (Duff 2002; Neff 2002; Peeples 2011). Although this seems low, the conservative probability calculated by Mahalanobis distance and Hotelling's T^2 allows for very low thresholds, especially when probabilities of membership in other groups are extremely low or 0. In this analysis, for a sample to be considered a core member of a core group it must have above a 2.5% membership probability in any one group, greater than 5 times probability of belonging to that group than any other group, and less than a 10% probability of belonging to any other group. For instance, if a sample has 70% probability of belonging to one group, but 10% probability of belonging to another group, then the sample is not considered a member of that core group. This is an iterative process, as removing a sample from or adding one to a group has the potential to change the probability of all sample memberships. Thus, when a sample was removed from a group, it was labeled as "unassigned," and the membership probability analysis was redone. When a sample was added to a group the analysis was also redone. Throughout the process, the unassigned samples were reevaluated for membership to all groups and added back to groups as necessary. This process was repeated until the core groups only contained members that met the aforementioned criteria. In some cases, there are unassigned samples that meet the threshold for adding to a group, but when added they change the probability of several other core members, thus those samples were removed and labeled as unassigned. This culling process usually leaves between 30-40% of the total sample as unassigned.

Once core groups with core members were created, other samples were then added to these groups as "probable" members or "non-core" members as a way to make use of as much data as possible. These non-core members were frequently added to a group based on their projection within a cluster within the first several principal components of a PCA. For a sample to be added to a core group as a non-core member via PCA, it must possess a membership probability five times greater than in any other group, and less than 10% probability of belonging to any other group. Finally, to incorporate more samples, a canonical discriminant analysis (CDA) was conducted. Since this is less statistically sure than the previous methods, the requirements for group membership become more stringent. The membership probability was redone using the CDA as a means of assigning group membership, but a sample must possess a membership probability 10 times greater than in any other group with less than a 10% probability of belonging to any other group. At this point, all unassigned samples were tested against foreign compositional groups within MURR's Mesoamerican NAA Database. The remainder of this chapter addresses the ceramic groups including core members and those included using PCA and CDA.

Geographic Assignment of Neutron Activation Analysis Groups

I used three main sources of information to assign the NAA groups to geographic locations (i.e., production zones): 1) the criterion of abundance, 2) geological information, and 3) temporal distributional information. The criterion of abundance is simply the theory that the area in which the majority of a compositional group is found is the likely production zone of that compositional group (Bishop et al. 1982; Bishop and Blackman 2002). For instance, if 60% of an NAA group was located at the site of Baking Pot, and approximately 10% of that group was found at four other sites totaling the remaining 40%, then the production location of that specific NAA group was likely Baking Pot. In cases where multiple sites had similar proportions of a compositional group, I also considered the proportions of each compositional group at each site to shed light on which NAA groups dominated individual site assemblages. In cases where a site contained both the highest proportion of a compositional group across sites and within its own assemblage, that site was assigned as the likely production zone for that compositional group.

Geological information was also helpful for assigning production zones. For example, as presented below, during the LMPC, Pacbitun was the likely production zone of a compositional group that was relatively high in arsenic, an element that is not found in high percentages of the Melinda soil suite along the Belize River, but is found in granites, such as those in the Mountain Pine Ridge Batholith geological zone of the Maya Mountains. Pacbitun is nestled in the foothills of the Mountain Pine Ridge, and is the closest site in the study area to this region. Previous studies have shown that during the Late Classic period the inhabitants of Pacbitun had an abundance of granite and were heavily invested in granite mano and metate production (Balinger et al. 2015; Skaggs et al. 2020; Ward 2013). Additionally, and perhaps more convincingly, previous petrographic analyses of Late Classic pottery from Pacbitun show frequent use of granitic temper (Sunahara 2003). Microphotographs of the LMPC High Arsenic Group samples consistently reveal feldspars, orthoclase, and microcline, all of which are consistent with granitic sand temper, and the chemical analyses are consistent with volcanic landscapes.

The distribution of compositional groups across periods provided useful evidence for identifying production locations, especially in cases where relative abundances alone were inconclusive (see Schachner et al. 2011 for a similar analysis in the U.S. Southwest). For instance, the Fine Ware 1 Groups from the EMPC and LMPC periods overlap in multivariate space, strongly indicating that the LMPC group represents a continuation of the EMPC group. During the EMPC, Pacbitun held the highest proportion of this group, with the Belize River site of Blackman Eddy close behind. However, in the LMPC, Pacbitun no longer contains any Fine Ware 1 Group ceramics, while Belize River sites account for the overwhelming majority of this compositional group. This suggests that production of the Fine Ware 1 Group was likely concentrated in the Belize River area during both periods.

Since the elemental composition of a ceramic vessel is highly correlated with the local geological context of its production, and geological contexts tend to spread across large areas, it was not always possible to assign a compositional group to a specific site or even to a specific geographic location. Of the 18 compositional groups identified across all time periods, only two were not assigned to any geographic location due to an even dispersion of samples across the study area. Additionally, five of the groups could only be attributed to a sub-region, in all such cases a specific river valley was identified (i.e., Mopan, Macal, or Belize). The remainder of the chapter presents the results of the NAA group attribution. For chemical information on the NAA groups, please see Appendix B.

Early Preclassic Neutron Activation Analysis Groups

The EPC sample consists of a total of 71 sherds from the sites of Actuncan, Blackman Eddy, Cahal Pech, and Xunantunich (Table 4.1), 32 of which came from Cahal Pech and were part of a previous NAA study (Ebert et al. 2019). Table 4.2 presents the distribution of sherds across the four groups at the four EPC sites, including the non-core samples. Figure 4.11 presents the distribution of samples in visual form as well as their subregion-to-subregion flows based on inferred provenance of NAA groups. Only 44 of the sherds could be attributed to an NAA group, so due to the current sample size, these results should be seen as tentative.

Table 4.2. Distribution of Early Preclassic Sherds into Neutron Activation Analysis Groups. The percentage of each site's assemblage, except the unassigned sherds, is presented in parentheses.

Site	Belize Valley Dull Ware 1	Belize Valley Dull Ware 2	EPC High Calcite	EPC Utilitarian	Unassigned
Actuncan	2 (25%)	1 (13%)	5 (63%)	0 (0%)	4
Blackman Eddy	4 (33%)	2 (17%)	3 (25%)	3 (25%)	5
Cahal Pech	7 (33%)	6 (29%)	0 (0%)	8 (38%)	11
Xunantunich	3 (60%)	0 (0%)	2 (40%)	0 (0%)	3

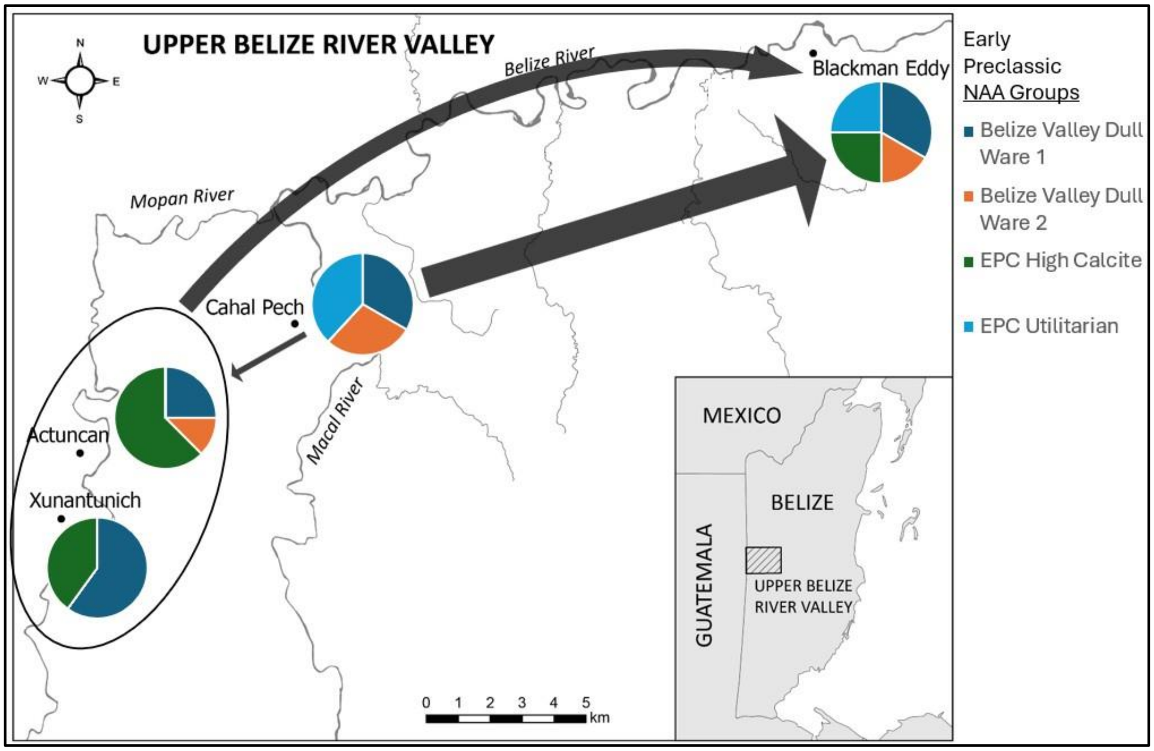

Figure 4.11. Early Preclassic Neutron Activation Analysis Group Distributions with Subregion-to-Subregion Flow.

Two distinct Belize Valley Dull Ware groups are present in the assemblage. Belize Valley Dull Ware 1 is relatively evenly distributed across all sites, while Belize Valley Dull Ware 2 appears to originate from Cahal Pech. The EPC Utilitarian group also likely comes from Cahal Pech, based on its distributional pattern.

The EPC High Calcite group is primarily concentrated at the Mopan River Valley sites of Actuncan and Xunantunich, with a smaller number of sherds appearing downstream at Blackman Eddy. Given the stronger concentration of high calcite ceramics in the Mopan River Valley during later periods, production of this group likely occurred in the Mopan River area. To further support this inference, I compared the EPC High Calcite data to a recent NAA study from the Mopan River Valley and identified overlap in both UMAP and PCA plots with Villarreal's (2024) Group E, which includes EMPC daub samples from Xunantunich and San Lorenzo. Daub is a building material that almost certainly comes from nearby clay. This compositional similarity reinforces the interpretation that high calcite ceramics originated in the Mopan River Valley.

Xunantunich notably contains two unique sherds not found at any other site, though the small sample size raises the possibility of sampling bias. One of these sherds belongs to the Calam Buff pottery group, which Callaghan and Neivens de Estrada (2016) documented in greater concentrations in the Petén Lakes region. This suggests that these sherds may represent imports from the Petén region of Guatemala. Further comparison of the NAA data for these two sherds with samples from Holtun, Guatemala (Callaghan et al. 2017a, 2017b, 2018), reveals a strong elemental match with many Preclassic period sherds produced in that area. These findings suggest that, during the EPC, the villagers at Xunantunich formed connections with sites located further inland.

Twenty-three of the samples remained unassigned to any compositional group during this period. Of these sherds, 11 of them are 10 times more likely to belong to UBRV compositional groups than to foreign groups. The remaining 12 samples did not strongly match any known groups in MURR's Mesoamerican NAA Database. Thus there is very little evidence for ceramic movement beyond the region during this period.

The overall distributional patterns for the EPC suggest that most ceramic exchange flowed downstream from Cahal Pech to Blackman Eddy. Some pottery also moved downstream from the Mopan River Valley to Blackman Eddy. A small amount of pottery moved from Cahal Pech to the Mopan River Valley. Notably, there is no evidence of ceramic flow moving upriver from Blackman Eddy during this period. The overall pattern suggests that Cahal Pech exported a lot of pottery, or what was in the pottery, and pottery generally flowed downstream.

There are three potential explanations for this pattern: 1) Belize Valley Dull Ware 1, which cannot be assigned to a specific production location, may have been produced at Blackman Eddy, but the distribution is too diffuse to confirm this; 2) the pattern may reflect sampling bias; or 3) Blackman Eddy may have been exchanging non-ceramic goods for pottery, or the contents of the pottery, from other sites. I favor the third explanation, as Blackman Eddy was the first site in the UBRV through which coastal resources likely passed into the rest of the region. Additionally, a growing body of research shows cacao was used and possibly cultivated in this part of the region during the Middle Preclassic, and perhaps earlier (Fedick 1995; Walden et al. 2023; Weller 2009; Willey et al. 1965:574). Dozens of Early and Middle Preclassic spouted vessels, many of which likely contained cacao (Powis et al. 2002), have been located at Blackman Eddy and other sites within the region (Awe 1992; Gifford 1976; Powis 2002). Cacao was an important export crop grown in the region during the Colonial period (Caso Barrera and Aliphat F. 2009; Jones 1989), and it may have also been an important economic product during the formative period of the region; however, a soil auguring survey is needed to confirm this hypothesis. Other communities may have exchanged goods, including pottery, in return for access to coastal resources or other goods such as cacao.

Early Middle Preclassic Neutron Activation Analysis Groups

The EMPC sample consists of 210 sherds from the sites of Actuncan, Blackman Eddy, Cahal Pech, Chan, Lower Dover, Pacbitun, and Xunantunich (Table 4.1), including 50 sherds from a previous NAA study by Ebert and colleagues (2019). Table 4.3 presents the distribution of samples by NAA group and site, while Figure 4.12 illustrates the spatial distribution of these samples and inferred subregion-to-subregion flows based on group provenance.

Six distinct NAA groups are identified for this period. One is the Ash group, a continuation from the EPC, which persisted into the Middle Preclassic. Due to its broad distribution, the provenance of this group is unclear. It may have been produced at sites inhabited during the EPC or at offshoot settlements from those communities. However, no direct evidence currently supports specific site splintering, making this hypothesis tentative.

Three fine ware groups are present during the EMPC, all of which continue into the LMPC, aiding provenance assessment. This continuity is supported by overlapping 90% confidence ellipses in UMAP and PCA plots. While Fine Ware 1's EMPC distribution complicates provenance determination, 33% of Blackman Eddy's assemblage falls within this group. Although Pacbitun has the highest proportion of Fine Ware 1 during the EMPC, it lacks this group entirely in the LMPC. In contrast, the Belize River sites of Blackman Eddy, Lower Dover, and Baking Pot comprise 62% of the Fine Ware 1 assemblage in the LMPC, strongly suggesting that this subregion was its source. Fine Ware 2 appears to have been produced at Chan, where 66% of the group occurs. This ware was traded eastward to Pacbitun and downriver to sites along the Belize River. Fine Ware 3 was likely produced at Cahal Pech, where 68% of the group is found, and was circulated to the nearby sites of Pacbitun and Chan.

As noted in the EPC discussion, the EMPC High Calcite group likely originated in the Mopan River Valley. During the EMPC, 46% of the High Calcite group samples come from Mopan Valley sites, including 71% of the Xunantunich assemblage and 53% of the Actuncan assemblage. While present in smaller proportions elsewhere, the group again appears to have moved primarily downstream to Lower Dover and, to a lesser extent, Blackman Eddy.

Table 4.3. Distribution of Early Middle Preclassic Sherds into Neutron Activation Analysis Groups. The percentage of each site's assemblage, except the unassigned sherds, is presented in parentheses.

Site	EMPC Ash	EMPC Fine Ware 1	EMPC Fine Ware 2	EMPC Fine Ware 3	EMPC High Calcite	EMPC Utilitarian	Unassigned
Actuncan	0 (0%)	6 (40%)	0 (0%)	0 (0%)	8 (53%)	1 (7%)	3
Blackman Eddy	4 (27%)	5 (33%)	1 (7%)	0 (0%)	1 (7%)	4 (27%)	8
Cahal Pech	10 (24%)	3 (7%)	0 (0%)	19 (46%)	4 (10%)	5 (12%)	9
Chan	4 (10%)	3 (8%)	14 (35%)	4 (10%)	3 (8%)	12 (30%)	11
Lower Dover	3 (27%)	0 (0%)	1 (9%)	0 (0%)	4 (36%)	3 (27%)	4
Pacbitun	5 (17%)	9 (30%)	5 (17%)	5 (17%)	3 (10%)	3 (10%)	14
Xunantunich	1 (14%)	1 (14%)	0 (0%)	0 (0%)	5 (71%)	0 (0%)	3

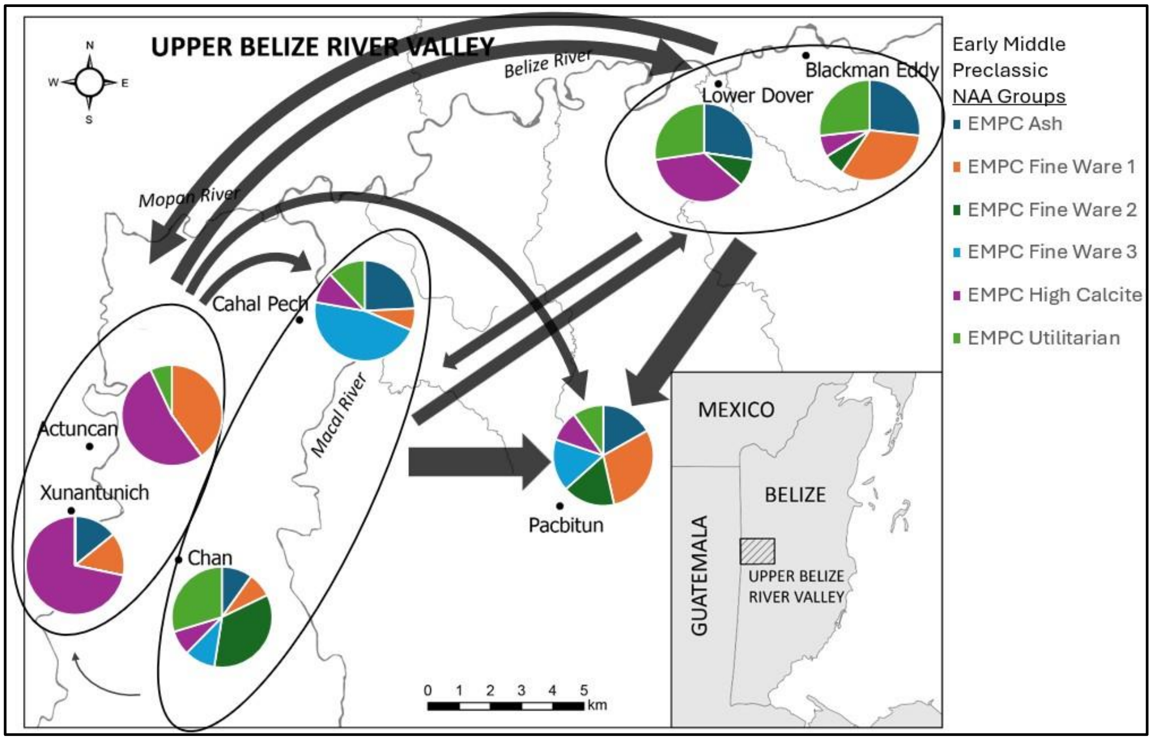

Figure 4.12. Early Middle Preclassic Neutron Activation Analysis Group Distributions with Subregion-to-Subregion Flow

The EMPC Utilitarian group, stylistically similar to the High Calcite group, was likely produced in the Macal River Valley at the sites of Cahal Pech and Chan. The majority of this group was located at Chan (43%) with Cahal Pech comprising the second highest percentage (18%). Additionally, there is overlap with the LMPC Utilitarian 1 group, which was almost certainly being made at Cahal Pech, which likely suggests a similar provenance during this earlier period.

Fifty-two of the samples were not assigned to any group, and they were tested against MURR's Mesoamerican NAA Database. Of these unassigned samples, 14 are 10 times more likely to belong to the UBRV, and the remainder were not attributable to any other region. Once again, it seems unlikely that much pottery was circulating into the region from elsewhere.

Overall, the EMPC distribution patterns indicate increased inter-site interaction, consistent with population growth and the development of new communities. The evidence suggests that the inhabitants of Pacbitun imported ceramics, or their contents, from many other sites in the region but did not send many ceramics elsewhere, which could mean that the site functioned as a logistical settlement focused on procuring goods from the Mountain Pine Ridge, such as granite and pine, in exchange for other goods from elsewhere. The large number of unassigned sherds at Pacbitun may suggest a localized cottage industry of potting to support individual households without any shared tradition during this period. Similarly, Chan appears to have produced many of its own ceramics while also importing pottery from multiple sources. Additionally, downstream trade persists, but unlike during the EPC, there is now evidence of reciprocal ceramic exchange between upriver and downriver sites; however sites to the east tend to have access to more pottery sources, suggesting that river flow likely had an impact on exchange, or early evidence for regionalization.

Late Middle Preclassic Neutron Activation Analysis Groups

The LMPC sample consists of 258 sherds from the sites of Arenal, Baking Pot, Blackman Eddy, Buenavista, Cahal Pech, Lower Dover, Pacbitun, and Xunantunich (Table 4.1), including 57 sherds from the earlier NAA study by Ebert and colleagues (2019). Table 4.4 shows the distribution of samples by NAA group and site, while Figure 4.13 illustrates their spatial distribution and the inferred subregion-to-subregion flows based on group provenance.

Eight distinct chemical groups are identified for this period. The three fine ware groups chemically overlap with those from the EMPC, suggesting continuity in production locations, though with some nuanced differences. For example, Fine Ware 1 production appears to have expanded to the nearby site of Baking Pot, likely due to its geological similarity and probable shared ceramic traditions with neighboring sites. It is not surprising that Baking Pot functioned as a production center even at this early date, as various scholars argue that it was also a primary source of Belize Red pottery, one of the most prevalent ceramic types across the Maya Lowlands during the Late Classic period (Aimers 2002; Chase and Chase 2012; Hammond et al. 1976; among others).

Table 4.4. Distribution of Late Middle Preclassic Sherds into Neutron Activation Analysis Groups. The percentage of each site's assemblage, except the unassigned sherds, is presented in parentheses

Site	LMPC Fine Ware 1	LMPC Fine Ware 2	LMPC Fine Ware 3	LMPC Joventud	LMPC High Calcite	LMPC Utilitarian 1	LMPC Utilitarian 2	LMPC High Arsenic	Unass-igned
Arenal	2 (11%)	5 (28%)	1 (6%)	3 (17%)	3 (17%)	1 (6%)	3 (17%)	0 (0%)	13
Baking Pot	18 (39%)	1 (2%)	1 (2%)	1 (2%)	2 (4%)	3 (7%)	20 (43%)	0 (0%)	14
Blackman Eddy	5 (29%)	1 (6%)	1 (6%)	1 (6%)	4 (24%)	0 (0%)	4 (24%)	1 (6%)	3
Buenavista	1 (6%)	0 (0%)	6 (33%)	6 (33%)	4 (22%)	0 (0%)	0 (0%)	1 (6%)	3
Cahal Pech	13 (30%)	6 (14%)	4 (9%)	4 (9%)	5 (11%)	8 (18%)	3 (7%)	1 (2%)	13
Lower Dover	8 (33%)	0 (0%)	0 (0%)	3 (13%)	3 (13%)	0 (0%)	9 (38%)	1 (4%)	3
Pacbitun	0 (0%)	0 (0%)	0 (0%)	1 (7%)	0 (0%)	0 (0%)	0 (0%)	13 (93%)	2
Xunantunich	3 (19%)	2 (13%)	6 (38%)	2 (13%)	2 (13%)	0 (0%)	1 (6%)	0 (0%)	10

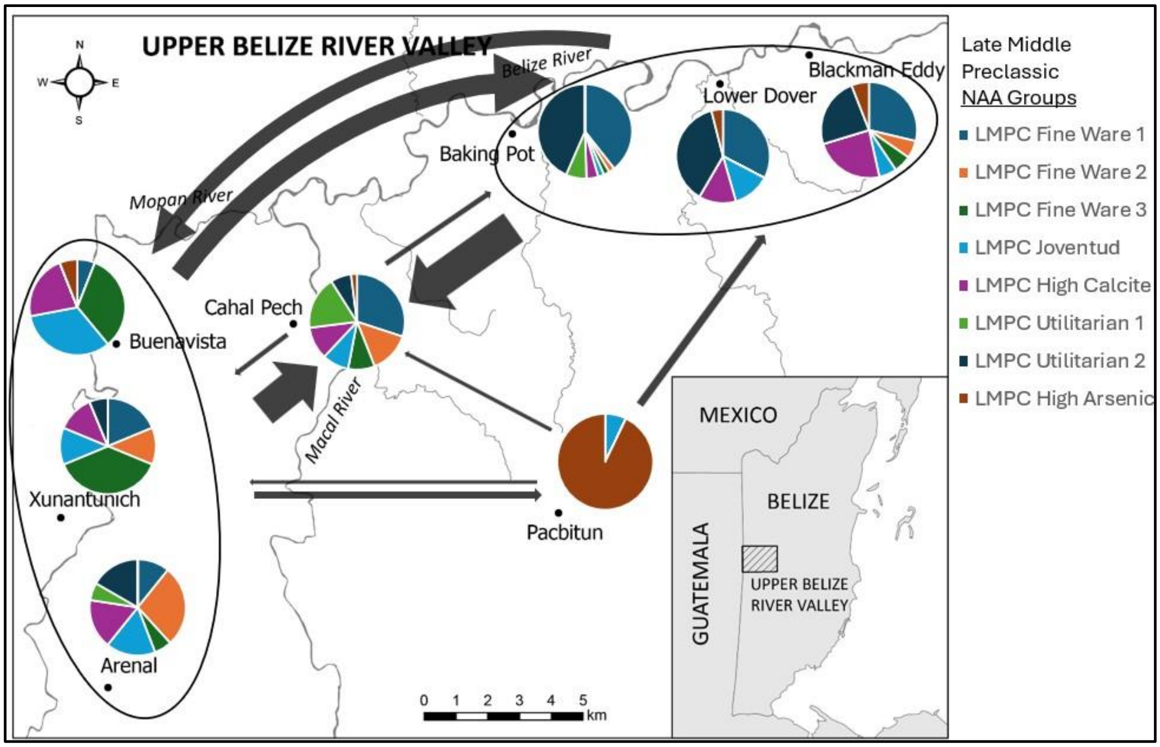

Figure 4.13. Late Middle Preclassic Neutron Activation Analysis Group Distributions with Subregion-to-Subregion Flow

Fine Ware 2, which was previously produced at Chan during the EMPC, also appears to have been manufactured at the nearby site of Arenal during the LMPC. Although the sample size from Chan was too small to include in this phase of the analysis, the majority of Chan's LMPC sherds continue to cluster within this group, reinforcing continuity in production.

Fine Ware 3 appears in small quantities in the Mopan River Valley during the LMPC, where it was previously absent in the EMPC. During the EMPC, Fine Ware 3 was almost exclusively produced at Cahal Pech, but it declines in frequency there during the LMPC. This shift may reflect changes in access to clay and temper sources or evolving regional preferences in fine ware products.

A chemically distinct group of Joventud sherds also emerges, with 27% of the group documented at Buenavista del Cayo. Although additional samples were found at Cahal Pech and Lower Dover, the high frequency and elevated calcite content of the group, previously indicative of Mopan River Valley production, suggests that manufacture of the Joventud Group likely occurred at Buenavista del Cayo.

The LMPC High Calcite group is more evenly distributed across the entire region during the LMPC but in relatively low proportions. This could indicate that it continued to be produced in the Mopan River Valley and was widely traded, or that heavy calcite-tempered pottery production had spread more broadly across the UBRV. However, interpreting these patterns is complicated by a known issue in NAA: high calcite content can obscure subtle chemical distinctions among local clays (Cogswell et al. 1998).

Two utilitarian groups are present during the LMPC. LMPC Utilitarian 1 was likely produced at Cahal Pech, where 67% of the group is found, and was primarily traded to Baking Pot, which accounts for 25% of the group. LMPC Utilitarian 2 was likely produced in the Belize River Valley where it is most common at Baking Pot (50%), with smaller proportions at Lower Dover (23%) and Blackman Eddy (10%).

Finally, a chemically distinct High Arsenic group is identified, concentrated at Pacbitun, where 93% of the group's sherds were recovered. The scarcity of this group elsewhere suggests localized production, likely using granitic tempering materials sourced from the Mountain Pine Ridge Batholith geological region, as noted above.

Sixty-one of the LMPC samples could not be assigned to any compositional group, so they were tested against MURR's Mesoamerican NAA Database. Of the unassigned samples, 18 were 10 times more likely to belong to the UBRV than any foreign group. One sample from Lower Dover was 10 times more likely to belong to the Lower Sibun region; however, the database samples from that region are all Late Classic pottery types. The remaining samples did not strongly belong to any group. As with the previous periods, it does not seem like much pottery was flowing into the region from elsewhere.

Overall, the LMPC distributional patterns reflect increased regionalization. While subregion-to-subregion exchange patterns remain broadly consistent with those of the EMPC, key differences emerge. Notably, Pacbitun, which had previously imported many of its ceramics, now appears to be relying more on local production, potentially indicating a shift away from broader regional economic networks. Additionally, there is a small increase in exchange between the Mopan and Macal River valleys, yet Cahal Pech seems to be receiving more pottery than it was sending out. Beyond these patterns, there is a general rise in inter-site connectivity, as most sites now possess ceramics from multiple groups, an increase in diversity compared to earlier periods, when sites tended to have access only to a few production groups.

Conclusion

This chapter has established the foundation for identifying pottery production locations and patterns of ceramic exchange in the Upper Belize River Valley during the Early and Middle Preclassic periods. The distributional patterns of Neutron Activation Analysis groups demonstrate both an increase in subregion-to-subregion interaction and a gradual shift toward more regionalization, with hints of potentially important sites and exchange mechanisms within the economic network.

During the EPC, sites generally had access to fewer pottery groups, and most ceramic exchange appears to have moved downstream to Blackman Eddy. This downstream flow likely reflects Blackman Eddy's strategic location as the first major site in the UBRV through which coastal resources or other goods would have passed, potentially granting it a monopoly over some aspects of regional trade.

As populations expanded and more sites were occupied during the EMPC, evidence emerges for increased ceramic production, higher levels of exchange, and growing differentiation in access to various pottery groups at different sites. Notably, both Pacbitun and Chan had access to all known pottery sources during this period, suggesting their widespread participation in the economic system. This broad access may reflect the presence of economic mechanisms such as marketplaces, widespread trading connections via traveling merchants, or, in the case of Pacbitun, the establishment of a well-connected logistical settlement for exporting goods from the Mountain Pine Ridge. Blackman Eddy appears to have retained its economic influence during this period, likely continuing to manage the flow of coastal goods, cacao, or other resources. Moreover, the introduction of new fine wares and their reverse movement upriver suggests that downstream sites had begun to export their ceramics, or the contents they carried, upstream.

By the LMPC, interaction patterns intensified further. However, an examination of NAA group proportions reveals the emergence of regional preferences at sites across the UBRV. The most significant shift occurred at Pacbitun, where the site began producing its own local ceramic group, using temper sourced from arsenic-rich materials from the Mountain Pine Ridge. This marked departure from importing pottery could signal Pacbitun's withdrawal from the broader regional economic network. Overall, most LMPC sites had access to a wide range of ceramic groups, raising new questions about the mechanisms of exchange. These patterns suggest complex systems of interaction, the nature of which merits further investigation in later chapters.

Until relatively recently, this chapter might have marked the conclusion of such a study. However, advances in formal network analysis now allow for a deeper exploration of these patterns. In the following chapter, I apply these methods to shift the analytical scale from subregion-to-subregion to site-to-site interactions. Through various network methods and models, I will identify general trends in the economic system and show which sites held influence within that system. This network-based approach offers a new level of resolution for understanding interactions in the UBRV, contributing to our knowledge of ancient Maya society, economic systems, and political strategies.

CHAPTER 5

EARLY AND MIDDLE PRECLASSIC SOCIO-ECONOMIC NETWORKS IN THE UPPER BELIZE RIVER VALLEY

In the previous chapter, I established the foundations for examining socio-economic interactions among sites in the Upper Belize River Valley (UBRV) during the Early Preclassic (EPC), Early Middle Preclassic (EMPC), and Late Middle Preclassic (LMPC) periods using Neutron Activation Analysis (NAA) of pottery as a proxy for exchange. This chapter builds on that foundation by applying formal network methods and models to investigate inter-site connections. The aim is to illuminate both the global and local structures of the networks, addressing questions about which sites occupied influential positions, how those positions shaped regional political and economic dynamics, and how they contributed to the historical trajectories of individual sites.

I begin by reviewing relevant literature on reconstructing exchange networks using geochemical data, followed by a description of how the formal network models used in this study were constructed. I then compare the empirical networks with Exponential Random Graph Models (ERGMs) to identify the political and economic processes likely driving network formation and change. The ERGM section offers a novel approach to exploring and understanding the emergence of complex organizational structures. Next, I analyze network positions through time using various centrality measures to identify sites that likely served as key hubs for the movement of goods and ideas. Finally, I present the results of a community detection analysis to examine the internal structure of the networks, allowing me to situate each period's network configuration along the socio-economic spectrum introduced in Chapter 2.

Previous Geochemical Based Network Studies

A central goal of this study is to reconstruct patterns of socio-economic interaction among prehistoric communities by identifying which sites exchanged goods and the intensity of those exchanges. The use of geochemical data to reconstruct exchange networks through formal network methods represents a relatively new area of archaeological inquiry. Several prominent studies have employed X-Ray Fluorescence (XRF) analysis of obsidian to map social networks across diverse regions, including Mesoamerica (Feinman et al. 2019, 2022; Golitko and Feinman 2015; Golitko et al. 2012), the U.S. Southwest (Mills et al. 2013), New Zealand (Ladefoged et al. 2019), and the Kuril Islands (Phillips 2011). Obsidian XRF data tend to produce more chemically homogeneous results compared to ceramic NAA data because obsidian's composition reflects distinct volcanic events, making source attribution relatively straightforward.

Elliot Blair (2015, 2016) applied Laser Ablation-Inductively Coupled Plasma-Mass Spectrometry (LA-ICP-MS) to historic glass beads to reconstruct exchange networks and infer communities of practice in the barrier islands of southeastern Georgia. Like NAA, LA-ICP-MS generates elemental composition profiles, though it differs by focusing directly on the sample matrix (e.g., glass or clay) rather than analyzing a bulk material sample which may also contain temper.

Fewer studies have applied geochemical data from pottery to directly reconstruct archaeological networks, though this line of research continues to grow. Erik Gjesfjeld and

Colby Phillips (2013) and Gjesfjeld (2015), for example, used ICP-MS to examine ceramic exchange as a function of environmental adaptation. More recently, John Hart and colleagues (2025) used LA-ICP-MS to reconstruct male-oriented networks based on ceramic pipe production and distribution among the ancestral and colonial-era Huron-Wendat of New York, Ontario, and Quebec. The authors compared their geochemically derived network to other female-oriented networks based on pottery design similarities to highlight structural differences between male and female social networks.

Even fewer researchers have used NAA on pottery to directly reconstruct prehistoric networks. Wesley Bernardini (2007) used NAA to trace Jeddito Yellow Ware production and distribution within the Hopi area of northern Arizona, linking known kiln sites to vessel distributions at consumer sites. Angus Mol (2014) used existing NAA data to construct fragmentary bimodal networks that link pottery source groups to specific sites in the Caribbean. Collectively, these studies demonstrate the growing potential of geochemical sourcing methods for reconstructing ancient socio-economic networks. This project adds to this growing corpus of research.

Network Model Creation

To generate a network model of ceramic circulation based on NAA data, I used both the inferred production zones for each chemical compositional group, as described in the previous chapter, and the proportional representation of each group at each site. I defined directed ties from presumed production locations to consumption sites, with weights corresponding to the estimated volume of ceramic flow. For example, if a specific compositional group originated at Cahal Pech, I created directed ties from Cahal Pech to each site where that compositional group was present, assigning tie weights based on the proportion of that NAA group found at the receiving site.

When NAA data clearly linked ceramic groups to specific production sites, establishing these ties was straightforward. However, when a compositional group could plausibly come from multiple production sites, I divided the weights proportionally among those potential sources. For instance, if 20 percent of a receiving site's assemblage belonged to a compositional group with two potential source sites, I assigned a 10 percent weight from each source site to the receiving site, creating directed ties from both potential producers. This approach assumes equal contribution from all candidate production sites, a conservative choice given the limits of current sourcing precision. Additionally, when sites were located within the same production zone, which aligns with the individual river valleys (i.e., Mopan, Macal, and Belize Rivers), I created bi-directional ties between all sites within that zone with a maximum tie weight. This reflects both their similar ceramic compositional profiles and the expectation that these sites engaged in frequent interaction based on their geographic proximity.

I assigned tie weights based on the proportional volume of flow between production zones and consumer sites, then binned these values into integers from 0 to 4 to meet the statistical requirements of the ERGM models described later. Specifically, ties with proportions between 0.01 and 0.09 received a weight of 1, 0.10 to 0.19 a 2, 0.20 to 0.29 a 3, and anything above 0.30 received a 4 (max = .42), while non-existent ties with no flow were assigned a weight of 0. For example, during the EMPC, Fine Ware 1 was produced at Blackman Eddy and accounted for 14 percent of the assemblage at Xunantunich, resulting in a directed tie from Blackman Eddy to Xunantunich with a weight of 2.

In cases where multiple compositional groups flowed from a single production zone to a consumer site, I treated tie weights as additive across groups. For example, during the EPC, Cahal Pech produced both Belize Valley Dull Ware 2 and EPC Utilitarian group ceramics. Blackman Eddy contained 17 percent Belize Valley Dull Ware 2 and 25 percent EPC Utilitarian, so I assigned a total weight of 4 for the directed tie from Cahal Pech to Blackman Eddy (0.17 plus 0.25 equals 0.42, which falls into the highest weight category of 4).

The resulting network model thus represents a weighted, directed site-to-site network where direction reflects ceramic flow from producers to consumers and weights capture relative volume based on proportional representation. While this model rests on some necessary assumptions regarding production zones and site-specific sourcing, I designed it to adopt the most conservative interpretations supported by the available evidence. I used this network model to generate weighted edge lists for each period considered in this study. Network visualizations appear in Figures 5.1 – 5.6. A thorough discussion of these networks is presented after the networks are subjected to several further analyses, to which I now turn.

Exponential Random Graph Models

Exponential Random Graph Models (ERGMs) are a family of network statistical models that help identify the local and global processes within networks that are likely to generate observed global structures using random graphs to permit inference in light of statistical uncertainty. ERGMs provide a statistical framework for both simulating networks based on predetermined relational processes and evaluating how well different

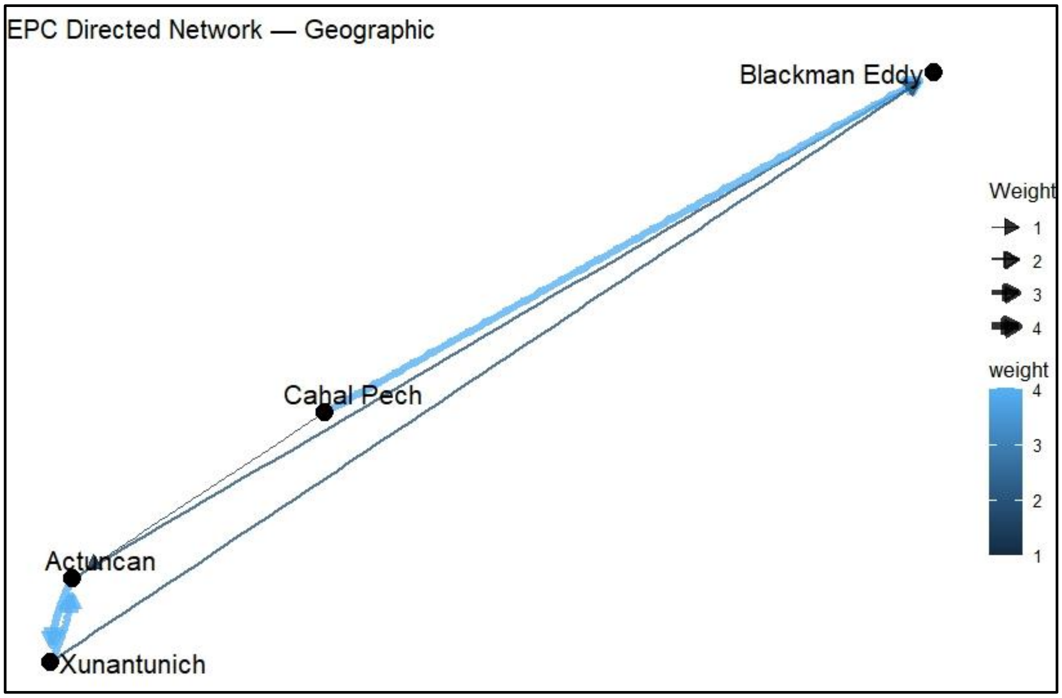

Figure 5.1. Early Preclassic Socio-Economic Network. The network is plotted in geographic space. The network is directed and weighted. Stronger ties are a lighter shade of blue.

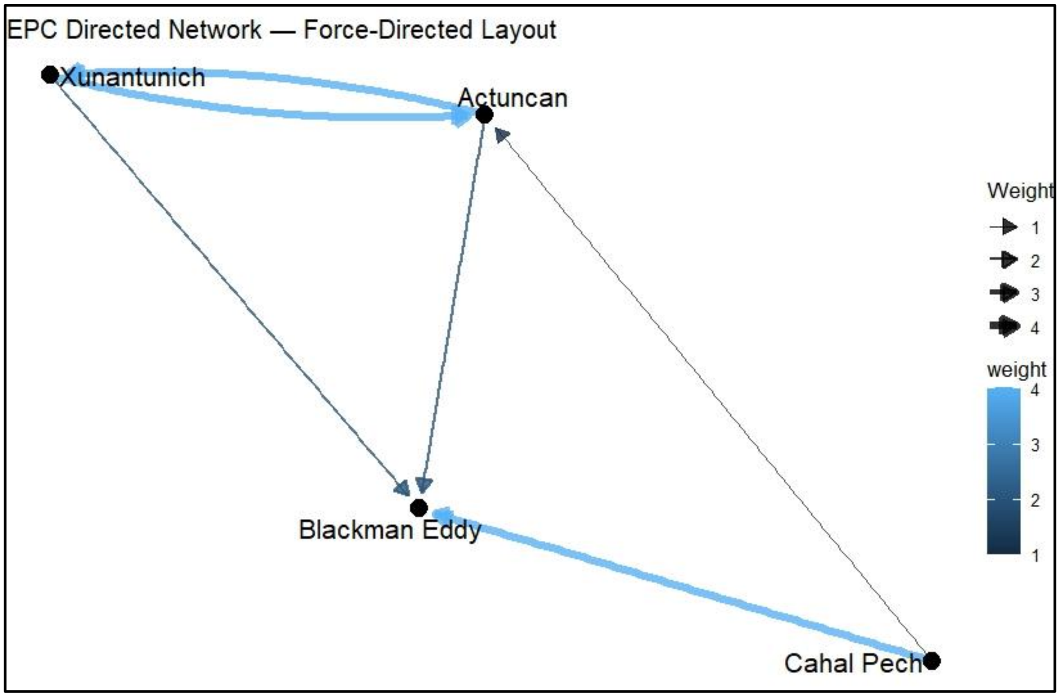

Figure 5.2. Early Preclassic Socio-Economic Network. The network is plotted in social space (Fruchterman-Reingold Algorithm). The network is directed and weighted. Stronger ties are a lighter shade of blue.

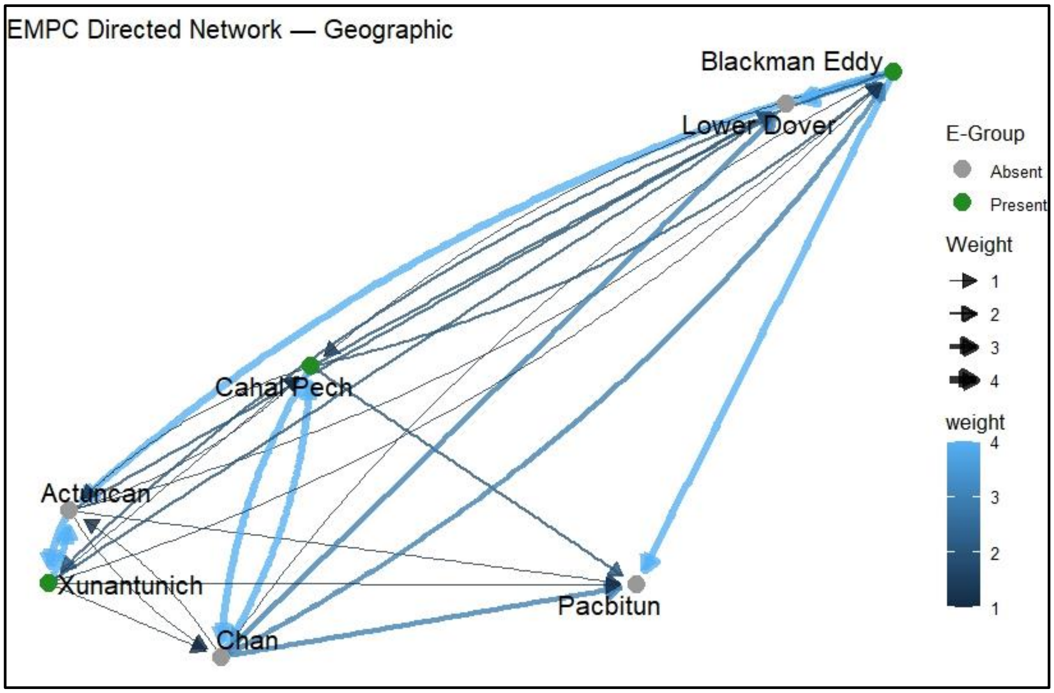

Figure 5.3. Early Middle Preclassic Socio-Economic Network. The network is plotted in geographic space. The network is directed and weighted. Stronger ties are a lighter shade of blue.

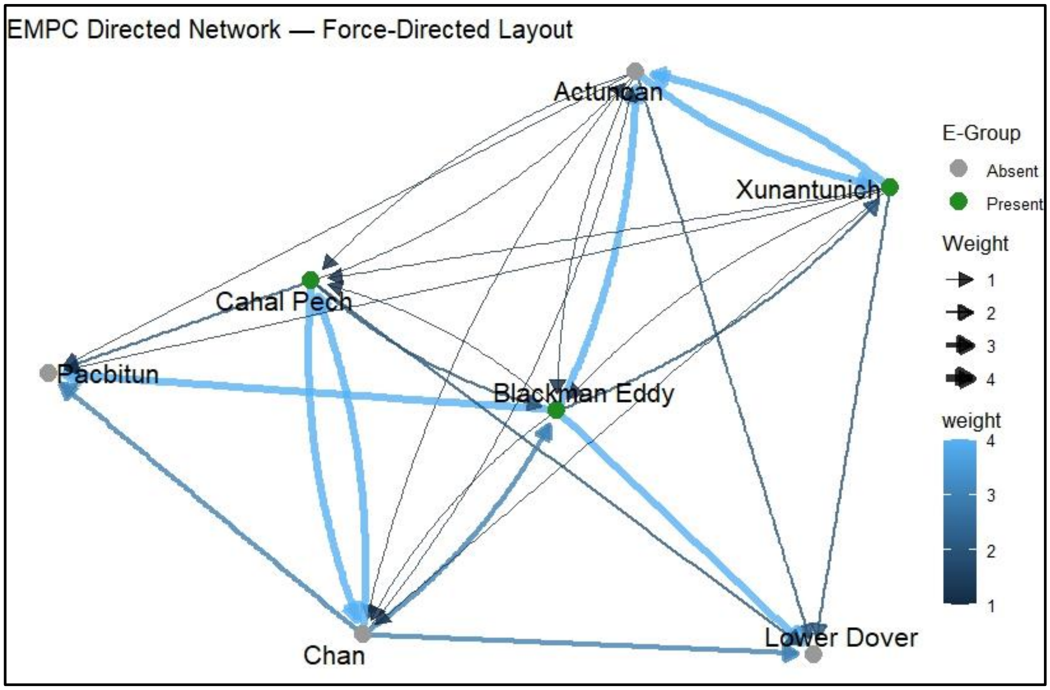

Figure. 5.4. Early Middle Preclassic Socio-Economic Network. The network is plotted in social space (Fruchterman-Reingold Algorithm). The network is directed and weighted. Stronger ties are a lighter shade of blue.

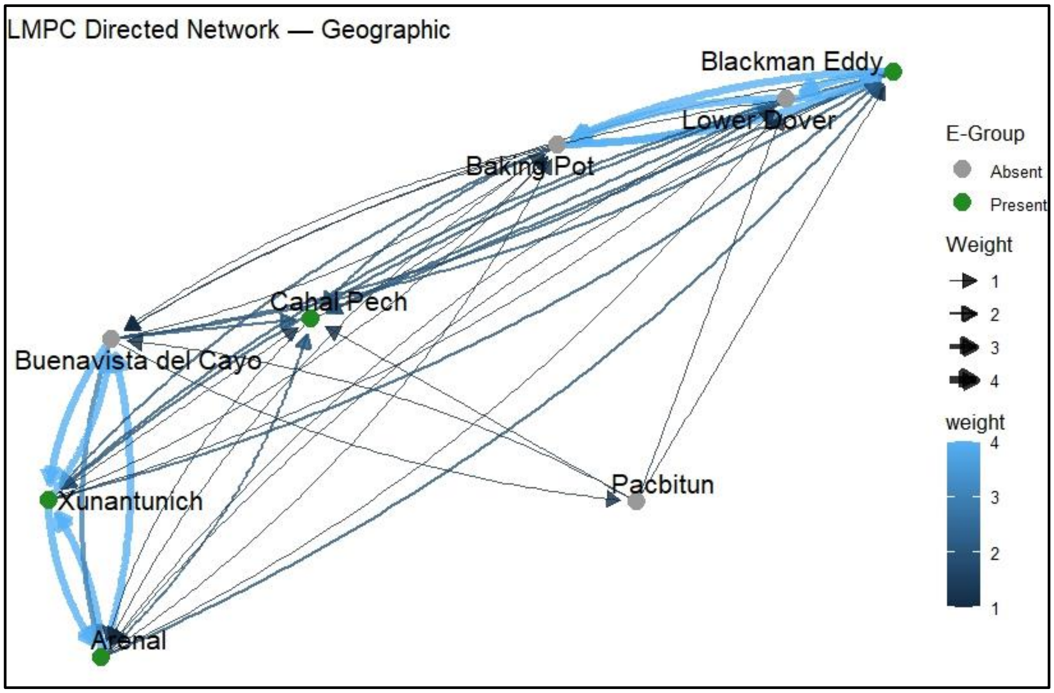

Figure 5.5. Late Middle Preclassic Socio-Economic Network. The network is plotted in geographic space. The network is directed and weighted. Stronger ties are a lighter shade of blue.

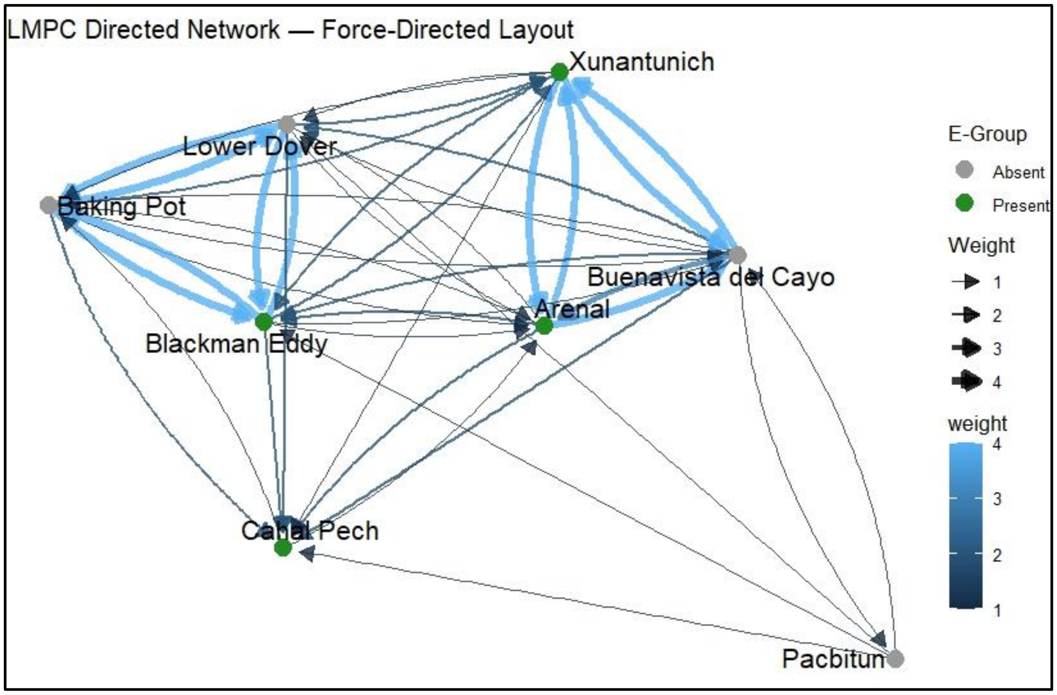

Figure. 5.6. Late Middle Preclassic Socio-Economic Network. The network is plotted in social space (Fruchterman-Reingold Algorithm). The network is directed and weighted. Stronger ties are a lighter shade of blue.

theoretical models and generative processes might explain the global structure of an observed network. Researchers use ERGMs to simulate thousands to millions of networks based on specified model parameters and then compare these simulated networks to the empirical one. The goal is to determine whether particular network factors or node/edge attributes, such as architectural features, geographic distance, or certain relationship configurations, significantly influence the global network structure observed in the empirical network. While sociologists have applied ERGMs for several decades (Frank and Strauss 1986; Lusher et al. 2013; Wasserman and Pattison 1996), archaeologists have only recently begun to adopt this method (Amati et al. 2018, 2020; Brughmans et al. 2014; Brughmans and Brandes 2017; Cegielski 2020; Wang and Marwick 2021). ERGMs are especially valuable for archaeologists because our networks are reconstructed through indirect inference from material remains, rather than through direct observation of interactions, as in ethnographic research. Despite their relatively recent introduction to archaeological studies, ERGMs have quickly proven to be a powerful tool for theory testing.

An example helps illustrate the kinds of hypotheses ERGMs can evaluate. In this study, if the presence of E-Groups signals exclusionary leadership strategies, one might hypothesize that sites with E-Groups would import more pottery from more locations than sites without them. ERGMs allow us to test this by building models where E-Group presence affects tie formation and strength, then compares the simulated networks to the observed network reconstructed from NAA data. This approach makes it possible to assess whether the observed pattern of pottery exchange is statistically consistent with the hypothesized social process.

Development of Exponential Random Graph Models

Since ERGMs are still relatively new to archaeology, before presenting my own models, it is useful to briefly review the historical development of ERGMs and the mathematical principles behind them to situate this research within the broader history of ERGM use. The statistical analysis of social networks began as early as the 1930s, when Moreno and Jennings (1938) proposed comparing observed network structures against null models to determine whether observed social configurations resulted from choice or chance. Anatol Rapoport (1953, 1957) expanded on these ideas with his "biased net theory," which introduced additional probabilistic thinking into network analysis.

By the late 1950s, Erdős and Rényi (1959) developed models of random graphs that provided a more rigorous baseline for comparing real-world networks. Ove Frank (1981) further advanced the statistical modeling of networks by introducing new forms of random graph models. In the early 1980s, Paul Holland and Samuel Leinhardt (1981) introduced the "p1 model," which formalized the concept of dyad independence. This concept assumes that the probability of a tie between any two nodes is unaffected by the presence or absence of ties between other node pairs.

Around the same time, Ove Frank and David Strauss (1986) introduced Markov random graphs, or Markov chains, to network modeling, further expanding the range of network dependencies that could be modeled. A Markov chain is a mathematical model that describes a sequence of events in which the probability of transitioning to the next state depends only on the current state and not on the series of states that preceded it. This makes Markov chains useful for modeling random processes over time where future outcomes are conditional only on present circumstances.

The 1990s saw the introduction of the “p* model,” which incorporated a log-linear framework that allowed researchers to include multivariate and weighted network data (Pattison and Wasserman 1999; Robins et al. 1999). An important contribution of the p* model is that it can predict “conditional ties,” or the presence of a tie based on other ties in the network. By the early 2000s, ERGMs were increasingly used to test theories related to social influence and selection (Contractor et al. 2006; Robins et al. 2001a, 2001b). Since then, ongoing methodological refinements have improved the ability of ERGMs to fit empirical networks more accurately (Snijders et al. 2006; Robins et al. 2007), bringing the method to its current form.

The mathematics behind ERGMs as they are used today is based on the p* model, which is written as:

$$P(Y = y) = \frac{\exp(\theta' g(y))}{k(\theta)}$$

Where $P(Y = y)$ represents the probability that the observed network will take on a particular configuration y from the set of all possible network configurations Y. The term $g(y)$ refers to the set of ERGM statistics (i.e., network features or structural terms) included in the model. The parameter θ' represents the vector of coefficients associated with these model terms. Finally, $k(\theta)$ is the normalizing constant that ensures the total probability sums to 1, calculated as the sum of the numerator for each possible network configuration over all networks with the same node set as y.

Previous archaeological applications of ERGMs have focused on binary networks, where ties represent the presence or absence of a connection. For example, scholars have modeled visibility networks between long barrows at Cranborne Chase (Brughmans and

Brandes 2017; Peeples and Brughmans 2023) and Iron Age sites in southern Spain (Brughmans et al. 2014), social networks in the Aegean (Amati et al. 2018) and the pre-Colonial Caribbean (Amati et al. 2020), social stability in Middle and Late Bronze Age Spain (Cegielski 2020), shifting burial networks in Taiwan (Wang and Marwick 2021), and road networks in ancient Mesopotamia (Priß et al. 2025). These studies have effectively tested whether ties exist between nodes based on theoretical variables such as visibility, geographic distance, or shared attributes.

This study takes a different approach. It represents the first archaeological study of which I am aware to apply valued (i.e., weighted) ERGMs, which allow for the modeling of both the presence and the strength of ties. While directed binary ERGMs can assess the likelihood of reciprocal ties between dyads, they cannot capture differences in trade volume between site pairs. This weighted approach is critical for determining whether sites were connected and whether certain hypothesized factors influenced the quantity of exchanged materials.

The Model in Theory

My model focuses on evaluating how node attributes, edge characteristics, and structural network features contributed to the formation of the observed networks. One of the site attributes that I am interested in modeling is whether the presence of an E-Group influenced either the existence of a connection or the quantity of goods flowing into or out of a site. As discussed in Chapter 2, several scholars argue that the construction of specific forms of monumental architecture, such as E-Group complexes, reflects exclusionary leadership strategies that shaped patterns of socio-economic capital accumulation.

Including E-Groups as a variable in this model is therefore critical for addressing these political and economic questions that archaeologists continue to explore.

I also examine the role of geographic proximity in shaping trade relationships. Sites located closer together likely interacted more frequently than distant ones. As populations grew and some communities exceeded their local carrying capacities, processes of social fission likely led to the founding of new settlements nearby. These new communities would have maintained strong socio-economic ties to their places of origin, sustained through kinship, apprenticeship, shared traditions, or other social mechanisms. Overlap in ceramic assemblages between geographically close sites, as discussed in the previous chapter, supports this assumption.

In addition to distance, I explore whether sites tend to cluster within the network. In network terms, this inclination toward clustering is captured by transitivity. Newly founded or immigrant communities likely developed or maintained socio-economic connections with their immediate neighbors. Even groups migrating from outside the region would probably integrate into the local network through these mechanisms. This dynamic reflects the principle of transitivity, where "friends of friends become friends." For example, if Site A interacts with Sites B and C, then B and C are more likely to establish ties as well. Furthermore, the tendency towards transitivity may suggest that more sites were engaged in corporate leadership strategies or they formed coalitional or bonded network structures.

Another key factor under investigation is mutuality, or the extent to which ties between sites are reciprocal in both presence and volume. If goods predominantly flow in only one direction or if there are large imbalances in the volume of exchanged goods, this asymmetry may indicate hierarchical relationships, where certain sites exert greater control over exchange dynamics.

In addition to these factors, I also consider overall network density as a structural feature influencing network formation. Network density refers to the proportion of observed ties relative to the total number of possible ties within the network. Higher density values indicate a more interconnected network, where many sites maintain ties with one another, while lower density reflects a more fragmented or sparsely connected network. Density provides a useful baseline for understanding whether the observed level of connectivity exceeds what would be expected by chance, given the number of nodes present. In this context, evaluating density allows me to assess whether shifts in the number and intensity of ties across periods reflect broader changes in regional socio-economic integration or fragmentation.

In summary, this ERGM analysis evaluates the effects of E-Group presence, geographic distance, transitivity (i.e., network closure or clustering), mutuality (i.e., reciprocity and volume balance between node pairs), and overall network density on the formation of the observed networks. Modeling these weighted relationships is particularly important for this study, given that site-level characteristics likely influenced not only the presence of ties but also the intensity of economic interactions which I use to inform my overall model of socio-political complexity in the UBRV. The following section presents the specific ERGM models along with their results and interpretations.

The Model in Practice

I constructed the ERGMs in RStudio (R Core Team 2023) using the “ergm” (Handcock et al. 2025; Hunter et al. 2008) and “ergm.count” (Krivitsky 2012; Krivitsky et al. 2023, 2024) packages, which are part of the “statnet” suite for statistical network modeling (Handcock et al. 2025). For each period, EPC, EMPC, and LMPC, I prepared two .csv files: one containing a directed and weighted edge list, and another with node attributes such as site coordinates and presence or absence of an E-Group. Both datasets were imported into RStudio for analysis. To build the models, I selected node attributes, edge characteristics, and structural network features from the list of terms available within the “ergm” package. Each term adds new statistics to the model, increasing computational complexity.

All three models include the terms “sum”, “nonzero”, “mutual”, “edgecov”, and “transitiveweights” (Table 5.1). The “sum” term calculates the total weight across all edges in the network, capturing whether overall tie values tend to be higher or lower than expected by chance. The “nonzero” term models the general likelihood that a tie exists between two nodes regardless of weight. Using both “sum” and “nonzero” allows the model to distinguish between processes that drive volume and those that drive connectivity. The “mutual” term models reciprocity between node pairs, assessing whether reciprocal exchanges are more likely at low or high volumes. The “edgecov” term incorporates an edge-level covariate, in this case geographic distance between nodes, to evaluate how distance influences tie formation and strength. The “transitiveweights” term models triadic closure, capturing whether strong connections between node pairs increase the likelihood of forming a third tie.

Table 5.1. Exponential Random Graph Model Terms used in Model

ERGM Term	Description
Sum	Baseline tendency for total network weight to be high or low
Nonzero	Baseline tendency for edges to form between nodes
Mutual	Tendency for weighted reciprocity between node pairs
Edgecov	Influence of distance on tie weight
Transitiveweights	Tendency for the network to form clusters (i.e., triad closure)
Nodeifactor	Tendency for E-Group presence to receive more volume
Nodeofactor	Tendency for E-Group presence to send more volume

For the EMPC and LMPC models, I included two additional terms to evaluate the impact of E-Groups on the network. The "nodeifactor" term tests whether sites with E-Groups are more likely to receive higher volumes of goods compared to sites without them. The "nodeofactor" term tests whether sites with E-Groups are more likely to send higher volumes of goods than those without.

Since ERGMs rely on Markov chains to simulate thousands to millions of random graphs, researchers have adopted Monte Carlo sampling, specifically called Markov Chain Monte Carlo (MCMC), to efficiently explore the vast number of possible network configurations. The total number of potential networks grows exponentially with each additional node, making it computationally impossible to calculate exact probabilities for every possible configuration. MCMC addresses this challenge by providing a method to sample the network space effectively.

In practice, ERGMs use MCMC to generate a sequence of random networks by making small, stepwise changes to the current network, such as adding, removing, or altering a tie. Each new step depends only on the current state of the network, which reflects the Markov property. The algorithm accepts or rejects each proposed network based on how well it fits the specified model parameters. After many iterations, the chain produces a sample of networks that collectively approximate the probability distribution defined by the ERGM. This process allows researchers to estimate model parameters and compare simulated networks to the observed empirical network. However, researchers must take care to avoid degeneracy, a situation where the chosen model terms result in networks that cannot realistically exist. Degenerate models fail to converge and do not produce simulations that approximate the empirical network.

In valued ERGMs, where tie weights represent ordered, discrete categories, such as the binned volumes of ceramic exchange, coefficient estimates are interpreted as log-odds ratios associated with incremental changes in tie weight, relative to the specified reference distribution. In this study, I use a binomial reference distribution, which treats each possible unit increase in tie weight (from 0 up to 4) as a distinct outcome. As such, each coefficient represents the change in the log-odds of observing a higher tie weight, holding all other factors constant. Positive coefficients indicate that the associated term increases the likelihood of higher tie weights between node pairs, while negative coefficients indicate that the term reduces this likelihood. While the interpretation remains log-odds based, it now reflects the probability of observing stronger ties rather than the simple presence or absence of a tie.

ERGM Results

Table 5.2. presents the results of the three valued ERGM models, each of which evaluates whether specific structural and attribute-based processes account for the observed distribution and volume of pottery exchange more effectively than random chance. During the EPC, the “sum” term suggests that the overall volume of exchange was slightly higher than would be expected in a randomly generated network of the same size. At the same time, the “nonzero” term is strongly negative, indicating that the network contained fewer ties than would typically occur by chance. Taken together, these terms suggest that while ties were fewer than expected, those that did exist were relatively stronger than what would be expected under random conditions. The mutuality and distance terms show little deviation from random expectations, implying that reciprocal exchanges and geographic proximity did not strongly shape the structure of the network. Similarly, the transitivity term aligns with random models, indicating that clustered triadic patterns were no more or less common than would be anticipated.

Table 5.2. Results of Exponential Random Graph Models. P-values are presented in parentheses.

ERGM Term	**Early Preclassic**	**Early Middle Preclassic**	**Late Middle Preclassic**
Sum	1.088 (p=0.0659)	0.300 (p=0.4913)	-2.904 (p=0.0055)
Nonzero	-4.731 (p=0.0014)	-1.521 (p=0.0216)	-1.328 (p=0.0109)
Mutual	0.089 (p=0.8863)	0.197 (p=0.6640)	1.521 (p=0.0315)
Edgecov(distance)	-0.000 (p=0.5225)	-0.000 (p=0.8506)	-0.000 (p=0.0089)
Transitiveweights	-0.108 (p=0.7406)	-0.535 (p=0.0189)	2.647 (p=0.0074)
Nodeifactor(E-Group)	N/A	-0.412 (p=0.6513)	0.969 (p=0.0129)
Nodeofactor(E-Group)	N/A	0.635 (p=0.0413)	-0.678 (p=0.0988)

In the EMPC, the "sum" term shifts, suggesting that the total volume of exchange in the observed network was not substantially higher or lower than would be expected by chance. However, the "nonzero" term remains strongly negative, indicating that the probability of observing such a sparse network is low. The positive "nodeofactor" coefficient indicates that sites with E-Groups were more likely to export larger volumes of goods than would typically be expected in a random network. The transitivity term is slightly lower than expected, implying that triadic closure occurred less frequently than in a random network. Mutuality and geographic distance show little deviation from randomness, suggesting that reciprocity and proximity had limited influence on tie formation or volume. The "nodeifactor" term also aligns with random expectations, indicating that E-Group sites were neither more nor less likely to receive goods than would be expected by chance.

By the LMPC, the network exhibits substantial structural changes. The “sum” term is strongly negative, indicating that the overall volume of exchange across the network was much lower than expected. The “nonzero” term also remains negative, showing that the network continued to exhibit fewer active ties than chance alone would predict. Mutuality shows a notable positive effect, suggesting that reciprocal exchanges between site pairs occurred more frequently than would be expected under random conditions. The distance term becomes slightly negative, indicating that geographic proximity began to play a small but consistent role in shaping exchange volumes; in other words, closer sites were more likely to exchange in higher volumes. Transitivity shows an elevated effect, meaning triadic closure occurred more frequently than expected, pointing to increased clustering. E-Group presence continues to matter, but with a notable shift from the previous period. Sites with

E-Groups during the LMPC were more likely to receive higher volumes of goods, while their role as exporters diminished. This pattern suggests that E-Group sites were increasingly functioning as focal points of exchange and may have been consolidating political authority in the region.

In summary, the valued ERGM results reveal a trajectory of change when compared against random network expectations. The EPC network was sparse but dominated by a few high-volume exchange ties. By the EMPC, the network remained sparse, but with signs that E-Group sites were beginning to play a larger role as exporters. Also, triads were closing less frequently than we would suspect, suggesting some kind of preference for brokerage positions for some sites. By the LMPC, the network was still sparser than expected, but node pairs were more likely to exhibit reciprocity in exchange volume than during the previous periods. Additionally, the network was slightly structured by distance. E-Group sites changed roles and emerged as prominent goods-receiving centers, while no longer sending more than would be randomly expected. The growing significance of distance and transitivity in the LMPC also highlights a shift toward geographically regional sub-networks. This shift to a positive transitivity score, or the presence of more triadic closure, suggests that the sites that maintained brokerage positions did so by choice. The appearance of significant E-Group effects by this time further signals increasing institutional complexity and hierarchical differentiation in the UBRV socio-economic landscape. With this regional context established, the following section examines site-level positions to explore which communities actively shaped these network transformations.

Network Positions

Several network metrics can help reveal patterns of power and influence within socio-economic exchange networks. It is important to remember that network analysis models social space rather than physical space. As a result, sites located at the geographic margins of the study area may still occupy central positions within the social network. These metrics help identify such cases. One key measure is degree centrality, which can be calculated based on either the presence of ties (binary degree) or the weight of those ties (weighted degree). Degree centrality further divides into in-degree, which measures the number of ties or the volume of goods a site receives from others, and out-degree, which measures the number of ties or the volume a site sends to others. Binary degree centrality indicates a site's overall connectedness, while weighted degree centrality reflects the intensity of material flow along those connections. Borgatti (2005) emphasizes that nodes with higher degree centrality have access to more parts of the network, making them more likely to acquire specific goods quickly over time (i.e., days, months, years, etc.). In prehistoric political and economic contexts, sites with high in-degree centrality likely had the infrastructure to host large gatherings or were the recipients of gifts, tribute, or taxes. In contrast, sites with high out-degree centrality were probably centers of craft production, trade, or subordinate communities obligated to send goods to more dominant centers.

Another important metric for identifying influential nodes is betweenness centrality, which measures a node's role as an intermediary within the network. Formally, betweenness centrality calculates the shortest paths between all node pairs, counts how many of these paths pass through each node, and then divides that count by the total number of shortest paths in the network (Brughmans and Peeples 2023:128). In simpler terms, betweenness reflects how often a site acts as a conduit for goods moving between other sites. Socially, high betweenness centrality indicates a site's ability to control the flow of materials across the network. Sites with high betweenness centrality likely served as bridges between different regions or social groups and played key roles in connecting otherwise distant or isolated parts of the network.

Another key network metric is brokerage, which occurs when one site connects to two others that are not directly connected. This position gives the intermediary site the ability to control, or at least influence, the flow of goods between the other two (Peeples and Haas 2013). As outlined in Chapter 2, villages pursuing exclusionary leadership strategies are expected to occupy brokerage positions, effectively creating economic bottlenecks. To calculate brokerage potential, I use a triad census for each period to identify all intransitive triads, groups of three sites in which only one site links to the other two (Table 5.3), and then sum the total weighted degree for each site across all triads where it serves as a potential broker. Table 5.4 presents both binary and weighted degree centrality, weighted betweenness centrality, and brokerage potential scores for the overall network and for individual sites across the Early and Middle Preclassic periods.

During the EPC, the network shows relatively low overall connectivity, as reflected in the mean degree centrality (0.22). Actuncan stands out as the most balanced site, with equal in-degree and out-degree (2/2) and the highest betweenness centrality (2), suggesting a strategic position in connecting different parts of the network. Furthermore, Actuncan has the highest brokerage potential (9), giving the site a greater possibility to control the flow of resources through the network. Blackman Eddy displays a high binary in-degree (3) and weighted in-degree (8), suggesting it acted primarily as a receiving hub, likely bringing in

Table 5.3. Intransitive Triads

Period	Triad Code*	Triads*
EPC	021U	CHP->BME<-XUN
	111D	XUN<->ACT<-CHP
EMPC	021D	LWD<-ACT->PAC
		LWD<-BME->PAC
		LWD<-CHP->PAC
		LWD<-CHN->PAC
		LWD<-XUN->PAC
LMPC	021U	XUN->CHP<-PAC
	111D	ARN<->BME<-PAC
		ARN<->CHP<-PAC
		ARN<->LWD<-PAC
		BKP<->BME<-PAC
		BKP<->CHP<-PAC
		BKP<->LWD<-PAC
		XUN<->BME<-PAC
		LWD<->XUN<-PAC
	201	ARN<->BVC<->PAC
		BKP<->BVC<->PAC
		XUN<->BVC<->PAC

*Triad Code refers to the type of triad, or the direction of goods flow, which is visually represented with arrows in the "Triads" column. The site in the middle of the "Triad" column is in the brokerage position.

goods but not sending much out. However, Blackman Eddy also has a high brokerage potential, granting it some ability to control the flow of goods through the network. Cahal Pech shows the opposite trend with a strong out-degree (3), suggesting it was more active in sending goods but not receiving them. Xunantunich sits somewhere in between, with a slight bias toward sending goods. The low betweenness scores for all sites except Actuncan suggest a decentralized and weakly integrated network.

By the EMPC, the network shows continuing integration with a mean degree centrality (0.19). Actuncan and Blackman Eddy emerges as key hubs with the highest binary degree centrality (10 ties: 4 in, 6 out) and the highest weighted degree (20 and 23, respectively), indicating they were both sending and receiving large volumes of goods.

Table 5.4. Centrality Scores and Brokerage Potential for each Period and Site. Red text indicates a higher out-degree than in-degree.

Period/Site	**Degree Centrality (in-degree/out-degree)**	**Weighted Degree Centrality (in-degree/out-degree)**	**Weighted Betweenness Centrality**	**Brokerage Potential**
Early Preclassic	0.22 (0.50/0.17)	N/A	N/A	N/A
Early Middle Preclassic	0.19 (0.17/0.43)	N/A	N/A	N/A
Late Middle Preclassic	0.18 (0.23/0.23)	N/A	N/A	N/A
EPC				
Actuncan	4 (2/2)	11 (5/6)	2	9
Blackman Eddy	3 (3/0)	8 (8/0)	0	8
Cahal Pech	2 (0/2)	5 (0/5)	0	0
Xunantunich	3 (1/2)	10 (4/6)	0	0
EMPC				
Actuncan	10 (4/6)	20 (10/10)	7.50	3
Blackman Eddy	10 (4/6)	23 (7/16)	3.00	8
Cahal Pech	9 (4/5)	18 (7/11)	2.50	4
Chan	9 (4/5)	21 (7/14)	1.25	6
Lower Dover	5 (5/0)	17 (13/4)	0.00	0
Pacbitun	5 (5/0)	11 (11/0)	0.00	0
Xunantunich	8 (2/6)	16 (6/10)	0.25	3
LMPC				
Arenal	12 (6/6)	26 (12/14)	5.67	0
Baking Pot	12 (6/6)	26 (12/14)	7.83	0
Blackman Eddy	12 (6/6)	29 (15/14)	0.83	18
Buenavista	13 (6/7)	28 (12/16)	8.83	24
Cahal Pech	9 (7/2)	14 (12/2)	1.17	11
Lower Dover	12 (6/6)	27 (13/14)	3.67	12
Pacbitun	5 (1/4)	5 (1/4)	2.17	0
Xunantunich	11 (5/6)	27 (13/14)	0.00	4

Actuncan also holds the highest betweenness centrality (7.5), highlighting its role as both a hub and a bridge in the network, with an average ability to serve as a broker (3). Blackman Eddy follows closely with a betweenness of 3.0, suggesting it too facilitated regional connectivity, albeit less centrally. However, Blackman Eddy presents the highest brokerage potential (8). Cahal Pech and Chan show identical binary degrees (9 each) and comparable weighted degrees (18 and 21, respectively), marking them as active participants in both inbound and outbound exchange. Chan also possessed the second highest brokerage potential (6), pointing to the ability to direct goods flow. Lower Dover and Pacbitun both have high in-degree but no or limited outgoing ties, suggesting they primarily served as terminal receiving sites during this period. Xunantunich, with a degree of 8 (2 in, 6 out) and a relatively low betweenness (0.25), appears moderately integrated, contributing to exchange but with limited influence over the overall flow of the network. Overall, betweenness values remain low but are more widely distributed than in the EPC, signaling a broader shift toward regional interconnectivity.

In the LMPC, the network becomes noticeably denser and more complex. The overall degree centrality remains comparable to the previous period (0.18). Blackman Eddy remains a central hub with one of the highest binary degrees (12), the highest weighted degree (29), and the second highest brokerage potential (18). Baking Pot emerges as a central hub, with the joint-highest degree (12), and high weighted degree (26), and a high betweenness centrality (7.83), suggesting it became a key location for influencing the flow of goods through the network. Buenavista, with a degree of 13, a weighted degree of 27, and a betweenness of 8.83, also ranks highly, facilitating multi-directional flows across the region. Additionally, Buenavista possesses the highest brokerage score (24), suggesting the inhabitants were likely able to leverage their network connections to influence the flow of goods throughout the regional economy. Lower Dover and Arenal have balanced degree distributions and high weighted degrees, with betweenness scores of 3.67 and 5.67, respectively—further supporting their roles as important network connectors. This is a change from Lower Dover's receiving role during the previous period. Cahal Pech, while maintaining some connectivity (degree 9, weighted 14), shows a decline in network prominence with relatively low betweenness (1.17). Xunantunich, despite balanced ties (11 total) and a strong weighted degree (27), has a betweenness of 0.0, reflecting its peripheral role in regional flow dynamics. Pacbitun, with the lowest metrics across all categories, remains marginal in terms of both interaction volume and influence.

Across the three periods, the network shows a clear trend toward increased connectivity, rising centrality scores, and a greater ability for some sites to influence the flow of goods through the network. The EPC was characterized by sparse, generally one-directional flows, influenced by Actuncan. By the EMPC, sites like Blackman Eddy and Actuncan had become major players, acting as both senders and receivers and facilitating broader regional integration. By the LMPC, the network had grown into a well-connected organizational system where multiple sites, especially Baking Pot, Buenavista, and Lower Dover, played central roles in both goods flow and network cohesion. The rising number of sites with high betweenness centrality reflects increasing regional interdependence and complexity in socio-economic relationships. Sites that held brokerage potential in one period tended to maintain that potential in later periods, suggesting that brokerage positions were beneficial, desirable, and purposeful. This trajectory reflects a shift from a sparse, loosely connected system toward a somewhat dense, integrated network where both volume and connectivity actively shaped the political and economic landscape.

Spectrum of Socio-Economic Networks

Building on the results of the previous analyses, we can now address the spectrum of socio-economic network structures outlined in Chapter 2 (Figure 2.11). Social networks fall along a spectrum with three main categories, based on the type of social capital realized through their ties. At one end of the spectrum are bonding networks, characterized by dense clusters of strong ties rooted in high-trust, reciprocal relationships, that are often shaped by shared social identities such as kinship and ethnicity. At the opposite end are bridging networks, which feature sparse connections made up of weaker ties that provide access to external resources through inter-group interactions or formal institutions, such as trade relationships or cross-community religious organizations. Between these two poles lie coalitional networks, which combine both forms: clusters of strong, internal, bonding ties connected to other clusters by weaker, bridging ties.

To help evaluate the networks along this spectrum, I apply a community detection analysis using the Walktrap algorithm and classify edges into two categories: strong and weak (Figures 5.7–5.9). The Walktrap algorithm identifies network subgroups by simulating short random walks, or a predefined number of node-to-node steps along existing ties. I repeatedly tested both four- and five-step walks, with no difference in outcome. When edge weights are included, the algorithm favors stronger ties during the walks. Communities are formed where random walks frequently overlap, indicating areas of high internal connectivity (Pons and Latapy 2005). Edges were classified as either strong or weak based on their modeled weight. Ties with a weight of 3 or 4, indicating that more than 20% of a site's pottery was associated with that connection, were labeled as strong (i.e., bonding). Ties with a weight of 1 or 2, representing 19% or less, were labeled as weak (i.e., bridging). Table 5.5 presents the number of bonding, bridging, and cross-factional ties present in each network. Cross-factional ties are usually bridging ties, but they may be bonding ties as seen during the EMPC between Actuncan and Blackman Eddy.

The results of the community detection analysis indicate a consistent trend toward coalitional networks tending towards bridging capital across all periods. During the EPC, the only bonding ties are bidirectional between Actuncan and Xunantunich, and one from Cahal Pech to Blackman Eddy. Bridging capital accounts for 60% of the ties in the network, suggesting an early emphasis on weak ties. Two communities are detected, which likely reflects the influence of geographic proximity and smaller populations in encouraging group cohesion. These two groups are connected by bridging ties, just as we would expect between forming coalitions.

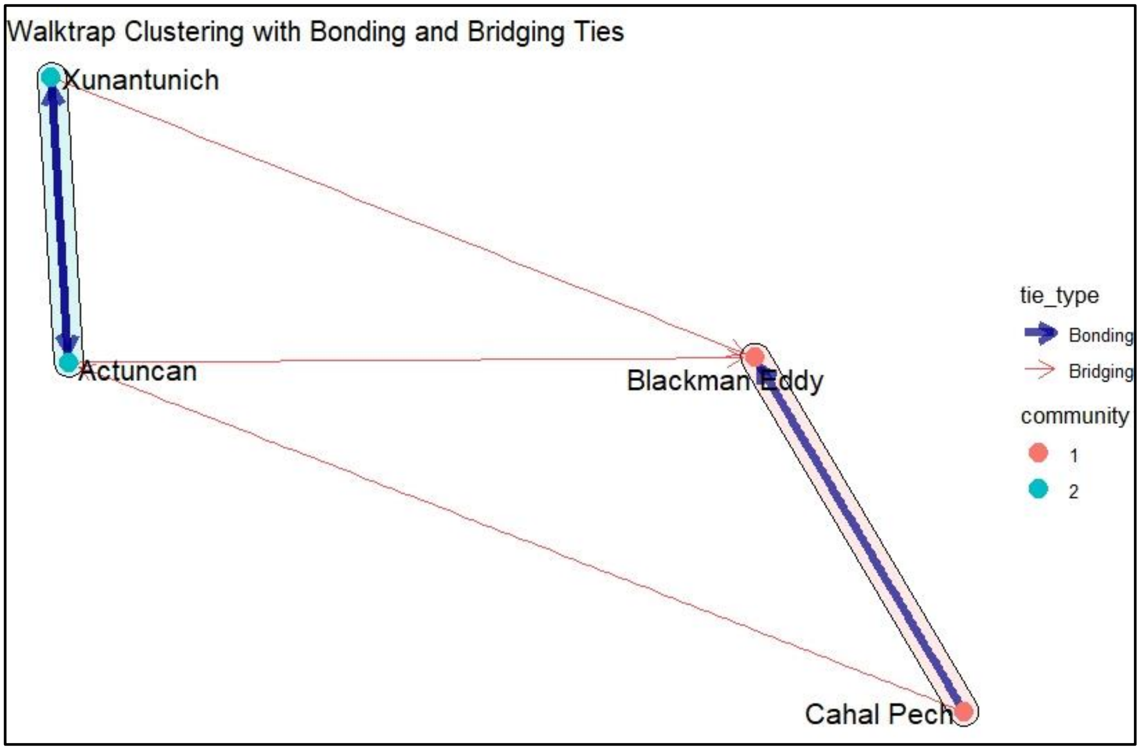

Figure 5.7. Early Preclassic Community Detection. Bonding ties are blue, and bridging ties are red. The figure is based on the 5-walk iteration of the analysis.

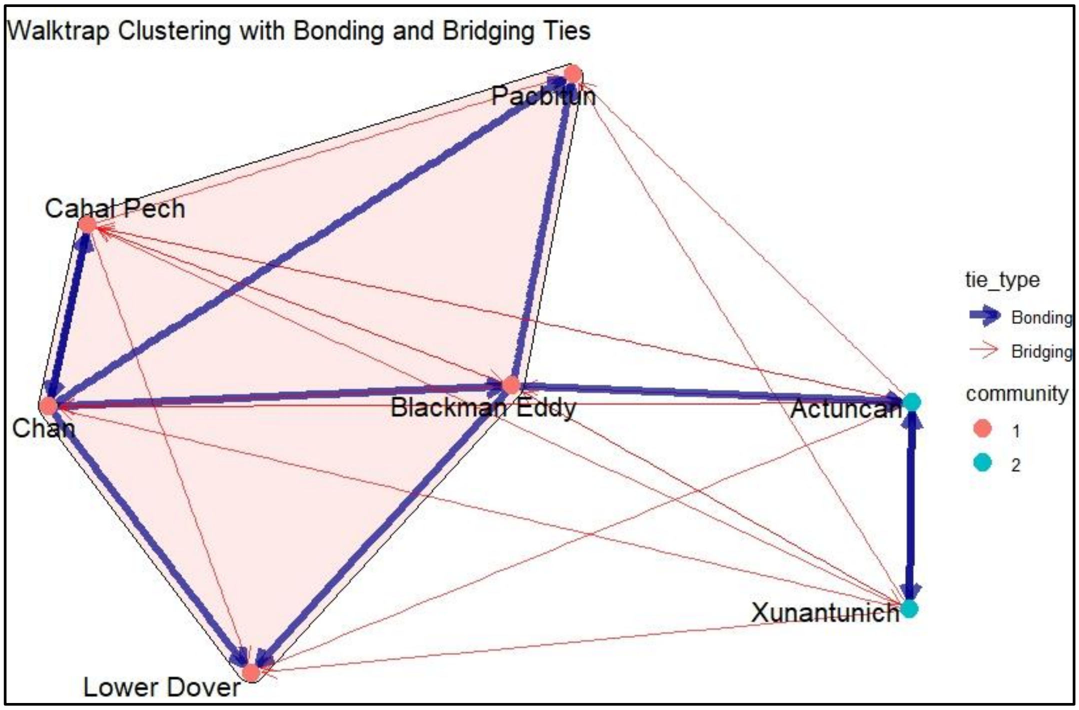

Figure 5.8. Early Middle Preclassic Community Detection. Bonding ties are blue, and bridging ties are red. The figure is based on the 5-walk iteration of the analysis.

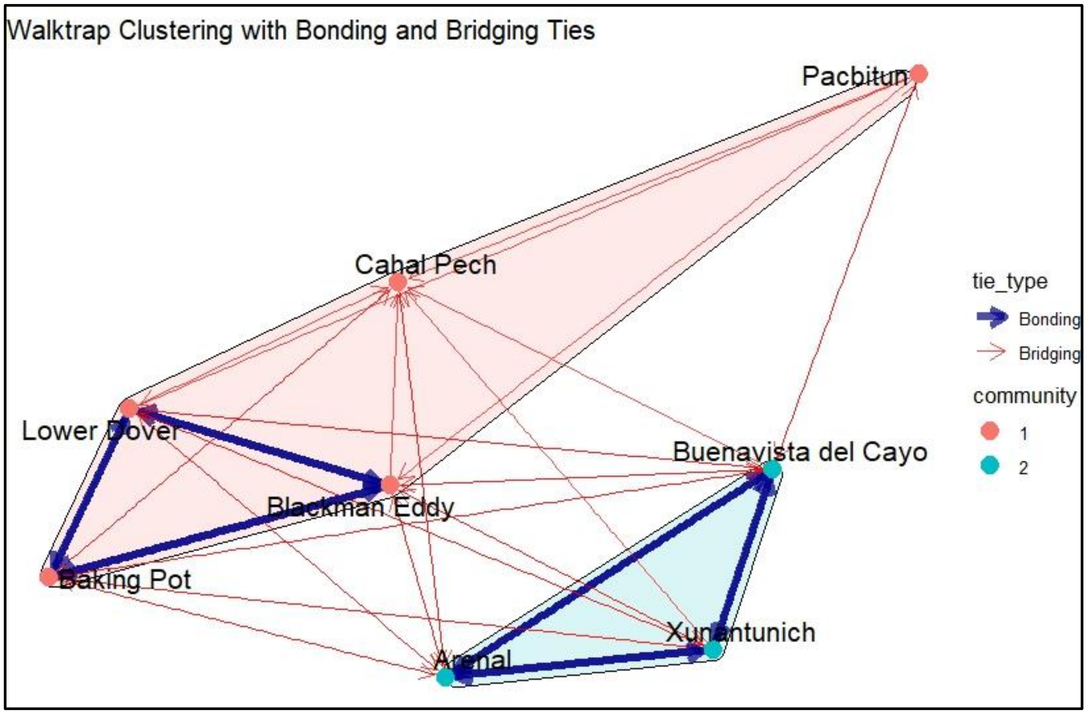

Figure 5.9. Late Middle Preclassic Community Detection. Bonding ties are blue, and bridging ties are red. The figure is based on the 5-walk iteration of the analysis.

Table 5.5. Distribution of Social Capital Types Across Periods. The percentage of capital types is included in parentheses.

Period	Bonding Ties	Bridging Ties
Early Preclassic (1200-900 BC)	2 (40%)	3 (60%)
Early Middle Preclassic (900-600 BC)	8 (40%)	12 (60%)
Late Middle Preclassic (600-300 BC)	6 (24%)	19 (76%)

By the EMPC, two distinct larger factions emerge: one in the Mopan River Valley, and one containing all other sites. However, one bonding tie crosses the division, suggesting that Blackman Eddy and Actuncan retained important relationships from the previous period, likely through familial or other strong social relationships. Importantly, there are still a lot of bridging ties between sites in the different communities, which is likely to reflect weaker economic relationships. As seen during the EPC, bridging capital makes up 60% of the tie types within the network. This combination and structure of the ties represents a coalitional network leaning towards the bridging side of the spectrum.

In the LMPC, two communities are again present. One is composed primarily of strong bonding ties among Baking Pot, Blackman Eddy, and Lower Dover, the other is composed of the Mopan River Valley sites of Arenal, Buenavista, and Xunantunich. This is likely a reflection of geographic proximity and shared NAA profiles, and this cluster was highlighted by the LMPC ERGM model. Interestingly, the larger community is held together by just as many bridging ties as bonding ties, suggesting a rise in regional social institutions that facilitated broader, but weaker integration. Indeed, bridging capital makes up 76% of the social capital within the network, highlighting the growing influence of bridging capital across the network structure. Pacbitun appears only marginally connected to the network at this point, while Cahal Pech is now primarily an endpoint in the network.

Overall, the results point to a persistent tendency toward coalition formation, likely reflecting the emergence of multiple centers of power within the region. As pointed to by the ERGM models, the villages with E-Groups tend to shift roles across the EMPC/LMPC divide, which is likely to reflect the creation of politically dominant communities with the ability to bring in more resources during the LMPC. With these network results in place, I am now able to address the political correlates.

CHAPTER 6

POLITICAL MANIFESTATIONS: ARCHITECTURE, ARTIFACTS, NETWORKS, AND SITE TRAJECTORIES

In the previous two chapters, I examined socio-economic interactions among the inhabitants of sites in the Upper Belize River Valley (UBRV) during the Early and Middle Preclassic periods by reconstructing economic networks through formal network methods. This chapter shifts focus to the evolution of political complexity in the region by analyzing evidence for exclusionary and corporate leadership strategies at each site included in this study. I consider architectural features, patterns of artifact use and access, and examine the local patterns from the socio-economic networks through a political lens. These three categories and their archaeological correlates were outlined in Chapter 2. Here, I apply an approach modified from Qualitative Comparative Analysis (QCA) to translate these correlates into measurable data, allowing me to situate sites along a political spectrum. This approach highlights both the individual trajectories of sites and the broader developmental trajectory of the region.

Although archaeological investigations in the UBRV date back to the late 19th century, sustained research on the Preclassic period has gained momentum only in the past three decades. As a result, most of the data used in this chapter come from recent projects. It is important to note, however, that data coverage varies considerably across sites. Ancient and modern construction often obscures Preclassic architectural and artifactual remains beneath meters of ancient and modern urban sprawl, and differing temporal research foci and excavation strategies have produced uneven datasets. Thus, data are only available where explicit research foci have targeted those contexts. In the context of this chapter, I have developed a conservative analytical approach that considers evidence for both the presence and absence of certain political and economic infrastructure and processes that can also accommodate situations where a lack of evidence is due to the current limits of the data. These limitations constrain direct comparison in some cases, yet broader regional patterns remain visible. As excavations continue it is possible that these results and interpretations may change. The fuzzy nature of these types of data makes QCA style analyses, focusing on varying degrees of membership in formal "sets," a natural fit.

This chapter begins with an overview of QCA formal comparative methods and the approach that I use that was inspired by this approach, followed by the questions and anchors used in the analysis. I then present the dataset and the results of the analysis. Briefly, the results indicate that one data type (i.e., architectural, artifactual, or network) cannot predict exclusionary or corporate tendencies alone, justifying the necessity to examine and synthesize different lines of evidence. Additionally, the results indicate a steady increase from corporate-leaning strategies to exclusionary-leaning strategies through time.

Formal Comparative Analysis as a Method

Qualitative Comparative Analysis (QCA) and similar methods provide a systematic way to compare multiple cases by translating qualitative observations into quantitative form. Comparative analysis itself is not new to archaeology. As Smith and Peregrine (2012) note, such work has been part of the discipline since the late 19th century, declined somewhat in the late 20th century, and has seen renewed interest more recently. Over time, different approaches have developed depending on the size and quality of available datasets. Smith and Peregrine (2012) identify two primary strategies in historical disciplines: intensive and systematic comparison. Intensive approaches focus on a small number of cases using many variables, typically resulting in narrative descriptions. Systematic approaches, by contrast, compare larger numbers of cases with fewer variables, favoring quantitative analysis. My research falls somewhere in between, with a medium number of cases and variables, which makes a QCA inspired method particularly well suited to the task.

QCA was first developed in sociology by Charles Ragin (1989, 2000, 2009) to compare social entities using multiple data types while also identifying patterns of correlation between those data types to build explanatory models. Ragin's method consists of using Boolean logic and set-theoretic relationships among related cases (which can be individuals, organizations, events, etc.) and looking for configurations of conditions within a sample that may be necessary or sufficient to explain differences in outcomes for those cases. This method is particularly well suited to comparative research focused on causal complexity, equifinality, and multiple paths to the same outcome among a medium number of cases. The method has since inspired related approaches which build on the set-theoretic nature of Ragin's approach without focusing primarily on causal complexity (Breiger 2009; Hegmon and Peeples 2018). For example, archaeologists Michelle Hegmon and Matthew Peeples (2018) recently adapted QCA-inspired methods to compare qualitative datasets from the US Southwest and North Atlantic. The authors adapt QCA by using expert-coded fuzzy set scales and configurational comparisons to explore how different combinations of transformational processes affected human security, emphasizing exploration and pattern detection over strict Boolean minimization.

In this study, I employ a method informed by QCA as well as the work of Breiger (2009) and Hegmon and Peeples (2018) to pursue an exploratory rather than an explanatory analysis focused on the changing states of political complexity in the Early and Middle Preclassic UBRV. Specifically, I draw on the QCA technique of coding "sets" based on qualitative "anchors." At the core of QCA, a "set" represents a group of cases that share membership according to a particular variable. For instance, in the case of exclusionary monumental architecture such as an E-Group, a site either has or does not have that form, producing two sets: members and non-members. These are typically coded as 1 for full membership and 0 for non-membership.

QCA has since expanded to include "fuzzy sets," which allow for partial membership (Ragin 2000). Qualitative "anchors" are used to determine partial membership. For instance, fully corporate domestic architecture would exhibit little diversity in size, while fully exclusionary domestic architecture would show clear evidence of diversity, including large, centralized structures. Sites with some limited diversity fall somewhere between these extremes, closer to the corporate side. On a scale ranging from fully corporate (-1) to fully exclusionary (1), such a site might be coded as -0.5, or "somewhat corporate." The anchors in this example are predetermined qualitative criteria based on the amount of diversity within architecture and the presence or absence of large structures.

The qualitative questions used in this analysis are adapted directly from the archaeological correlates for exclusionary and corporate leadership strategies presented in

Chapter 2 (Table 2.1). Following the same framework, the questions are divided into three categories: architecture, artifacts, and networks (Table 6.1). Each anchor is coded on a scale from -1 (fully corporate) to 1 (fully exclusionary), with "fuzzy" codes of -0.5 or 0.5 applied where appropriate. For questions that only address one pole of the political spectrum, anchors are coded as 1 (membership) and 0 (non-membership).

For each category—architecture, artifacts, and networks—the total score is calculated by adding the values and dividing by the number of questions addressed. To generate an overall placement on the exclusionary–corporate spectrum, all individual scores (rather than category scores) are added together and divided by the total number of questions addressed. Zeros, which indicate the absence of a specific data type for questions dealing with only one side of the spectrum, are excluded from the calculations. Similarly, when sufficient data are not available to address a particular question at a site, an "N/A" is assigned, and these are also excluded from the calculations. With this framework in place, I now turn to the datasets used to address the comparative questions.

Table 6.1. Comparative Analysis Questions and Anchors.

Arch. Does the architectural data point towards exclusionary or corporate political strategies?		
1. Domestic Structures	The site has very little diversity in residence size and no large elaborate houses	-1
	The site has limited evidence for diversity in residence size but no large elaborate houses	-0.5
	The site has limited evidence for diversity in residence size and potential large or centrally located residences	0.5
	The site has clear evidence for diversity in residence sizes and elaborate, centrally located residences	1

2. Corporate Monumental Architecture	The site has clear evidence for communal monumental structures such as round and keyhole shaped structures and low platforms	-1
	The site does not have clear evidence for communal monumental structures such as round and keyhole shaped structures and low platforms	0
3. Exclusionary Monumental Architecture	The site does not have clear evidence for exclusionary monumental architecture such as tall dynastic temples	0
	The site has clear evidence for exclusionary monumental architecture such as tall dynastic temples	1
4. Public Spaces	The site has clear evidence for public spaces	-1
	The site does not have clear evidence for public spaces	0
5. Restricted Spaces	The site does not have clear evidence for restricted spaces	0
	The site has clear evidence for restricted spaces	1

Art. Does the artifactual data point toward exclusionary or corporate political strategies?

1. Fertility/ Cosmology/ Public Artifactual Symbolism	The site has clear evidence for fertility/cosmology symbolism	-1
	The site does not have evidence for fertility/cosmology symbolism	0
2. Ancestor/ Private Artifactual Symbolism	The site does not have clear evidence for ancestor-centered symbolism	0
	The site has clear evidence for ancestor-centered symbolism	1
3. Portable Wealth	The site has clear evidence for evenly dispersed portable wealth	-1
	The site has limited/ambiguous evidence for evenly dispersed portable wealth	-0.5
	The site has limited/ambiguous evidence for concentrated wealth	0.5
	The site has clear evidence for concentrated wealth	1
4. Access to Non-Sub-Region Pottery	The site has no access or access to pottery from 1 site in other sub-regions	-1
	The site has access to pottery from 2 or 3 sites in other sub-regions	-0.5
	The site has access to pottery from 4 or 5 sites in other sub-regions	0.5
	The site has access to pottery from 6+ sites in other sub-regions	1
5. Access to Obsidian Sources	The site has access to 1 type of obsidian	-1
	The site has access to 2 types of obsidian	-0.5
	The site has access to 3 types of obsidian	0.5
	The site has access to 4+ types of obsidian	1

Net. Does the network data point toward exclusionary or corporate political strategies?		
1. Strength of Ties to Distant Sites	The site has a non-sub-region weighted degree below the IQR	-1
	The site has a non-sub-region weighted degree within the IQR below the median	-0.5
	The site has a non-sub-region weighted degree within the IQR above the median	0.5
	The site has a non-sub-region weighted degree above the IQR	1
2. Strength of Incoming Ties	The site has a weighted in-degree below the IQR	-1
	The site has a weighted in-degree within the IQR below the median	-0.5
	The site has a weighted in-degree within the IQR above the median	0.5
	The site has a weighted in-degree above the IQR	1
3. Betweenness Centrality	The site has a betweenness below the IQR	-1
	The site has a betweenness within the IQR below the median	-0.5
	The site has a betweenness within the IQR above the median	0.5
	The site has a betweenness above the IQR	1
4. Brokerage Potential	The site is not broker, or has a brokerage score below the IQR	-1
	The site has a brokerage score within the IQR below the median	-0.5
	The site has a brokerage score within the IQR above the median	0.5
	The site has a brokerage score above the IQR	1

Architectural Dataset

The architectural dataset was assembled to address five primary questions within the comparative analysis. These questions focus on the diversity of domestic structures, the presence of corporate or exclusionary monumental architecture, and the existence of public and private spaces. Together, they provide a framework for evaluating whether a site reflects more corporate or exclusionary political strategies. The theoretical rationale and material correlates for these data types are outlined in detail in Chapter 2. Because excavations and research strategies vary across sites, not all sites contain evidence relevant to every question. This section is organized in a way that sites with more data are listed toward the beginning of the discussion.

Early Preclassic (1200-900 BC)

The sites of Actuncan, Blackman Eddy, Cahal Pech, and Xunantunich provide the clearest evidence for EPC domestic occupation in the UBRV, each containing discrete, radiocarbon-dated contexts. Other sites, including Baking Pot, Chan, and Pacbitun, have yielded EPC ceramics only in mixed deposits with later Middle Preclassic materials. Excavations at Arenal may also indicate EPC occupation, though these results are preliminary (but see Brown et al. 2025). As research continues, additional sites may produce stratified EPC deposits that will further clarify early settlement patterns in the region.

The most extensive EPC domestic architecture comes from Cahal Pech. The earliest permanent occupation appears in the basal level of Structure B4 (B4-1st), built directly on leveled bedrock and dated to 1205–990 cal BC (Awe 1992; Cheetham 1995; Ebert et al. 2017; Peniche May 2016). Bayesian modeling identified three rapid construction phases, each associated with pure EPC ceramics that confirm their early date (Ebert et al. 2017). The final phase (B4-4th) consisted of a raised platform with a wattle-and-daub superstructure and red-banded walls (Peniche May 2016), likely reflecting a higher-status household relative to surrounding residences.

Additional EPC houses have been documented nearby in Plaza B, where tamped-earth floors with postholes suggest multiple wattle-and-daub buildings of various sizes (Cheetham 1996; Ebert et al. 2017; Horn 2015; Peniche May 2016). Together, these structures indicate long-term domestic investment during the EPC. Although large-scale monumental architecture is absent, the construction of a single, centrally located, raised domestic platform provides early evidence of emerging diversity at the site. For this period, distinctions between public and restricted spaces remain difficult to identify.

At Blackman Eddy, archaeologists documented six round domestic structures (B1-13th through B1-8th) defined by postholes cut into bedrock. These overlapped across construction phases, with B1-9th and B1-8th, associated with elevated stone platforms, likely postdating the earlier four (Hartman 2003). Nearby, a two-chambered chultun contained EPC ceramics and faunal remains, evidence of domestic refuse and long-term residential use (Brown and Garber 2003; Garber et al. 2004b). During the EPC, domestic architecture at Blackman Eddy shows little diversity, and public versus restricted spaces are difficult to distinguish.

Although no intact EPC houses have been recovered at Actuncan, several features point to early occupation. Excavations beneath Structure 41 revealed a burned marl floor, an EPC-period colander, and a ceramic jar used as a brazier, with associated charcoal producing EPC radiocarbon dates (LeCount 2015; LeCount et al. 2017, 2019). Adjacent work exposed three courses of uncut stones bonded with marl mortar, likely the foundation of an early platform (LeCount et al. 2019). In Plaza F, beneath Structure 26-sub-2, a mound built on carved bedrock later incorporated into the site's E-Group, archaeologists uncovered a ceramic cache with burned organic material dating to 1125–1015 cal BC (LeCount et al. 2017; Simova and Mixter 2016; Simova 2023). This mound represents the earliest public-oriented monumental construction in the region. A plaza floor speckled with daub, radiocarbon dated to 1115–930 cal BC, likely associated with this mound, also suggests domestic activity. Simova (2023) argues that these spaces functioned as public areas due to the presence of public-oriented ritual artifacts, discussed further below.

At Xunantunich, no EPC houses have been documented, but multiple lines of evidence indicate early occupation. In Group E ("Early Xunantunich") and the central precinct, archaeologists uncovered leveled bedrock surfaces associated with EPC ceramics (Brown et al. 2011, 2017; LeCount and Yaeger 2010). Excavations beneath El Castillo revealed a dark paleosol containing EPC sherds beneath an Early Classic platform. This context suggests either late abandonment of an EPC occupation on the summit or redeposition of EPC ceramics as construction fill (LeCount and Yaeger 2010; Leventhal 2010). Although no preserved EPC structures have been confirmed, evidence for landscape modification and ceramic deposition supports an early presence at the site.

Broadly, EPC settlements exhibit small-scale domestic architecture, often constructed directly on leveled bedrock, with wattle-and-daub superstructures and tamped-earth floors. Cahal Pech stands out for its centrally located raised platform with red-banded walls suggesting higher-status households, and multiple adjacent dwellings of varying sizes. Blackman Eddy shows overlapping round structures with limited diversity, while Actuncan and Xunantunich provide subtler evidence of early occupation, including burned floors, ceramic caches, and leveled bedrock, sometimes associated with early public or ritual spaces. Notably, although monumental architecture is generally absent, Actuncan hints at early public-oriented construction with a mound later incorporated into an E-Group, suggesting that distinctions between domestic and communal spaces were emerging.

Early Middle Preclassic (900-600 BC)

Substantially more evidence for domestic architecture and the first signs of monumentality appear during the EMPC. Domestic settlement is documented at Actuncan, Blackman Eddy, Buenavista del Cayo, Cahal Pech, Chan, Lower Dover, Pacbitun, and Xunantunich. Monumental construction emerges at Blackman Eddy, Cahal Pech, and Xunantunich.

At Cahal Pech, builders repeatedly renovated earlier structures. Between 950–820 cal BC, they transformed Structure B4 into a 1.5 m-high round platform interpreted as the site's first communal building (Ebert et al. 2017; Healy and Awe 1995; Healy et al. 2004). From 750–600 BC, construction expanded with an E-Group assemblage in the core and several round and keyhole-shaped platforms (Awe et al. 2017; Ebert et al. 2021; Horn 2015; Peniche May 2016). Although the round structures' function is debated, their form and placement suggest communal or ritual use. Garber and colleagues (2005, 2006, 2007) also documented Platform B, a 17.5 m-square foundation for two residences, likely restricted space for emerging elites. Despite several public projects, domestic construction persisted in the core, and the scale of platforms points to growing inequality.

At Blackman Eddy, new EMPC construction included rectangular stone-faced platforms B1-7th and B1-6th, built over earlier houses (Brown and Garber 2003). Later, builders added a round platform atop B1-6th, giving the structure a more public character (Brown and Garber 2003). By the end of the EMPC, they erected B1-5th, a triadic group of three formally arranged structures (Garber et al. 2004b). As at Cahal Pech, these data point to the presence of both open and restricted spaced.

At Actuncan, EMPC evidence is limited. No architecture from this phase has been identified, and the site shows a hiatus in construction until the Late Preclassic (McGovern 2004; LeCount et al. 2019; Simova 2023). However, scattered Middle Preclassic ceramics, likely EMPC rather than LMPC given the nature of hiatus, suggest continued communal use of Plaza F (Simova 2023).

At Xunantunich, Group E provides the first monumental construction evidence. Ceramics and radiocarbon modeling suggest the three-tiered western structure of the E-Group, Structure E-2-2nd, dates to 800–700 BC, representing the earliest construction of its scale in the UBRV (Brown et al. 2017). Many filled postholes were found within the plaza directly in front of the Structure E-2-2nd stairs, leading investigators to infer the presence of perishable altars for communal ritual (Brown 2017; Brown et al. 2017). Concerning domestic spaces, an extensive settlement survey of the Xunantunich core and periphery located 38 Preclassic domestic settlement mounds of varying size classes, many of these contained Middle Preclassic ceramics, and it is likely that some of these were occupied during the EMPC (Neff et al. 1995).

At Pacbitun, excavations in Plaza B yielded large, apsidal domestic platforms B-1 and B-4, each 8 × 4 m with limestone walls, marl floors, and northeast–southwest orientation (Crow and Powis 2023). Excavations revealed postholes for perishable superstructures, including one with a cache of 50 intact marine shell beads, the site's earliest offering (Crow and Powis 2023:143). A radiocarbon date from Structure B-1 (825–540 cal BC) suggests EMPC occupation. Additional dates from Structure B-3 (755–405; 760–416 BC) indicate prolonged use (Crow and Powis 2023:149). The narrow alleyways associated with several of the Plaza B structures indicate some restriction of space. During

Summer 2024, excavators encountered a tower-like feature beneath a LMPC structure, meaning this feature is likely to date to the EMPC (Terry Powis, personal communication). It is unlike anything else in the region, and at this time a function cannot be determined. Further investigations will likely shed more light on this strange phenomenon.

At Chan, EMPC activity centers in what would become the site core. The earliest feature is a centrally-placed cist burial carved into bedrock and dated 780–410 cal BC (Kosakowsky 2012). This is clear evidence for early ancestor veneration at the site. I believe this burial likely falls toward the earlier end of the radiocarbon range given its association with ash-tempered ceramics which largely fall out of fill contexts by the LMPC. In the lands surrounding the site core, there is limited evidence for variability in domestic house mounds based on size (Robin et al. 2012b). No monumental architecture has been documented for this period.

At Lower Dover, EMPC remains complicate questions of settlement boundaries. Later, the site core likely administered Barton Ramie and Floral Park, long treated as separate sites (Willey et al. 1965; Glassman et al. 1995). Walden's (2021) survey indicates they formed districts of a unified polity during the Classic Period. Whether this integration began in the Middle Preclassic is unclear, but EMPC domestic architecture occurs across all three areas. Near the Lower Dover core, Walden identified a household whose size and assemblage suggest intermediate elite status. In Floral Park, a platform in Plaza A dates to the EMPC, but its function remains uncertain (Glassman et al. 1995; Walden 2021:417). Barton Ramie offers the clearest evidence: Willey's team excavated 65 house mounds, 18 with Middle Preclassic ceramics, though these were not separated by phase (Willey et al.

1965). Many contexts contain Gifford's "Early Facet Jenney Creek," which is likely EMPC (Gifford 1976).

In sum, at Cahal Pech, repeated renovations of Structure B4 created one of the earliest communal buildings in the region, later supplemented by an E-Group and round platforms suggesting ritual or communal use alongside restricted elite residences. Blackman Eddy likewise shows a mix of domestic and increasingly public structures, culminating in a large platform mound. At Xunantunich, the EMPC sees its earliest monumental construction with a three-tiered E-Group structure and associated perishable altars, while survey evidence indicates extensive domestic settlement. Pacbitun provides unusually detailed domestic evidence, including large apsidal platforms with offerings and narrow alleyways implying restricted spaces, along with a peculiar tower-like feature of unknown function. Chan shows early ancestor veneration through a central cist burial, though monumental construction is absent, and Lower Dover demonstrates dispersed domestic architecture across multiple areas. Overall, the EMPC is marked by a trend toward greater architectural complexity, differentiation between domestic and communal spaces, and the emergence of formal monumental projects.

Late Middle Preclassic (600-300 BC)

Continued population expansion, new site settlement, and monumental construction are evident during the LMPC at Arenal, Baking Pot, Blackman Eddy, Buenavista del Cayo, Cahal Pech, Chan, Lower Dover, Pacbitun, and Xunantunich. At Actuncan, however, there is currently little evidence for LMPC activity aside from potential continued use of Plaza F (Simova 2023).

At Cahal Pech, architectural activity reached a new scale, accompanied by greater social differentiation. Structure B4, still a domestic structure, was enlarged and elevated to two meters in height (Awe 1992; Peniche May 2016), while Structure B8, the western building of the E-Group, was expanded into a radial pyramid (Ebert et al. 2021). Builders also completed the northern and southern temples of the E-Group, establishing the eastern boundary of Plaza B, simultaneously restricting entrance to the site core yet providing a large plaza for communal events (Awe et al. 2017; Peniche May 2016). Platform B remained occupied by elites in the early LMPC, but by the end of the period the plaza was elevated, sealing earlier domestic architecture beneath (Horn 2015). This transformation reflects a near-total replacement of residential space with monumental construction in the site core. Peniche May (2016) further documented major building projects at surrounding groups such as Cas Pek, Tolok, Tzinic, Zopilote, Zotz, and Zubin, pointing to both population growth and large-scale mobilization of labor.

At Blackman Eddy, Structure B1-4th was remodeled into a large rectangular platform with an inset stair and a widened basal platform that enclosed the earlier triadic form. A prominent mask flanking the stairway presaged later Late Preclassic traditions of public iconography across the Maya world (Brown and Garber 1999; Garber et al. 2004a). Brown and Garber (2003:49) suggest this monumental imagery was used to legitimize emerging elites. The later dismantling and burning of the mask's upper portions may reflect either conflict (Brown and Garber 2003; Garber et al. 2004) or ritual termination (Mock 1998). Structure B1 continued to evolve throughout the LMPC, with rapid sub-constructions (B1-3rd-e, -f, and -g). These additions produced the first three-tiered pyramid at the site (Brown and Garber 2000). Evidence for a public plaza is present, but no domestic architecture is evident in the site core.

At Xunantunich, radiocarbon dates place the construction of Structure F1, a communal platform northeast of the E-Group, between 804–431 cal BC, though modeled to the LMPC (Rawski 2020). Mixed Middle and Late Preclassic materials were also found beneath Plazas A-I, A-II, and A-III, Structure A-12, and Ballcourt 2 (Jamison and Wolff 1994; Keller 1994; Ramirez 2023; Ramirez et al. 2023; Yaeger 1997). A newly identified LMPC platform, Structure A7-Sub-3, lies just northwest of El Castillo. Excavations in 2023 and 2024 confirmed the associated ceramics date to the Middle Preclassic, although radiocarbon samples remain under analysis (Watkins et al. 2024; Kumorek et al. 2025).

At Pacbitun, architectural traditions shifted markedly. Earlier apsidal platforms in Plaza B were replaced with larger rectangular and square platforms oriented 20° west of north, preserving the site's original narrow alleyway system. Substructure B-2, measuring 9 × 6 meters, is the largest known Middle Preclassic domestic building in the UBRV (Crow and Powis 2023:153). A major LMPC construction was El Quemado, a 31.5 × 20.4 meter T-shaped ceremonial platform in Plaza A, coated in lime plaster and decorated with stucco masks (Powis et al. 2019a, 2019b). Around 400–300 BC, the structure was ritually terminated through burning and dismantling, with two Savana Orange vessels deposited on the summit before the platform was sealed (Davis and Powis 2015; Powis et al. 2019a).

At Arenal, excavations revealed a substantial LMPC village (Taschek and Ball 1999). More recent work may push its origins into the EPC, though this remains tentative (Brown et al. 2025). Ongoing investigations have uncovered 50 postholes carved into bedrock, multiple burials, caches of greenstone, and a 176 m² area containing more than

350,000 freshwater shells, hundreds of marine shell beads, over 218,000 lithic flakes, and Middle Preclassic ceramics (Brown et al. 2025; Brown and Horowitz 2023; Horowitz et al. 2023). A radiocarbon date from Plaza A (748–409 cal BC) has a high probability of falling within the LMPC (Brown and Horowitz 2023). These features, aligned with the E-Group, likely date the earliest monumental phase to this period.

At Lower Dover, beneath the Classic-period northern structure at the Tutu Uitz Na group, Walden (2021) documented a LMPC rectangular platform dated to 540–400 cal BC. Below it was an extraordinary deposit estimated to contain approximately 20 million freshwater jute shells placed directly on bedrock (Biggie et al. 2024; Walden 2021). Walden interprets this as the work of a high-status household given the labor demands. At nearby Mamna, a smaller LMPC platform was constructed atop a jute deposit of 1,234 shells dated to 465–385 cal BC, which Walden suggests reflects emulation by lesser elites. Public plazas and plazuelas are present across Lower Dover, Barton Ramie, and Floral Park.

At Baking Pot, recent excavations recovered ash-tempered ceramics in mixed Middle Preclassic contexts (Davis et al. 2023). Radiocarbon dates from Courtyard 1 (775–545 cal BC) indicate EMPC occupation (Hoggarth et al. 2024a), yet no architectural information and too few artifactual materials were recovered to understand much about this early period. However, Plaza B excavations have yielded moderate quantities of LMPC ceramics in the lowest layers (Davis et al. 2023; Hoggarth et al. 2024a, 2024b, 2025). Although no LMPC architecture has been documented, the density of the ceramic assemblage points to the presence of at least a small village.

At Buenavista del Cayo, the earliest occupation dates to 800–650 BC (Ball and Taschek 2004), but evidence is limited to artifact scatters rather than architecture. The

LMPC occupation follows the earlier pattern of dispersed settlement, with architecture emerging only in the Late Preclassic (Ball and Taschek 2004; Helmke et al. 2018). Scattered LMPC materials recovered by ongoing research nonetheless suggests population growth (Cap 2015; Yaeger et al. 2011).

At Chan, settlement expanded from the central group rather than nucleating more tightly (Robin et al. 2012b:30). LMPC ceramics were identified in nearly one-fifth of house mounds, with an estimated population between 249 and 418 people (Robin 2012b:28–29). Monumental construction did not appear at Chan until the Late Preclassic. Due to access issues with ceramic materials dating to the LMPC, Chan does not appear in the LMPC analysis.

Overall during the LMPC, at Cahal Pech, domestic architecture expanded alongside large-scale E-Group constructions, including radial pyramids and temple platforms, transforming much of the site core from residential to monumental space and reflecting pronounced social differentiation. Blackman Eddy similarly saw the enlargement of platforms into multi-tiered pyramids with public iconography, while Xunantunich features LMPC communal platforms. Pacbitun shows a marked architectural shift, replacing earlier apsidal platforms with larger rectangular and square buildings, including the T-shaped ceremonial platform El Quemado, which was later ritually terminated. Arenal provides evidence of a substantial LMPC village with postholes, burials, and shell and lithic deposits. Lower Dover exhibits elite labor investment in massive shell deposits beneath LMPC platforms and public plazas across surrounding districts. Sites like Baking Pot, Buenavista del Cayo, and Chan show dispersed LMPC occupation with limited architectural expression, suggesting population growth without corresponding monumental construction. Overall, LMPC trends emphasize the intensification of large-scale labor mobilization, and the near-total transformation of central cores into ceremonial and elite spaces, though some sites lagged in monumental development or retained primarily domestic functions.

Artifact Dataset

The artifact dataset was assembled to address the series of questions presented above. The theoretical background and correlates of leadership orientations are outlined in detail in Chapter 2. In brief, the artifact analysis considers the presence of corporate-related symbolism, often tied to themes of fertility, cosmology, and public ritual, alongside exclusionary-related symbolism, which tends to emphasize ancestor veneration and more private ritual contexts. The dataset also includes evidence for diversity in the distribution of portable wealth, typically exotic items such as jade, obsidian, and marine shell, as indicators of access and control over valuable materials.

In addition, data from previous chapters of this study are used to evaluate the number of non-subregional sites from which each community received pottery, providing a measure of connectivity to external places. Here, "non-subregion" refers to interaction with sites in a different river valley, or with Pacbitun, which is off the river system. Finally, the analysis considers access to obsidian sources, as greater access reflects participation in broader exchange networks often associated with exclusionary leadership strategies. As with the architectural dataset, uneven research coverage means that not every site has evidence to address all questions. Like the previous section, this section is organized in a way that sites with more data are listed toward the beginning of the discussion.

Early Preclassic (1200-900 BC)

The earliest occupations at Cahal Pech were associated with Cunil-phase ceramics, which were found in pure deposits within successive construction phases of Structure B4 (Sullivan and Awe 2023). NAA indicates that much of this pottery was produced and consumed locally (Ebert et al. 2019). This is supported by the NAA results of the present study, which show that Cahal Pech does not appear to have received pottery from other sites during this period. At the same time, imported exotic goods such as greenstone, marine shell, and obsidian were present by the Early Preclassic, suggesting that long-distance exchange networks had already been established. A pXRF analysis of obsidian confirms that all specimens from Cahal Pech come from the El Chayal source (Ebert 2017:140). There is also evidence for the uneven distribution of these imported materials across households, potentially indicating early social differentiation (Horn 2015; Sullivan et al. 2018).

At Blackman Eddy, investigators report a dense deposit (Cache 1:2002) that was placed after the dismantling of Structure B1-13th, as artifacts were found both inside and outside the postholes. The cache contained a variety of materials, including “partial and whole bowls, jars, spouted vessels, plates, a ceramic roller seal, incised ceramics, obsidian blades, a jade bead, several pieces of raw and polished greenstone, worked and unworked marine shell, large carbon fragments, chert flakes and cores, and chunks of hematite” (Hartman 2003:9). This assemblage provides strong evidence for established long-distance trade networks, as items such as obsidian, jade, and marine shell were imported from distant regions. Notably, all the obsidian from Blackman Eddy has been sourced to San Martin Jilotepeque with pXRF (Kersey 2006), suggesting that Cahal Pech and Blackman

Eddy were accessing different external exchange networks. This is particularly interesting because the NAA results of this study show that Blackman Eddy had access to pottery not only from Xunantunich but also from Cahal Pech, raising questions about overlapping economic and political webs. Furthermore, the cosmological motifs on ceramics share stylistic similarities with other regions of Mesoamerica, suggesting that the inhabitants of Blackman Eddy, like other sites in the region, participated in a broad pan-Mesoamerican symbolic system (Garber and Awe 2008, 2009; Garber et al. 2004a).

At Actuncan, researchers have identified several dedicatory deposits dating to the EPC. These deposits do not contain exotic goods, only pottery, but Simova (2023:135). argues that "the value of the contents of the cache are less important than the symbolic act of birthing or ensouling new constructions. And yet, the use of a utilitarian jar to mark the ritual burning location, at a time when ceramic technologies were first appearing in Maya Lowlands, speaks to the needs and interest of the population constructing this public space at Actuncan." These features emphasize the cosmological significance of dedicatory caches. Few other Early Preclassic contexts have been documented at the site, but Plaza F appears to have been the hub where any portable wealth was concentrated. Actuncan did receive some pottery from Cahal Pech, although there is no evidence of reciprocal exchange. At present, there is no obsidian sourcing data for the site.

At Xunantunich, relatively few contexts date to this period, and little evidence exists for cosmological or ancestor-focused artifact deposits. Where such contexts do appear, there is limited variation in the materials, with potentially more wealth items found in Early Xunantunich than in the site core (Brown et al. 2017; LeCount and Yaeger 2010). Numerous excavations carried out by the Belize Valley Archaeological Reconnaissance

Project in the site core (Ramirez 2023; Watkins et al. 2024) have revealed very few wealth items in association with Early or Middle Preclassic contexts overall, further suggesting that wealth was concentrated in the Early Xunantunich area. Based on proximity and overlapping material sources, it is likely that Xunantunich and Actuncan were exchanging pottery, although Xunantunich does not appear to have received pottery from other regional sources. However, the NAA results of this study show that Xunantunich did have access to pottery likely originating from Holtun in Guatemala. No obsidian sourcing data is currently available for the site.

In sum, at Cahal Pech, Cunil-phase ceramics were largely produced and consumed locally, with NAA confirming little incoming pottery from other sites, yet exotic imports—including greenstone, marine shell, and obsidian from the El Chayal source—demonstrate participation in early interregional networks. The uneven distribution of these goods across households suggests some diversity in access. Blackman Eddy shows complementary patterns; its dense Cache 1 deposit contained a wide range of imported materials—obsidian from San Martin Jilotepeque, jade, marine shell—alongside local pottery, indicating overlapping yet distinct exchange networks compared with Cahal Pech. The presence of cosmologically-inspired ceramic motifs further points to engagement with broader Mesoamerican symbolic systems. At Actuncan, dedicatory caches emphasize ritual and cosmological significance rather than exotic wealth; pottery from Cahal Pech appears, but no reciprocal exchange or obsidian sourcing is documented. Xunantunich shows minimal Early Preclassic wealth items in the site core, with slightly more in Early Xunantunich contexts, and evidence for pottery exchange with Holtun but limited interregional imports overall. Collectively, these patterns reveal a landscape where most ceramic production was local, exotic goods were selectively imported, and ritual deposits often expressed the cosmological value of artifacts, with variation across sites reflecting differences in participation in exchange networks and the concentration of wealth.

Early Middle Preclassic (900-600 BC)

At Cahal Pech during the EMPC, artifact assemblages reveal increasing diversity and clearer evidence of ritual practices. At the corners of the large domestic Platform B, ritual deposits contained figurines, obsidian, greenstone, river stones, and slate bars, arranged in patterned deposits suggestive of both ancestor veneration and cosmological resurrection (Garber and Awe 2008). Figurines were often intentionally broken and placed in construction fills, reinforcing their association with linking ancestors to new building phases (Delance and Awe 2022). Sherman Horn's (2015) analysis of ceramic fabrics suggests households either procured pottery from multiple producers or manufactured their own. Results from the present NAA study (Chapter 4) indicate that some ceramics came from beyond the immediate subregion, including Actuncan, Blackman Eddy, and Xunantunich. Access to prestige goods such as greenstone and obsidian varied by household. In terms of obsidian access, Cahal Pech continued to receive obsidian from El Chayal while also acquiring material from San Martin Jilotepeque and Ixtepeque (Ebert 2017).

At Blackman Eddy, deposits associated with EMPC construction included more than 10,000 freshwater shells and lithics, which Garber and colleagues (2004a) interpret as the remains of a large feast tied to the construction of Structure B1-7th. These types of deposits have been interpreted as cosmologically significant, symbolizing the recreation of the primordial sea and the first mountain from which people emerged (Biggie et al. 2024; Brown et al. 1998). While no domestic contexts from this period have been identified, limiting insights into household-level wealth differences, the site maintained wide ceramic connections, receiving pottery from the non-local sites of Cahal Pech, Xunantunich, Actuncan, and Chan. Blackman Eddy also retained access to San Martin Jilotepeque obsidian, with one additional unknown source represented in the assemblage (Kersey 2006).

At Actuncan, evidence suggests a population decline during the EMPC (Simova 2023; LeCount et al. 2019). Few materials remain to indicate ongoing occupation, and even less to suggest wealth differentiation. The main data for this period comes from the current study, which shows Actuncan's continued access to non-subregional pottery from Blackman Eddy, Cahal Pech, and Chan. The site appears to diminish significantly during this phase, with only limited evidence of continuity into the LMPC, before later reemerging with renewed habitation and the construction of a monumental temple pyramid in the Late Preclassic.

At Xunantunich, EMPC artifactual evidence is sparse, offering little indication of cosmological or ancestor-oriented symbolism. The distribution of wealth items resembles patterns seen in the EPC, with concentrations in Early Xunantunich rather than the site core or peripheral households (Brown et al. 2017; Neff et al. 1995). The site maintained exchange ties with Blackman Eddy, but no obsidian data are available for this period.

At Pacbitun, artifact evidence highlights intensive shell bead production. Excavations in Plaza B revealed caches and deposits associated with apsidal platforms, including a notable offering of 50 intact marine shell beads in a posthole of Substructure

B-1, representing the earliest dedicatory offering yet identified at the site (Crow & Powis 2023:143). Additional deposits contained ceramics, lithics, and large quantities of freshwater and marine shell remains and debitage, underscoring the importance of shell ornament manufacture as a household-level activity (Crow & Powis 2023:143; Hohmann et al. 2018). Concentrations of marine shell beads, chert microdrills, and associated ceramics recovered from floors and alleyways further demonstrate the central role of craft production at Pacbitun (Crow & Powis 2023:146). Unlike some sites in the region, there is little evidence for cosmologically oriented or ancestor-related uses of these materials. Pacbitun was, however, well connected, receiving pottery from Actuncan, Blackman Eddy, Cahal Pech, Chan, and Xunantunich. No obsidian data are currently available for this period.

At Chan, the earliest contexts include a centrally placed burial interred with jade, shell ornaments, quartz, and ceramics, offering some of the clearest evidence for ancestor veneration in the UBRV during the Middle Preclassic (Robin et al. 2012a). While many surrounding households likely date to this period, scarce excavation data limit broader comparisons of wealth distribution across the settlement. Chan’s non-subregional pottery came from Actuncan, Xunantunich, and Blackman Eddy. Obsidian procurement, however, appears limited to San Martin Jilotepeque (Meirhoff et al. 2012).

At Lower Dover, EMPC artifact evidence is limited, with no clear cosmological or ancestor-oriented symbolism and insufficient data to assess wealth differentiation. Despite this, the site maintained broad connections, receiving pottery from Actuncan, Cahal Pech, Chan, and Xunantunich. No obsidian evidence is currently available from this period.

In sum, during the EMPC, artifact evidence across the UBRV reveals increasing diversity in material culture, more evidence ritual practices, and expanding interregional exchange networks. At Cahal Pech, ritual deposits on Platform B contained figurines, obsidian, greenstone, and river stones, often intentionally broken and embedded in construction fills, reflecting both ancestor veneration and cosmological symbolism. Ceramics were sourced locally and from villages including Actuncan, Blackman Eddy, and Xunantunich, while obsidian came from multiple sources (i.e., El Chayal, San Martin Jilotepeque, and Ixtepeque), with access to prestige goods varying by household. Blackman Eddy's EMPC deposits, including large shell and lithic concentrations, suggest feasting tied to construction and cosmological symbolism, with ceramics imported from Cahal Pech, Xunantunich, Actuncan, and Chan, and obsidian primarily from San Martin Jilotepeque. Actuncan shows population decline, with fewer artifacts, though access to non-local pottery persisted. Xunantunich maintained exchange with Blackman Eddy but shows limited wealth items and minimal evidence for cosmological or ancestor-focused deposits, concentrating any valuables in Early Xunantunich. Pacbitun stands out for intensive shell bead production and craft-related deposits, including dedicatory offerings, but little ritual symbolism; the site received ceramics from multiple regional centers. Chan provides early evidence for ancestor veneration via a central burial with jade, shell, quartz, and ceramics. Lower Dover maintains broad ceramic exchange with neighboring sites. Collectively, these patterns indicate the EMPC was a period of broad regional exchange, though wealth and symbolic items were unevenly distributed across households and sites.

Late Middle Preclassic (600-300 BC)

At Cahal Pech, artifact distributions in the LMPC highlight increasing social stratification and expanding exchange networks. Imported pottery from the Petén and Northern Belize became more common, particularly in association with keyhole-shaped platforms, some of which were decorated with incised motifs depicting cosmological, anthropomorphic, and zoomorphic imagery (Peniche May 2016). Although figurines declined during this period, they remained more numerous than at other sites in the region (Delance and Awe 2022; Zweig 2010). Scholars argue that this decline reflects the consolidation of elite power, which reduced the need to reinforce ancestral connections through figurines (Delance and Awe 2022). Exchange networks diversified as well: chert from Northern Belize reappeared, jade became concentrated in monumental and peripheral structures, and slate disks, likely used as mirror backings, were restricted to domestic contexts in the site core, suggesting the emergence of an elite class (Peniche May 2016:310). Regional connections were also strong, as pottery in the site core came from Arenal, Baking Pot, Blackman Eddy, Buenavista, Lower Dover, Pacbitun, and Xunantunich. Obsidian from El Chayal, San Martin Jilotepeque, and Ixtepeque continued to circulate at the site, alongside a single piece from the more distant Ucareo source (Ebert 2017).

At Blackman Eddy, political symbolism is most clearly expressed in the mask on Structure B1-4th, which Brown and Garber (2003) argue reflects emerging elitism and the use of public architecture to legitimize elevated status. Since no domestic structures from this period have been excavated, the distribution of portable wealth remains unclear. The obsidian assemblage was still dominated by San Martin Jilotepeque material, but El Chayal and Ixtepeque obsidians were also present (Kersey 2006:49). Blackman Eddy maintained connections with other non-Belize River sites in the UBRV, including Arenal, Buenavista, Cahal Pech, Pacbitun, and Xunantunich.

At Pacbitun, shell ornament production expanded dramatically. Plaza B yielded 8,783 shell artifacts, including 5,670 modified specimens and more than 3,000 pieces of production debris (Crow and Powis 2023:153; Hohmann et al. 2018; Powis et al. 2017). Formal tool assemblages of burin spalls and microdrills indicate a highly developed and specialized industry. A thick midden covering Plaza B's residential structures contained ceramics, lithics, faunal remains, shell ornaments, and thousands of freshwater *jute* shells (*Pachychilus indiorum*). Since shell ornaments are a form of portable wealth, then concentrations in the site core point to some degree of wealth centralization. A mask on El Quemado further reflects ancestor- and elite-centered symbology, paralleling Blackman Eddy (Powis et al. 2019a, 2019b). Unlike most UBRV sites, Pacbitun appears relatively isolated during this period, receiving pottery only from Buenavista. No obsidian data are currently available.

At Lower Dover, the massive shell deposit suggests cosmological themes, but because it was concentrated beneath the platform of a private residence, Walden (2021) interprets it as evidence of an elite household with access to significant labor. Settlement excavations revealed limited evidence for wealth items, which appeared concentrated in a few higher-status house mounds (Walden 2021). Lower Dover maintained moderate connections with Arenal, Buenavista, Pacbitun, and Xunantunich. NAA also identified a sherd with potential origins in the Lower Sibun River region, suggesting possible access to interregional trade. No obsidian data are available for this period, though Nick Suarez's forthcoming dissertation will address this issue.

At Arenal, postholes containing greenstone and shell caches point to cosmological symbology, though there is no evidence for ancestor- or elite-focused symbolism (Brown et al. 2025; Brown and Horowitz 2023; Horowitz et al. 2023). The distribution of portable wealth cannot yet be assessed, but ongoing excavations may clarify this in the future. Arenal was moderately well connected with Baking Pot, Blackman Eddy, Cahal Pech, and Lower Dover. No obsidian source data are currently available.

At Xunantunich, artifact evidence is sparse. Some wealth objects concentrated in Early Xunantunich hint at inequal distribution, but overall artifactual symbolism remains limited (Brown et al. 2017; Neff et al. 1995). Unlike other sites, Xunantunich was less well connected regionally, receiving pottery only from Baking Pot, Blackman Eddy, and Lower Dover.

At Baking Pot, data from this period are limited, but NAA results show moderate regional connections, with pottery arriving from Arenal, Buenavista, Cahal Pech, and Xunantunich. Obsidian sourcing is ongoing and will be presented in Nick Suarez's forthcoming dissertation on obsidian networks.

At Buenavista, evidence is also scarce, consisting mainly of artifact scatters with LMPC pottery. The site maintained moderate regional ties, with pottery linked to Baking Pot, Blackman Eddy, Lower Dover, and Pacbitun. No obsidian sourcing data are available.

At Chan, current chronological resolution makes it difficult to distinguish between EMPC and LMPC deposits, so the earlier EMPC interpretation remains applicable.

However, as previously noted, due to access issues with ceramic materials dating to the LMPC, Chan does not appear in the LMPC analysis.

Overall, at Cahal Pech, imported pottery from the Petén and Northern Belize became more common as well as local pottery decorated with cosmological and zoomorphic motifs, particularly near keyhole-shaped platforms. Obsidian sources diversified to include El Chayal, San Martin Jilotepeque, Ixtepeque, and a distant piece from Ucareo. Prestige goods such as jade and slate disks began to appear in restricted elite domestic contexts, with regional connections bringing pottery from Arenal, Baking Pot, Blackman Eddy, Buenavista, Lower Dover, Pacbitun, and Xunantunich. Blackman Eddy's monumental mask on Structure B1-4th expresses elite political symbolism, while obsidian continued to circulate from multiple sources; ceramic exchange was asymmetrical, with the site sending pottery to Cahal Pech but receiving little in return. Pacbitun exhibits a highly specialized shell ornament industry, with thousands of modified shells, production debris, and faunal remains concentrated in the site core, reflecting both craft centralization and ancestor-related symbolism, though the site appears relatively isolated, receiving pottery only from Buenavista. Lower Dover shows concentrated shell deposits beneath elite residences and moderate ceramic connections with regional centers, while Arenal displays postholes with greenstone and shell caches indicative of cosmological practices but limited evidence for wealth centralization. Xunantunich maintains sparse artifact distributions, with some wealth objects concentrated in Early Xunantunich, and limited regional connections. Overall, LMPC artifact patterns reveal increasingly stratified households, regional and interregional exchange, and selective deployment of ritual and prestige materials to reinforce evolving power structures, with variation in the scale and visibility of these trends across sites.

Network Dataset

The network dataset was developed to address questions within the qualitative analysis and derives directly from the metrics presented in Chapter 5. As outlined in Chapter 2, economic and political orientations are often interdependent; therefore, several of the local network metrics introduced earlier provide insight into political strategies. For the analysis presented here, I used summary statistics of multiple network measures to assign group membership for each question. Sites with values below the interquartile range (IQR) were coded as -1; sites within the IQR but below the median as -0.5; sites within the IQR and at or above the median as 0.5; and sites above the IQR as 1.

Four questions were selected for their direct relevance to political strategies. First, the strength of ties to distant sites, measured as weighted degree centrality to and from non-subregional sites, captures the extent to which communities exchanged with more distant partners. Corporate-oriented sites are expected to circulate goods primarily within their own subregion, while exclusionary leaders sought to access and import goods from afar. Second, the total weighted in-degree centrality of a site reflects the overall strength of incoming ties, or the amount of wealth flowing into the community. These goods could result from long-distance exchange, tribute, taxation, itinerant merchants, markets, or any number of economic processes. The exact process is not important for the present analysis. Corporate-oriented sites typically emphasize local goods, whereas exclusionary leaders rely more heavily on resources from external sources. Third, betweenness centrality measures the extent to which a site could influence the flow of goods through the network. In this case, corporate-oriented sites are expected to focus on local exchange, while exclusionary leaders leveraged access to outside goods to redistribute them to allies. Finally, brokerage potential was calculated to identify economic bottlenecks within the network. This metric, detailed in the previous chapter, is derived from weighted degree centrality restricted to ties where the site is the central node of an intransitive triad. In such cases, the site has the ability to channel goods between two otherwise unconnected communities. Corporate-oriented sites are unlikely to hold such positions, whereas exclusionary leaders are expected to exploit brokerage opportunities to consolidate influence and negotiate alliances. For the original presentation of these network metrics, see Table 5.4 in the preceding chapter.

Comparative Analysis Results and Conclusion

Tables 6.2, 6.3, and 6.4 present the results of the comparative analysis for the Early Preclassic, Early Middle Preclassic, and Late Middle Preclassic periods, respectively. Figures 6.1, 6.2, and 6.3 present the tabulated data in visual form.

Two points become immediately clear from the results of the analysis. First, no single spectrum of architectural, artifactual, or network data can fully explain a site's political strategy. Second, most sites in the region follow a trajectory toward increasingly exclusionary strategies through time. Regarding the first point, it is unsurprising that different lines of evidence sometimes point in different directions. When Blanton and colleagues (1996) introduced the dual-processual model, they emphasized that exclusionary and corporate strategies represent poles on a spectrum, and that societies—

or, as seen here, individual sites—often exhibit traits of both. The present analysis extends this perspective by examining multiple datasets. Previous studies in the Maya world have largely relied on architectural features and symbolic artifacts as proxies for political strategies. Yet a key distinction between exclusionary and corporate leadership lies in the economic strategies leaders employ, which makes network measures essential for a comprehensive assessment. What is most striking about these results is that architectural and artifactual data often place a site on one side of the spectrum, while network data place it on the other. For instance, during the Early Preclassic, architecture suggests that Actuncan and Blackman Eddy leaned toward corporate strategies while Cahal Pech leaned exclusionary. Network evidence, however, indicates the opposite.

Table 6.2. Early Preclassic Quantitative Comparative Analysis Results. N/As refer to a lack of data on those questions at those sites.

Qualitative Assessment Questions	**Actuncan**	**Blackman Eddy**	**Cahal Pech**	**Xunantunich**
Arch1.	N/A	-1	1	N/A
Arch2.	-1	0	0	0
Arch3.	0	0	0	0
Arch4.	-1	0	0	0
Arch5.	0	0	0	0
Total Arch.*	**-1**	**-1**	**1**	**0**
Art1.	-1	-1	-1	0
Art2.	0	0	1	0
Art3.	-0.5	-0.5	0.5	-0.5
Art4.	-1	-0.5	-1	-0.5
Art5.	N/A	-1	-1	N/A
Art Total*	**-0.63**	**-0.75**	**-0.30**	**-0.5**
Net1.	-0.5	1	0.5	-1
Net2.	0.5	1	-1	0.5
Net3.	1	-0.5	-0.5	-0.5
Net4.	1	0.5	-0.5	-0.5
Net Total*	**0.50**	**0.50**	**-0.38**	**-0.38**
Total Score*	**-0.28**	**-0.22**	**-0.20**	**-0.42**

*Total divided by number of answered questions. 0's are treated as N/As. E.g., Actuncan Arch Total is -2/2 = -1. E.g., Actuncan Total Score is -2.5/9 = -0.28

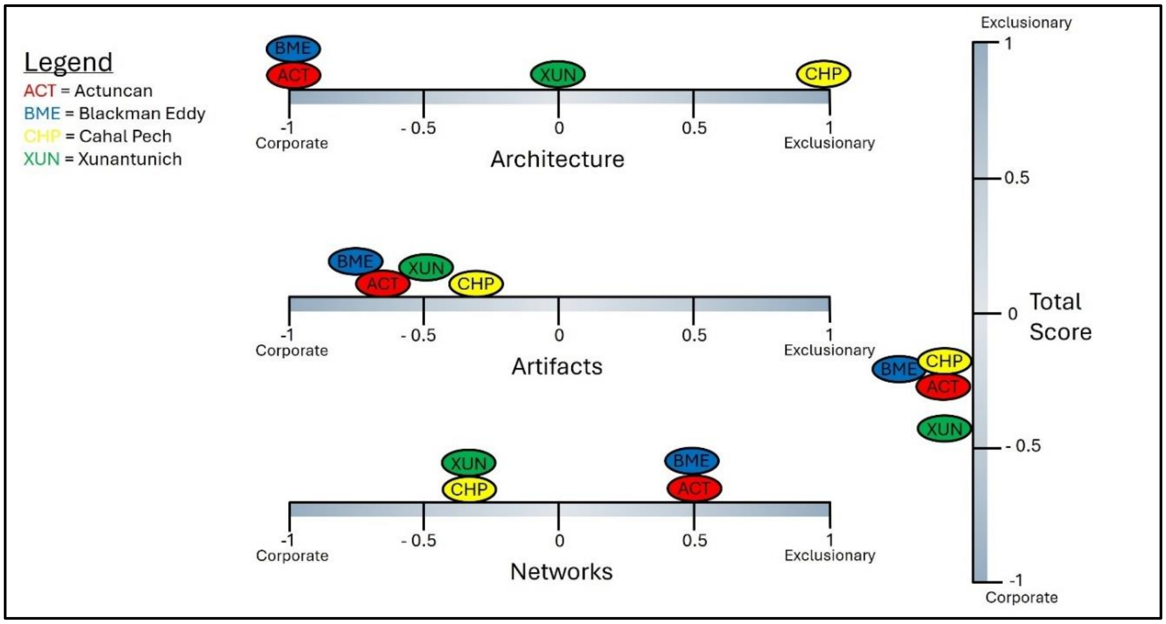

Figure 6.1. Early Preclassic Political Strategy Spectra.

Table 6.3. Early Middle Preclassic Quantitative Comparative Analysis Results. N/As refer to a lack of data on those questions at those sites.

Qualitative Assessment Questions	**Actuncan**	**Blackman Eddy**	**Cahal Pech**	**Chan**	**Lower Dover**	**Pacbitun**	**Xunantunich**
Arch1.	N/A	N/A	1	-0.5	-0.5	0.5	0.5
Arch2.	0	-1	-1	0	0	0	0
Arch3.	0	1	1	0	0	0	1
Arch4.	-1	-1	-1	-1	0	0	-1
Arch5.	0	1	1	0	1	1	0
Total Arch.*	**-1**	**0.20**	**0.20**	**-0.75**	**0.25**	**0.75**	**0.17**
Art1.	0	-1	-1	0	0	0	0
Art2.	0	0	1	1	0	0	0
Art3.	N/A	N/A	0.5	N/A	N/A	N/A	-0.5
Art4.	-0.5	0.5	-0.5	-0.5	0.5	0.5	-1
Art5.	N/A	-0.5	0.5	-1	N/A	N/A	N/A
Art Total*	**-0.5**	**-0.33**	**0.10**	**-0.17**	**0.5**	**0.5**	**-0.75**
Net1.	0.5	1	-0.5	0.5	-0.5	0.5	-1
Net2.	0.5	0.5	-0.5	-0.5	1	0.5	-1
Net3.	1	1	0.5	0.5	-1	-1	-0.5
Net4.	0.5	1	0.5	0.5	-0.5	-0.5	0.5
Net Total*	**0.63**	**0.88**	**0**	**0.25**	**-0.25**	**-0.13**	**-0.50**
Total Score*	**0.17**	**0.23**	**0.11**	**-0.11**	**0**	**0.21**	**-0.33**

*Total divided by number of answered questions. 0's are treated as N/As. E.g., Actuncan Arch Total is -1/1 = -1. E.g., Actuncan Total Score is 1/6 = 0.17

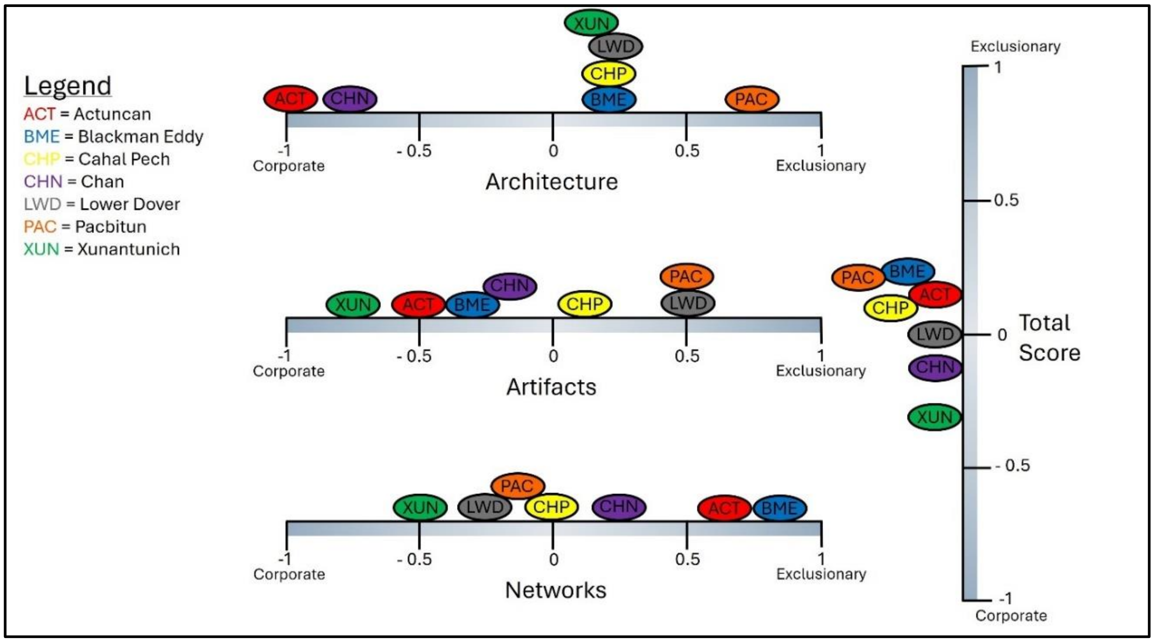

Figure 6.2. Early Middle Preclassic Political Strategy Spectra.

Table 6.4. Late Middle Preclassic Quantitative Comparative Analysis Results. N/As refer to a lack of data on those questions at those sites.

Qualitative Assessment Questions	**Arenal**	**Baking Pot**	**Blackman Eddy**	**Buenavista**	**Cahal Pech**	**Lower Dover**	**Pacbitun**	**Xunantunich**
Arch1.	N/A	N/A	N/A	-1	1	1	0.5	0.5
Arch2.	0	0	0	0	-1	0	-1	-1
Arch3.	0	0	1	0	1	0	1	1
Arch4.	-1	0	-1	0	-1	-1	-1	-1
Arch5.	0	0	0	0	1	0	1	0
Total Arch.*	**-1**	**0**	**0**	**-1**	**0.20**	**0**	**0.10**	**-0.13**
Art1.	-1	0	0	0	-1	-1	0	0
Art2.	0	0	1	0	1	1	1	0
Art3.	N/A	N/A	N/A	N/A	1	0.5	0.5	0.5
Art4.	0.5	0.5	0.5	0.5	1	0.5	-1	-0.5
Art5.	N/A	N/A	0.5	N/A	1	N/A	N/A	N/A
Art Total*	**-0.25**	**0.50**	**0.67**	**0.50**	**0.60**	**0.25**	**0.17**	**0**
Net1.	-0.5	-0.5	1	0.5	1	0.5	-1	0.5
Net2.	-0.5	-0.5	1	0.5	0.5	0.5	-1	0.5
Net3.	0.5	1	-1	1	0.5	0.5	-0.5	-1
Net4.	-0.5	-0.5	1	1	0.5	0.5	-0.5	-0.5
Net Total*	**-0.25**	**-0.13**	**0.50**	**0.75**	**0.63**	**0.50**	**-0.75**	**-0.13**
Total Score*	**-0.36**	**0**	**0.44**	**0.42**	**0.46**	**0.30**	**-0.17**	**-.10**

*Total divided by number of answered questions. 0's are treated as N/As. E.g., Actuncan Arch Total is -1/1 = -1. E.g., Actuncan Total Score is -1.5/7 = -0.36.

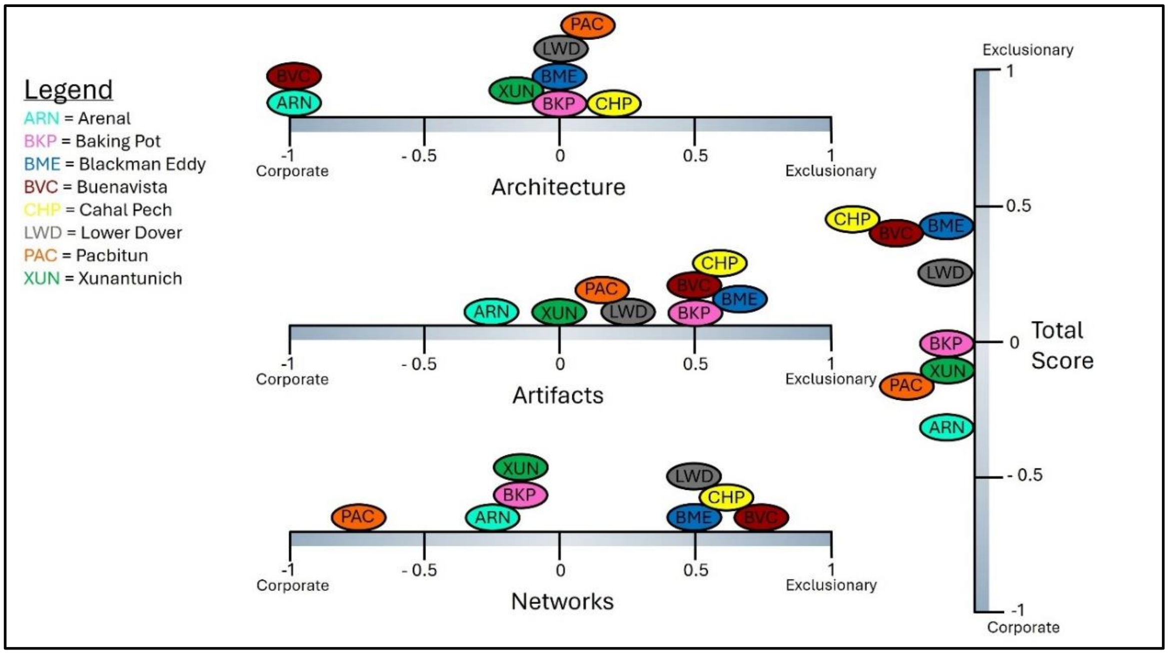

Figure 6.3. Late Middle Preclassic Political Strategy Spectra.

Although there is a general association between network position and political strategies, the relationship is not deterministic. Several cases show divergence between network position and political orientation. For example, some villages with relatively high brokerage potential exhibit mixed or corporate-leaning political traits, while others with more limited network centrality display evidence of exclusionary practices. These divergences indicate that network position alone does not define political strategy, but instead creates a range of opportunities and constraints that communities negotiated in different ways.

Before addressing the overall regional trajectory, several site-specific patterns stand out when considering total scores rather than individual lines of evidence. Xunantunich consistently appears on the corporate side of the spectrum, suggesting a sustained emphasis on collective decision-making over hierarchical authority. Pacbitun, by contrast, leaned exclusionary during the EMPC but shifted toward a more corporate strategy in the LMPC. It is the only site to make such a shift, aside from perhaps Actuncan, which was largely in hiatus by the LMPC. This shift likely reflects Pacbitun's history as a resource-extraction settlement integrated into regional economic networks, which became more self-sufficient and less engaged with broader regional dynamics over time. Meanwhile, Blackman Eddy, Cahal Pech, and Xunantunich, the three sites that span the full trajectory, show gradual but consistent movement toward more exclusionary orientations. Notably, Blackman Eddy and Cahal Pech remain closely aligned throughout, perhaps reflecting competition for influence within the region. These results will be further elaborated in the following chapter where I tie together all the available data to answer the overarching research question.

Despite differences between datasets and analyses, the analysis presented here supports Peniche May's (2016) argument that sites in the UBRV tend to become more exclusionary through time. This pattern may reflect what could be called "keeping up with the Tzib's[2]" (i.e., local competition), but this also demonstrates the driving forces contained within the structural webs that networks of interaction create. Blanton and colleagues (1996) argued that Early and Middle Formative Mesoamerican societies primarily pursued exclusionary strategies, although evidence from the Maya region was limited at that time and therefore excluded from their discussion. They did address the Late Preclassic (300 BC–AD 250), suggesting a more corporate orientation, and it is well established that Classic period Maya kingdoms (AD 250–900) exemplified exclusionary leadership

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[2] "Tzib" is a common surname amongst the modern Maya living in the region.

(Blanton et al. 1996). The dual-processual model anticipated such fluctuations along the spectrum, but growing evidence indicates a steady trend toward exclusionary strategies beginning as early as the Early Middle Preclassic. Future research on the Late Preclassic will help clarify whether this trajectory continued into that period. Now all the data are amassed, and all the analyses are complete. It is time to turn to the overarching research question.

CHAPTER 7

CONCLUSIONS, IMPLICATIONS, AND FUTURE DIRECTIONS

The preceding two chapters detailed the types of social capital created through the relationships between Early and Middle Preclassic (1200–300 BC) villages in the Upper Belize River Valley (UBRV), as well as the political strategies that these villages engaged in. This chapter integrates these lines of evidence to address the central research question set out in the introduction: *how did the interaction between regional socio-economic networks and local political strategies restructure patterns of social, political, and economic differentiation through time in the Upper Belize River Valley?*

The two spectra evaluated in this study, political strategies and socio-economic networks, are related, though not perfectly aligned. Political strategies reflect practices at the village level, while the distribution of social capital that shapes village-to-village interactions operates at the regional level, providing the broader context in which political strategies function and evolve. Conversely, the political strategies that villages adopt influence the structure of the regional network, meaning the two spectra mutually inform one another. By exploring these spectra through diachronic analyses, it is possible to see how they intersect within the Preclassic Maya cultural context. Examining both spectra allows for an analysis of the trajectory of socio-political complexity from two complementary perspectives: top-down, via political strategies, and bottom-up, via regional networks.

To address the research question, I first synthesize the study's results concerning political strategies and networks, then examine how these lines of evidence interact. I follow this synthesis with a discussion of the contributions this study adds to the field of archaeology and other social sciences. Finally, I conclude with suggestions for future research to build on the advances achieved by this study.

Study Results

This section summarizes the results of the previous chapters and recontextualizes them to address the broader research question. First, I present the findings on political strategies through time (Figure 7.1). Next, I will examine the dynamics of social capital through time and across space. Finally, I show how these two spectra intersect leading to consequences at both the local and regional levels.

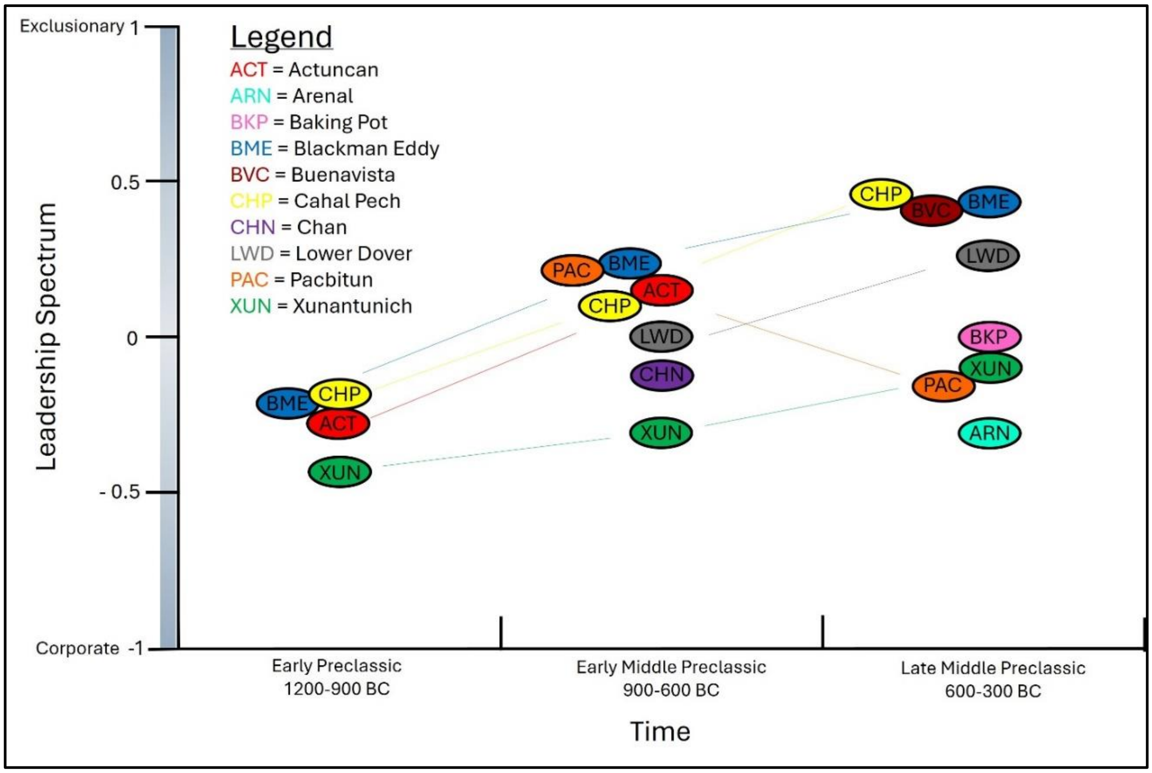

Figure 7.1. Political Strategies Through Time.

This study demonstrates that changes in the configuration of social, political, and economic differentiation in the Upper Belize River Valley were structured through the interaction between regional socio-economic networks and local political strategies. Rather than treating socio-political complexity as a singular outcome, the analysis shows how shifting network positions and leadership strategies co-evolved to produce increasingly differentiated and durable social arrangements over time.

Political Strategies

All societies employ a mix of exclusionary and corporate political strategies that position them along a broader spectrum of leadership (Blanton et al. 1996). Exclusionary strategies emphasize acquiring prestige goods and manipulating socio-economic networks to build and maintain power through alliances and followers. Leaders who favor this approach often act autocratically, concentrating power within a small group or dynasty. In contrast, corporate leadership strategies focus on the management and distribution of local goods to promote community cohesion. These leaders tend to act collectively, placing authority in the hands of many rather than a few. In Chapter 2, I developed a model based on this dual-processual framework (Blanton et al. 1996) and collective action theory (Blanton and Fargher 2008). This model establishes archaeological correlates that allow for the assessment of where individual villages fall along the spectrum of political strategies.

Within the spectrum of corporate to exclusionary leadership strategies, scholars often assume that less complex societies tend to fall closer to the corporate end. In the UBRV, this assumption holds during the Early Preclassic (EPC), the period when Maya communities in the region began to establish permanent settlements. Based on architectural evidence alone, one might conclude that Cahal Pech and Xunantunich were already moving toward exclusionary practices. However, when artifactual evidence and patterns of economic interaction are considered, a broader picture emerges: all the inhabited sites during this period, Actuncan, Blackman Eddy, Cahal Pech, and Xunantunich, leaned toward corporate strategies.

This corporate orientation did not last long. By the Early Middle Preclassic (EMPC), sites across the region began to shift closer to the center of the spectrum, with several showing exclusionary tendencies. Actuncan, Blackman Eddy, and Cahal Pech all moved into exclusionary territory, suggesting that early settlements may have leveraged a form of "right of first occupancy" as a source of power giving them a head start along the prevailing leadership trajectory.

By the Late Middle Preclassic (LMPC), the regional trajectory toward exclusionary leadership became more pronounced. Blackman Eddy and Cahal Pech, already exclusionary-leaning, pushed further in that direction, joined by the emerging center of Buenavista. Nancy Peniche May (2016) previously proposed that sites in the region would increasingly adopt exclusionary strategies, a hypothesis she demonstrated at Cahal Pech; the findings of this study extend and reinforce that conclusion. It is important to note, however, that not all sites followed this trajectory. Xunantunich consistently exhibited corporate strategies across all three periods and all categories of evidence, but it did tend to shift closer to the center of the spectrum through time. Pacbitun also stands out: while it adopted strongly exclusionary practices upon its emergence in the EMPC, it shifted to a predominantly corporate orientation in the LMPC. These two sites suggest that there were multiple pathways towards increasing socio-political complexity.

Regional Social Capital

From a regional perspective (Figures 5.7–5.9), the network analyses indicate that interaction occurred among settled villages even in the earliest period. The EPC network is small, consisting of only four sites and five ties, so its patterns of social capital should be interpreted with caution. Even so, bridging ties appear significant at this stage, particularly in linking the Mopan Valley with the Macal and Belize River areas. The EPC network is best characterized as a bridging network.

By the EMPC, more substantial patterns of social capital emerge. Strong ties associated with bonding capital account for 40 percent of network connections, although with little evidence of regional clustering. This observation is supported by the Exponential Random Graph Model (ERGM), which suggests that geography played little role in tie formation during this period. Instead, weak ties associated with bridging capital make up roughly 60 percent of connections. Thus, the EMPC network is best characterized as a bridging network.

During the LMPC, bridging capital becomes even more dominant, representing about 75 percent of ties. At the same time, clear regional clustering emerges in the Mopan and Belize River subregions, where bonding capital likely reflects kinship-based connections and sustained local interactions. The ERGM results align with this interpretation. Given the subregional clusters of bonding ties, yet the large number of bridging ties, this network is best characterized along the spectrum between a coalitional and a bridging network.

Taken together, the regional trajectory points to the increasing importance of bridging capital over time, alongside the emergence of strong local clusters by the LMPC. As populations grew and new sites were established, nearby communities were more likely to form bonds rooted in kinship and repeated interaction. The ERGMs also highlight an important shift in triadic closure. In the EMPC, village triads often remained open, giving an advantage in controlling economic flows to sites in brokerage positions, those sites linking otherwise unconnected communities. By the LMPC, the denser network shows a preference for closed triads. However, the few sites that maintained brokerage positions during this later period benefited even more, as they controlled flows within an increasingly interconnected and active network.

Intersection of Political Strategies and Social Capital

As noted in the previous sub-sections, local political strategies became increasingly exclusionary while regional social capital shifted toward greater reliance on bridging ties with some coalitions forming during the LMPC. This section examines how these two trajectories intersect. From the local perspective, two elements of political infrastructure are particularly important for understanding regional change: brokerage potential and the presence of monumental E-Group architecture.

Since the regional networks tend toward the bridging side of the social capital spectrum, the ability to manipulate the socio-economic network would have greatly benefited exclusionary, network-oriented leaders. Villages that occupied these intermediary network positions could accrue economic and social advantages by filling structural gaps and controlling goods flow within the network. Peeples and Haas (2013) argue that competition for these positions can generate network instability, and importantly that the value of these positions is negotiated differently within cultural context.

For example, in the US Southwest, for instance, brokerage roles were often short-lived and associated with settlement abandonment shortly thereafter (Peeples and Haas 2013). In modern Chinese businesses, individuals who sought brokerage positions were sometimes perceived as violating norms of cooperation, undermining the value of their role (Xiao and Tsui 2007). By contrast, in modern United States businesses, individuals in brokerage roles often enjoy long-term career advantages (Burt 2004; Seibert et al. 2001). Archaeologically, several examples of persistent, beneficial intermediary positions exist, such as Cahokia (Peregrine 1991) and Etowah (Lulewicz 2019) in the North American Eastern Woodlands, Chalcatzingo (Hirth 1978) and Monte Alban (White and Barber 2012) in Central Mexico, and amongst merchant guilds in the Indian Ocean region (Oka et al. 2020). This study shows that the Middle Preclassic Maya of the UBRV provide another important case in which brokerage produced durable economic and political advantages.

Beginning in the EMPC, the sites with the highest brokerage potential, Actuncan, Blackman Eddy, and Cahal Pech, were also those furthest along the exclusionary end of the political spectrum. This trend intensified during the LMPC, when Blackman Eddy, Buenavista, Cahal Pech, and Lower Dover all increased both their brokerage potential and their exclusionary strategies. From the perspective of the dual-processual model, this pattern is consistent with expected exclusionary leadership actions. Exclusionary leaders actively seek to restrict access to networks, and brokerage roles are one mechanism by which they achieve that goal. Therefore, the Middle Preclassic period presents one of the earliest clear examples of exclusionary leadership in Mesoamerica that was characterized by brokerage positions, well before the Classic Period when such strategies are more widely recognized.

The monumental E-Group also plays a part in this exclusionary trending trajectory. The ERGMs highlight that during the EMPC, sites with E-Groups tended to export more goods than they received, likely reflecting their function as gathering places and perhaps early market venues. By the LMPC, this pattern reverses, with E-Group sites receiving more goods than they sent, a hallmark of exclusionary leadership. What is striking is that both artifactual and network data tend to indicate exclusionary dynamics before they appear in the architectural record. This suggests that economic, social, and ideological foundations had to be established before exclusionary power could be materialized in monumental architecture, a point I will explore further below.

From a regional perspective, local coalitions, largely shaped by proximity and contained within the Mopan and Belize River valley subregions, emerged during the LMPC. This development was likely driven by population growth and denser network connections. In other world regions, studies have shown that coalitions often arose to balance power and prevent any single village from dominating the regional political landscape (Ames 1995, 2008; Angelbeck & Grier 2012). The early coalitions in the UBRV, however, present different trajectories. In the Mopan River Valley, power shifted between sites across time, while in the Belize River Valley, Blackman Eddy consistently held greater influence than its neighbors, and in the Macal River Valley, Cahal Pech remained unrivaled.

Another key factor shaping the regional network was the steady entrenchment and normalization of exclusionary leadership strategies. From a practice theory perspective (*sensu* Bourdieu), this dynamic illustrates how local strategies influence regional structures, which in turn reshaped the possibilities and norms of leadership at the local scale in future periods. With this summary in place, I now turn to addressing the central research question.

The Evolution of Socio-Political Complexity in the Upper Belize River Valley

In Chapter 2, I defined socio-political complexity as *the degree and configuration of social, political, and economic differentiation within a social system, such as variation in social relationships among individuals and groups, diversity in political roles and authority structures, greater heterogeneity in network positions and forms of interaction, and disparities in access to resources and economic power*. In this section, I bring the amassed data to bear upon the question of how patterns of social, political, and economic differentiation were structured and transformed within the UBRV within the UBRV during the Early and Middle Preclassic periods, a time that laid the political and socio-economic foundations for the better known Late Preclassic and Classic Maya kingdoms. I highlight the multiple pathways individual villages took towards this complexity through a series of vignettes which will show the importance of both regional socio-economic networks and local political strategies.

The Pace of Differentiation Through Political Change

Some sites develop traits of socio-political complexity more rapidly than others. Political centralization, whether concentrated in a single ruler or an institution, exclusionary or corporate, serves as a primary indicator of increasing political differentiation and the consolidation of authority in both archaeological and ethnographic records. Blanton and colleagues (1996) note that hierarchy can exist even in corporate societies, which makes linking political strategies directly to socio-political complexity challenging, as the organization of governance within exclusionary and corporate modes is culturally specific. Collective action theory (Blanton and Fargher 2008) is helpful for understanding this organization. In the Maya world exclusionary leaders also tend towards the autocratic side of the collective action spectrum, a trend also noted in other parts of the Americas (Fargher et al. 2010; Feinman 2013, 2018), while corporate strategies tend towards the collective side of the spectrum cross-culturally (Fargher 2016).

In the Maya case, shifts in political strategies provide a useful lens for tracing how patterns of differentiation and authority were reorganized through time because the centralization of power by emerging elites appears in the archaeological record as a transition from corporate, collectively oriented villages with broadly distributed access to socio-economic networks toward exclusionary, likely autocrat-led villages that progressively secured and maintained control over key aspects of the network. The Classic period Maya exemplify this exclusionary and autocratic model, making its earlier emergence in the Preclassic period a clear sign of increasing socio-political complexity. Additionally, the way I measure political strategy, such as the evidence of social stratification and monumental architecture, further reinforces this interpretation. Figure 7.1 illustrates the site-level and regional trajectory of political strategies over time.

Even from the earliest period, the EPC, there is already a gap in political strategy between both Blackman Eddy and Cahal Pech and the more corporate oriented village of Xunantunich. As time progresses, this gap widens. Interestingly though, there is not an associated gap in goods flow to and from Xunantunich during the latter periods, suggesting that political strategy, while perhaps perceived as an economic advantage, was not necessarily so (see Table 5.4). Although the current study does not address the Late Preclassic or Classic periods, it is notable that Xunantunich is one of the last sites in the region to fully embrace the architecture that is synonymous with the institution of kingship (i.e., large palaces and gigantic temples). Indeed the apex of monumental architecture at Xunantunich is the colossal 40 meter tall El Castillo that was constructed during the Late Classic, several centuries after other sites in the region had built large temple complexes (Leventhal 2010). Blackman Eddy and Cahal Pech on the other hand were consistently building more elaborate, and tall, structures that are associated with kingship throughout their trajectories.

Broadly, this study demonstrates that political change can serve as a measure of increasing differentiation and the consolidation of authority within communities, particularly in cases where such change leads to the consolidation of power within an individual or institution. However, political change rarely occurs in isolation; it often unfolds alongside similar developments in nearby villages. When one village experiences success in political and economic endeavors, others may imitate its strategies, especially as social and economic ties between them strengthen. Yet, political centralization also brings internal tension between collective interests and the ambitions of leaders. The balance between these forces helps define the range of acceptable responses to regional change. As a result, there are multiple pathways and varying tempos through which complexity emerges, reflecting diverse trajectories in the formation of large-scale political and socio-economic institutions. These pathways and tempos likely played out differently across other societies in ways that were influenced by population size, the scale of socio-economic networks, and the acceptable range of behaviors given unique cultural contexts.

Political Strategies and Network Positions

From the outset, Blanton and colleagues (1996) emphasized that exclusionary political strategies were rooted in the exclusivity of network positions. At the time, however, empirical datasets to demonstrate this phenomenon were limited. The present study provides a line of evidence that supports this proposition. By comparing the trajectory of sites along the spectrum of political strategies with their regional network positions, it is possible to draw a clear connection between leadership style and network positions.

For example, Xunantunich consistently falls on the corporate side of the spectrum, yet during both the EMPC and LMPC it maintained a comparable number of network connections and similar volumes of goods flow as more exclusionary sites (Table 5.4). Despite this, its brokerage potential remained low throughout, with the exception of scores comparable to Actuncan and close to Chan during the EMPC. In that same period, however, both Actuncan and Chan exhibited higher betweenness centrality, marking them as more significant nodes for channeling goods across the region. This suggests that the ability to control goods flow and the exclusivity of brokerage positions serves as a strong indicator of exclusionary leadership strategies, aligning with the expectations of the dual-processual model.

By the LMPC, it is clear that brokerage potential goes hand in hand with leadership strategy. The four sites that fall into the corporate side of the spectrum, Arenal, Baking Pot, Pacbitun, and Xunantunich, all have no or limited brokerage potential (i.e., scores range from 0-4), whereas those sites falling into the exclusionary side of the spectrum, Blackman Eddy, Buenavista, Cahal Pech, and Lower Dover all have relatively high brokerage potential (i.e., scores range from 11-24).

From a regional perspective, Blackman Eddy consistently occupied a central position in the economic network (Figures 5.2, 5.4, and 5.6). Its prominence likely stemmed from its role as a gateway connecting the coast to the interior, which would have provided privileged access to coastal resources. An interesting case of rapid transformation is the village of Buenavista, which rose to economic prominence during the LMPC. At that time, it held the highest brokerage potential, the highest betweenness centrality, the greatest number of ties, and the second-highest volume of goods flow. Buenavista's centrality in the network aligns with its role as the probable source of Joventud Red pottery, a precursor to Sierra Red one of the most widely traded ceramic types of the Preclassic. This pattern is consistent with its later importance as a major producer of Cabrito Cream Polychromes during the Late Classic (Reents-Budet et al. 2000). Buenavista's growing influence was also marked architecturally, as a monumental palace complex was constructed there in the Late Preclassic (Ball and Taschek 2004). Together, Blackman Eddy's enduring centrality and Buenavista's rapid ascent highlight the varied strategies through which villages could leverage geography, exchange, and architecture to negotiate power and authority within the region.

This study suggests that understanding leadership and socio-political complexity requires examining how individual villages interacted with one another while situating those interactions within the broader regional network. A relational perspective is therefore essential for interpreting the intersection of governance and economics. The results consistently show that villages exhibiting material evidence of exclusionary leadership also occupied exclusive positions within their networks. This pattern suggests that in societies where brokerage is considered a socially acceptable position, exclusionary leadership strategies are more likely to be tolerated. Future research should investigate this relationship to clarify how social norms surrounding network structure influence political behavior.

Exception to the Regional Trend

For the most part, UBRV villages tend to go from more corporate to more exclusionary leadership strategies through time. Pacbitun is the only exception to this pattern. During the EMPC, when Pacbitun first appears on the landscape, the site begins as primarily an importer of goods with a tendency towards an exclusionary leadership strategy, which is primarily reflected in its domestic architecture and artifactual data. However, by the LMPC, the inhabitants of Pacbitun are no longer interacting heavily with the rest of the regional network. Instead they are mostly making their own pottery, and there is an increase in public architectural manifestations and more corporate oriented artifactual remains. This divergence underscores that network position structured opportunities rather than strictly determining political strategies.

Briefly stepping away from Pacbitun, this pattern may suggest that proximity to other sites played a role in the expression of leadership strategy. The ERGMs show that by the LMPC distance likely played a role in the evolution of network dynamics, so it is also likely that due to the geographic isolation of Pacbitun from the rest of the villages in the region, that distance also played a role in the expression of leadership strategy.

The case of Pacbitun highlights that pathways to complexity are not necessarily linear. During the Classic period, Pacbitun became a major center on par with several other sites in the UBRV. Excavations into the major Classic period structures associated with elites show that they had their start during the Late Preclassic (Powis 2019b) suggesting that the shift towards corporate architectural manifestations were short lived.

It is reasonable to expect that not all villages operated in the same way. Different people bring different ideas, preferences, and expressions of identity. Some villages likely emerged as splinter communities that broke away from existing settlements due to internal conflict, further contributing to variation in regional development. This diversity presents a valuable avenue for future research, raising questions about the social and economic advantages or disadvantages of deviating from regional norms and how such deviations may have influenced the overall structure of the network.

Architectural Lag

At most sites in the region, artifact and network data shift toward the exclusionary side of the political spectrum before this trend becomes visible in the architectural record.

With the transition from the EPC to the EMPC, this pattern is clearest at Blackman Eddy, which already holds a strongly exclusionary network position. The shift intensifies with the move from the EMPC to the LMPC, as Blackman Eddy and Lower Dover both display increasingly exclusionary signatures. Although beyond the scope of this project, the same trajectory continues into the Late Preclassic with Actuncan, Arenal, Buenavista, and Chan. As noted above, this supports the idea that the ideological and economic infrastructure of exclusionary leadership needed to be established before emerging elites could mark the landscape with monumental architecture that materialized their power.

A few notable exceptions complicate this general pattern. During the EPC and EMPC, Actuncan records high network scores but delays the construction of dynastic architecture until the Late Preclassic, following the broader trajectory with an extended gap. Cahal Pech shows the reverse pattern: early on, its architecture trends exclusionary, while its artifact and network data trend corporate. This discrepancy balances out during the EMPC and eventually reverses in the LMPC. Pacbitun diverges further, beginning with high architectural and artifact scores that decline markedly during the LMPC. These cases remind us that while the regional pattern strongly favors a sequence of exclusionary strategies emerging in the networks before being monumentalized in architecture, local histories could diverge significantly, reflecting site-specific choices and constraints. Together, these patterns demonstrate that the roots of regional socio-political complexity lay both in the regional trajectory toward exclusionary leadership and in the diverse ways individual communities navigated and negotiated that process.

More broadly, the idea that ideological and regional networks must develop before the construction of monumental architecture appears to be a global phenomenon. Several examples illustrate this pattern. In ancient Egypt, the first dynastic pyramids emerged during the Third Dynasty, after the political and economic foundations of the Old Kingdom state had already been established (Bard 2003). In mainland Southeast Asia, at sites such as Oc Eo, Angkor Borei, Sambor Prei Kuk, and others in the greater Angkor region, the growing centralization of political, economic, and religious power between AD 400 and 1350 preceded the construction of increasingly elaborate temple complexes (Coe and Evans 2024). A similar sequence is evident in more corporate contexts, such as early Rome and Etruscan Veii, where communities first clustered around fertile, defensible river crossings and developed extensive economic networks before constructing monumental public spaces like the Roman Forum, which likely predated the establishment of the semi-mythical Roman monarchy (Crawford 2001). These examples suggest that across many regions of the world, ideological and social integration were necessary conditions for architectural expressions of power.

The Emergence and Evolution of Socio-Political Complexity

How did the relationship between regional socio-economic networks and local political strategies contribute to the development of socio-political complexity in the Upper Belize River Valley? As regional networks expanded and grew denser, certain villages, where emerging elites were consolidating power, were able to leverage their positions within the network to occupy exclusive roles. These positions translated into heightened economic and political authority for their rulers. Villages that hosted these leaders gained tangible advantages, particularly through the accumulation of diverse goods flowing in from across the network.

Over time, most villages sought to emulate these successes, attempting to secure similar benefits by shifting toward more exclusionary strategies. This process further increased the density of regional interactions. At the same time, coalitions of nearby sites became more pronounced, likely serving as leveling mechanisms to prevent individual leaders from consolidating too much power. Yet once the process of exclusionary consolidation began, a kind of political path dependence took hold. Pacbitun briefly attempted to resist this trajectory by reverting to corporate strategies, but this return proved short-lived. In the long run, the regional economic network shaped local political strategies, which in turn reshaped the regional structure. By the Classic period, exclusionary leadership became the norm, and as kingdoms tapped into super-regional networks, these dynamics scaled upward.

The origins of socio-political complexity in the UBRV thus lie in the interplay between local strategies and regional structures during the Early and Middle Preclassic. The key transitions that culminated in the *kuhul ajaw*, divine kingship political system can be traced to the exclusionary leaders of the Early and Late Middle Preclassic. Sites with an early advantage in this trajectory, especially Blackman Eddy, Cahal Pech, and to some extent Actuncan, were the first to display clear signs of kingship and cityscapes, developments likely fueled by their ability to centralize and control economic flows. In this way, the mutual reinforcement of local political strategies and regional network dynamics created the foundation for the emergence of socio-political complexity in the UBRV.

Contributions of the Study

This project has presented several theoretical and methodological contributions to the study of the ancient Maya, models of governance, and archaeological network analysis. In this section, I outline how these contributions may inform future scholarship both within Maya studies and in the social sciences.

With regard to the ancient Maya, this research demonstrates that political strategies tended toward exclusionary practices relatively early in their trajectory. The UBRV did not develop in isolation, and broader pan-Maya culture histories suggest that similar processes were unfolding in other regions as well. When Blanton and colleagues (1996) first proposed the dual-processual model, they noted that the Late Preclassic Maya exhibited traits of corporate leadership. While this study confirms that some villages in earlier periods did display corporate strategies, and many likely continued to do so into the Late Preclassic, it also shows that other villages were already pursuing exclusionary strategies. Recent scholarship (Beekman 2000, 2016), along with the results presented here, supports the idea that individual villages engaged in divergent strategies even within the same region. Consequently, it is likely that many villages across the Maya world had already begun trending toward exclusionary leadership by the Late Preclassic. It is the distribution of social capital across a network, the use of that capital at the local level, and the social acceptance or rejection of that use which creates boundaries within which future leaders can act. As network positions become more or less advantageous and social mores shift, societies are more likely to cycle back and forth across the spectrum of political strategies, as was presented by Blanton and colleagues (1996). However, beneath the large-scale societal shifts initially envisaged by the dual-processual model are individual actors, villages, and regions, each with differing trajectories, driving those shifts. Modern archaeological techniques allow us to delve deeper and explore these differing trajectories, adding greater nuance to our understanding of prehistory.

This study also highlights the importance of integrating multiple datasets when evaluating political strategies. Previous work often relied on a single type of evidence, such as architecture or artifacts, to infer aspects of local governance. My analysis shows that different datasets can produce markedly different perspectives on leadership, and only by synthesizing these lines of evidence can broader questions be adequately addressed. At the same time, the variation across data types opens promising avenues for future research into how different material domains reflect political strategies and how these domains intersect.

Methodologically, this is the first study of the Preclassic Maya to employ quantitative measures of economic interaction as a means of evaluating political strategies and reconstructing socio-economic networks. This led to the discovery that brokerage potential, the result of a specific network position, was a key mechanism of exclusionary power and the evolution of socio-economic networks within the study region. The study also assembles and makes public the largest Preclassic Maya ceramic geochemical dataset to date. To my knowledge, this is also the first study to demonstrate not only site-to-site interaction in the Preclassic Maya world but also the relative intensity of those interactions. Furthermore, this research applies Exponential Random Graph Models (ERGMs) in a novel way, using valued rather than binary models to investigate the intensity of goods flow within a regional network. Relational approaches remain relatively rare in Maya studies, and I hope this project illustrates their value.

Finally, this project has operationalized several theoretical models to address changes in socio-political complexity using archaeological data. While this is by no means the first study to explore socio-political complexity using archaeological data, it is one of the first to specifically take a relational approach to do so. I hope other scholars around the world see the importance of exploring both top-down and bottom-up political and socio-economic dynamics, and how their intersection provides both greater resolution and greater insight into prehistoric cultures.

Future Directions

From the outset, I conceived of this project as a large-scale pilot study, a proof of concept demonstrating that network methods and models as well as large-scale NAA analyses could be applied productively to the UBRV. This study has provided that proof. The next step is to extend the analysis into the Late Preclassic and Classic periods, when additional sites emerged on the landscape. Building a culture history that emphasizes village-to-village interaction among the ancient Maya of the UBRV would significantly deepen our understanding of regional social, political, and economic dynamics.

This research also has potential for expansion beyond the UBRV. Extending the study to include interactions with villages in neighboring regions would open new lines of inquiry. For example, were UBRV political patterns unique to this valley, or part of a broader Preclassic trajectory? And what role did different regions play within the larger economy of the Maya Lowlands and beyond? Ultimately, by tracing these networks of connection and influence across time and space, we move closer to understanding how complex societies like the ancient Maya emerged, and how communities everywhere have long woven the threads of politics, economics, and social norms into the fabric of civilization.

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APPENDIX A

GEOLOGY AND SOILS OF THE REGION

The Upper Belize River Valley (UBRV) lies at the intersection of several geological formations that supplied diverse clays and tempering materials to the prehistoric inhabitants of the region. At the broadest scale, the region forms part of the Maya (or Yucatán) Block, which extends from the eastern Gulf Coast of Mexico to the Caribbean Sea, and from the Yucatán Peninsula southward to northern Honduras and Guatemala (Donnelley et al. 1990; Weber et al. 2012). Within this structural block, the study area occupies the southernmost portion of the Corozal Basin. Just to the south of the study area lie the Maya Mountains, a basement high separated from the Corozal Basin by the La Libertad Arch, an east–west fault zone extending into Guatemala (Martens and Sierra-Rojas 2021; Vinson 1962).

Three main rivers define the project area. The Mopan River, flowing through primarily karstic terrain, supported the communities of Actuncan, Arenal, Buenavista del Cayo, and Xunantunich. The Macal River traverses multiple geological zones, from the crystalline and volcanic rocks of the Maya Mountains to the karstic lowlands, and was home to Cahal Pech and Chan. These two rivers join to form the Belize River, which flows eastward through the karstic lowlands while receiving tributary inputs from the Baldy Beacon area of the Maya Mountains. The sites of Baking Pot, Blackman Eddy, and Lower Dover are situated along this river. Pacbitun, though near the Macal River, lies against the foothills of the Maya Mountains, providing access to multiple geological zones. The following section examines the geology of both the Belize River Valley and the Maya Mountains in greater detail.

Geology

The Belize River Valley

Researchers have examined the geology of the UBRV since the colonial period, beginning with Leslie Ower's foundational reports on the geology of British Honduras in the 1920s (Ower 1927, 1928a, 1928b). More systematic work followed in the 1950s, when Giovanni Flores published a comprehensive report and geological map of northern Belize's surface stratigraphy (Flores 1952a) along with a shorter summary (Flores 1952b). Flores' informal nomenclature and age estimates heavily influenced government reports, geological maps, and academic studies for decades, even after their limitations became apparent.

Subsurface drilling during the 1970s revealed two previously unrecognized Corozal Basin formations, the Hill Bank and Yalbac formations, first described by Bryson (1975). In the same period, Jean Cornec produced the first modern geological maps of Belize, updating them regularly as petroleum exploration expanded (Cornec 1985, 2015, among others). The most current synthesis of Belizean geology, including updated chronological assessments, comes from King and Petruny (2023), based on two decades of nationwide geological research. The summary below follows their chronology, describing the geological development of the UBRV from the oldest to the most recent deposits, and Figure A.1. presents a map showing the underlying geology of the region..

The Margaret Creek Formation has been characterized with respect to its petrology, depositional settings, and thickness by King and Petruny (2013). They interpret it as a red-bed sequence deposited in braided fluvial systems and humid alluvial fans. Detrital zircon analyses further show that the formation contains Appalachian-derived zircon suites inherited from the underlying Upper Paleozoic Santa Rosa Group, whose sediments were originally sourced from Grenvillian terranes when Belize formed part of North America (King et al. 2019).

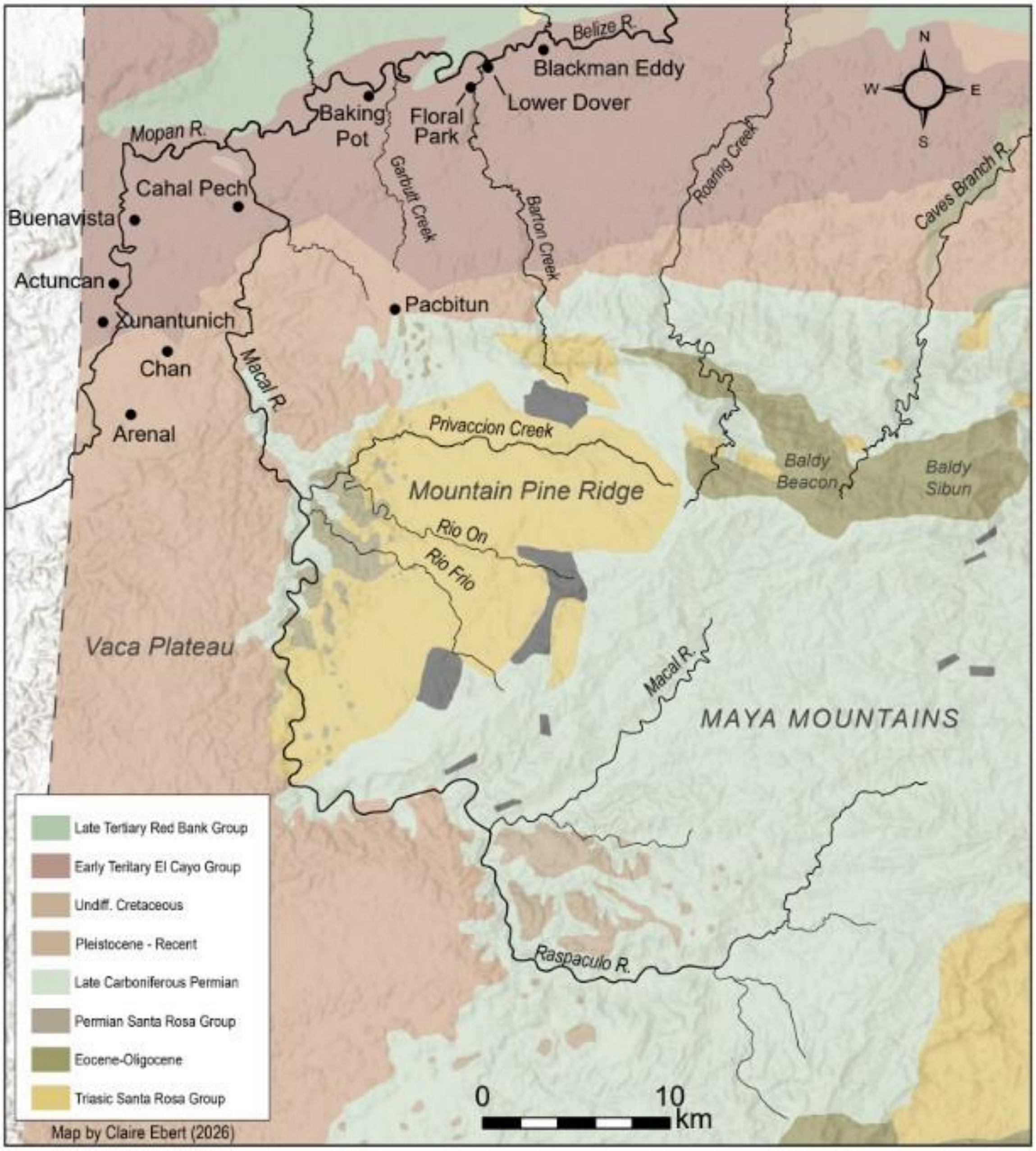

Figure A.1. Underlying Geology of the UBRV Region. Map by C. Ebert

The Hill Bank and Yalbac formations, which range from 50–300 meters and 100–975 meters in thickness respectively, were systematically studied by Gill (2017) and more fully described by Gill and colleagues (2018). The Hill Bank Formation records environments from clastic coastal plains to shallow-shelf carbonates, whereas the Yalbac Formation reflects sabkha to shallow-marine conditions. Strontium-ratio dating indicates a major chronostratigraphic gap between them, representing a significant unconformity within the Corozal Basin (Gill et al. 2018).

The Barton Creek Formation, a 450–650 meter thick, cretaceous age dolostone unit, was first described comprehensively by King and Petruny (2014). They identified a pronounced east–west environmental gradient, transitioning from shoreline and nearshore settings in eastern Belize to open-shelf and reefal environments toward the Guatemalan border. Although fossils are generally scarce due to pervasive dolomitization, a localized deposit at Albion Island preserves Late Cretaceous crabs, gastropods, pelecypods, and other fauna (Vega et al. 1997). In northern Belize, the upper surface of the Barton Creek Formation is truncated by ballistic erosion from Chicxulub impact ejecta (Ocampo et al. 1996; King and Petruny 2003).

The Cretaceous–Paleogene boundary interval, represented by the Albion Formation in northern Belize and the Cayo diamictite in central Belize, has been the subject of extensive study (Ocampo et al. 1996; Keller et al. 2003; Pope et al. 1999, 2005; King and Petruny 2001, 2003, 2015, 2020). This 10–15 meter interval consists entirely of ejecta from the Chicxulub meteor impact in the Yucatan peninsula.

Above the Cretaceous–Paleogene interval lie four informal northern Belize units: the El Cayo Group, Doubloon Bank Formation, Iguana Creek Formation, and Orange Walk

Group. The El Cayo and Doubloon Bank units remain poorly documented in the published literature and are mainly known from Flores' (1952a) descriptions of them as fine-grained shallow-shelf carbonates. The Iguana Creek Formation, composed of breccias and conglomerates, likely reflects alluvial processes triggered by uplift in the Maya Mountains. In contrast, the Orange Walk Group has been well studied; King and colleagues (2003) identified barrier-island sands, lagoonal limestones rich in mollusks and coralline algae, and patch-reef deposits, indicating a west–northwest–oriented coastal system.

The Red Bank Group, approximately 400–500 meters thick, has been examined through both surface and subsurface studies (King et al. 2018; Ricketts 2020; Ricketts et al. 2021). Researchers have identified tidal-flat and shallow-estuarine facies, as well as a distinctive lower zone characterized by clay infiltration into the karstic upper Barton Creek carbonates in the Spanish Lookout area. Subsurface data also show the Red Bank to be much thicker in places than Flores (1952a) originally estimated (Ricketts et al. 2021). A major hiatus, interpreted as a second "great unconformity," separates the early Eocene upper Red Bank from the overlying Quaternary deposits, which include reefal limestones, alluvium, soils, travertines, and shoreline sediments (King et al. 2004; Ricketts et al. 2021).

The Maya Mountains

Geological research in the Maya Mountains has been ongoing since the late 19th century (Sapper 1886, 1899, 1935; Ower 1928b; Dixon 1955; Bateson and Hall 1971, 1977). Our current understanding of the geological contents of the Maya Mountains comes from Bateson and Hall's work in the 1970s and has been supplemented by several more recent research programs. The following descriptions present the most up-to-date geological information on the four geological contexts which have an influence on the geology of the Belize River Valley, namely the Santa Rosa Group, the Mountain Pine Ridge Batholith, a northern outcrop of the Bladen Formation, and the Baldy Beacon.

Santa Rosa Group The Santa Rosa Group comprises approximately 80% of the Maya Mountains, and is primarily composed of conglomerates, limestone, phyllite, sandstones, shales, slate, and quartzite (Bateson and Hall 1971, 1977; Steiner 2005). This group dates to the Late Pennsylvanian to Middle Permian Periods of the Paleozoic Era. It was once believed that the Santa Rosa Group represented the oldest sediments in Belize with the three igneous batholiths (i.e., Mountain Pine Ridge, Hummingbird, and Cockscomb) intruding into it (Bateson and Hall 1971, 1977; Dixon 1955). However, recent U/Pb dates suggest the opposite, with the batholiths pre-existing the Santa Rosa Group (Martens et al. 2010; Steiner 2005).

Mountain Pine Ridge Batholith The Mountain Pine Ridge Batholith is a plutonic environment located within the northeast corner of the Maya Mountains, surrounded by the Santa Rosa Group. The area is primarily known for it’s granites of various qualities (Bateson and Hall 1977; Shipley 1978). As previously noted by Jordan (2018:234):

> Shipley (1978: 13-28) identified five granitic phases in the Mountain Pine Batholith: 1.) A coarse-grained granite composed of quartz, plagioclase, orthoclase, biotite with pyrite, muscovite, fluorite, sphene and possible monazite accessory minerals, 2.) A quartz-monzonite porphyry composed of quartz, potassium feldspar (perthitic or granophyric with quartz), sericitized plagioclase, biotite that is partly

> altered to chlorite with monazite, sphene, fluorite, and zircon accessory minerals, 3.) A muscovite-granite porphyry composed of quartz, potassium feldspar (perthitic), sericitized plagioclase, and muscovite with no accessory minerals, perhaps due to recrystallization, 4). A granodiorite composed of quartz, sericitized plagioclase, orthoclase and microcline (more abundant than orthoclase), hornblende and biotite with apatite, muscovite, monazite and pyrite accessory minerals, and 5). A dacite with a groundmass composed of felsic intergrowth of quartz, feldspar, and biotite with phenocrysts composed of quartz, plagioclase (some sericitized), and potassium feldspar (some perthitic). A more recent study (Jackson et al. 1995) identifies four petrographic types of granitic rocks present in the Mountain Pine Batholith: biotite leucogranite, muscovite leucogranite, granodiorite, and tonalite.

This area is important for this study because it drains into the Macal River, but also because it was a known resource extraction area for the inhabitants of Pacbitun (Brouwer Burg 2021; Skaggs et al. 2020; Tibbitts et al. 2023; Ward 2013).

Bladen Formation In the northern portion of the Maya Mountains, east of the Mountain Pine Ridge Batholith, there is a section of exposed Devonian Period Paleozoic Era rocks, primarily sandstone and conglomerates with tuff and rhyolite, which Dawe (1984:37) interpreted as stratigraphically equivalent to the Bladen Formation (also known as the "Bladen Volcanic Member") located some 30 miles south in the Southern Maya Mountains. Recent geochemical research on this zone has also argued that this portion is "correlative with the [southern] Bladen Formation" (Martens et al. 2010:819). Michael Druecker

(1978:56) reports geochemical assays from the southern Bladen Formation showing very high arsenic concentrations, attributed to the presence of arsenopyrite, along with elevated levels of vanadium, barium, and manganese. Jean Cornec (1986) inferred that the occurrence of alluvial gold along the Macal River points to the presence of arsenopyrite, a gold-bearing mineral commonly associated with plutonic environments, such as those in the Maya Mountains. This northern section of the Bladen formation is the most plausible candidate for clays and tempering materials that are high in arsenic, vanadium, barium, and manganese. Importantly, this area drains into the Macal River via Privaccion Creek, as is attested by volcanic materials located downriver near the Macal Gorge.

Baldy Beacon Perhaps the oldest exposed Paleozoic strata in the country of Belize, dating to a pre-Devonian to post-Ediacaran period, is the Baldy Beacon area in the north-central portion of the Maya Mountains (Martens et al. 2010; Weber et al. 2012). This area is comprised of sandstones, quartzites, and phyllites; however, there is a notable lack of granite in the area (Martens et al. 2010; Simmons 1972). This region drains into Roaring Creek to the north, which feeds into the Belize River near Belmopan, and the Macal River to the south. Although Roaring Creek runs approximately eight kilometers east of the project area, it is possible that materials from this area made their way into the UBRV. In her extensive petrographic study of Late Classic pottery from Baking Pot, Jill Jordan (2019:384,389) notes that two different ceramic fabrics contained tempering materials (i.e., rhyolite and sandstone with fluid inclusions and metamorphic features) that most likely came from this region of the Maya Mountains.

Soils

The soils of the UBRV reflect a complex geological history shaped by limestone uplands, granitic and metamorphic highlands, and active riverine systems. Together, these factors have produced a diverse mosaic of soil suites that vary in parent material, morphology, drainage, and nutrient availability, with important implications for vegetation, land use, and human settlement. The following soil descriptions are derived from the works of Baillie and colleagues (1993) soils survey and Jillian Jordan's (2019) recent archaeological work, and Figure A.2. presents a map of the soil types in the region.

Alluvial soils are widespread along the Belize and Mopan Rivers and are represented by the Melinda Suite, which formed on Pleistocene and Holocene riverine alluvial limestones. These soils range texturally from gritty sands to fine clays and are typically gray to brown in color. Muscovite is commonly present in floodplain contexts, reflecting the transport and deposition of upstream materials. Older Melinda soils preserved on river terraces differ markedly from younger floodplain deposits, consisting primarily of fine, reddish silty clays that have undergone substantial weathering. Prolonged exposure to acidic conditions has depleted key nutrients such as phosphorus, magnesium, and calcium, influencing both soil fertility and associated ecosystems.

Limestone-derived upland soils are represented by the Chacalte and Yaxa suites, which developed on Cretaceous and Paleocene–Eocene limestones, respectively. Chacalte soils are generally shallow, slightly acidic dark brown to reddish clays containing iron and manganese concretions, and are most commonly found in the foothills of the Maya Mountains. In contrast, Yaxa soils tend to be deeper dark gray and reddish clays, sometimes containing gypsum, and are distinguished by relatively high calcium and magnesium contents. These nutrient-rich conditions support diverse vegetation communities and have historically been favorable for agriculture.

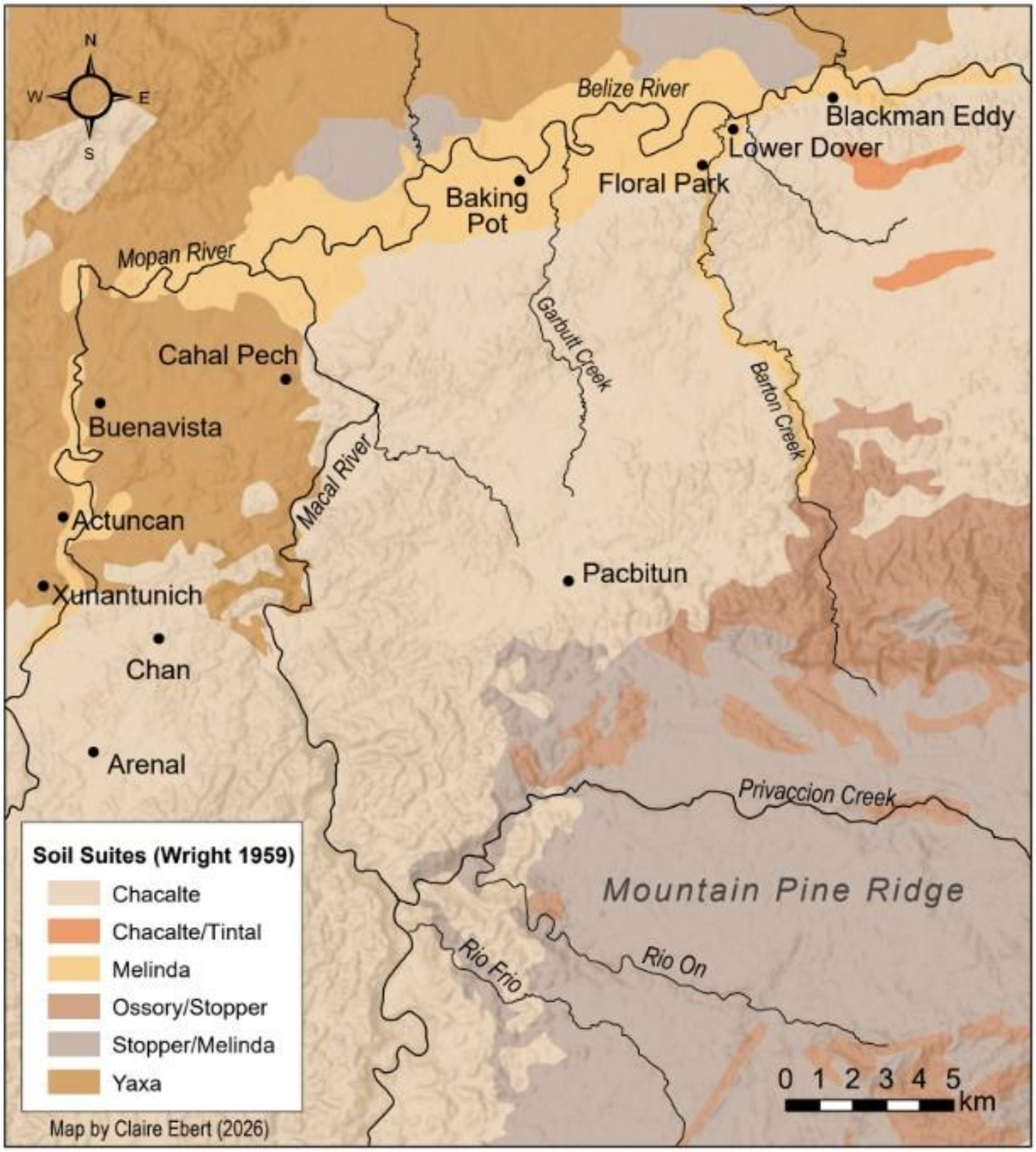

Figure A.2. Soil Suites Across the UBRV Region. Map by C. Ebert.

In the surrounding highlands, non-limestone parent materials give rise to more acidic and nutrient-poor soils. The Stopper Suite developed on granite and occupies large areas of the Mountain Pine Plateau as well as lower-elevation granite basins such as the Cockscomb. These soils are characterized by abundant angular quartz grit and coarse sand, making them highly susceptible to erosion, particularly gullying. They are strongly acidic, highly leached, and low in available nutrients, with total potassium and magnesium contents that are low to moderate. Morphologically, Stopper soils are highly variable, ranging from pale yellow and grey loamy sands to bright red sandy clays, and include a wide range of soil depths.

The most extensive soils in the Maya Mountains belong to the Ossory Suite, which developed on hard, slowly weathering meta-argillite and quartzite. These conditions produce predominantly shallow, stony, and weakly developed soils, especially on steep slopes. Ossory soils are uniformly acidic and low in available nutrients, though they retain relatively high total potassium and magnesium levels. Morphological variability within the suite is pronounced, encompassing shallow stony sands over quartzite, deep red and yellow clays formed in hillwash deposits on lower slopes, and yellowish, columnar, stony clays characteristic of the Bald Hills.

Hydromorphic environments throughout the UBRV are represented by the Tintal Suite, which is defined by soil profile characteristics rather than parent material. This suite includes soils that remain wet to the surface for all or much of the year and occurs in perennial and seasonal swamps ranging from freshwater to saline conditions. Textures range from sand to clay, often with pronounced stratification inherited from alluvial deposition. Common features of mineral Tintal soils include grey colors, rust-brown mottling along active or relict root channels, and surface accumulation of organic matter. Prolonged waterlogging suppresses microbial activity, in some cases allowing sufficient organic material to accumulate for the soil to be classified as muck or peat.

APPENDIX B

NEUTRON ACTIVATION ANALYSIS DETAILS AND COMPOSITIONAL GROUP DESCRIPTIONS

All the data for this dissertation can be located on TDAR: https://core.tdar.org/dataset/520272/early-and-middle-preclassic-naa-data-dissertation-research-upper-belize-river-valley. This section follows the procedures used at the University of Missouri Research Reactor (MURR; see Glascock 1992), with minor modifications for the inclusion of additional clustering methods. The Neutron Activation Analysis (NAA) data collection process at MURR typically yields elemental concentration data for 33 elements in most samples. To standardize the data and improve interpretability, the concentrations are converted to base-10 logarithms. This transformation helps manage the wide range of values, particularly between major elements like calcium and trace elements such as rare earth elements. Additionally, using logarithms often results in a more normal distribution for trace element data, facilitating statistical analysis.

Detailed discussions on interpreting compositional data in archaeological studies can be found in works such as Baxter and Buck (2000), Bieber and colleagues (1976), Bishop and Neff (1989), Glascock (1992), Harbottle (1976), and Neff (2000). In summary, the primary goal of such analyses is to identify distinct, chemically homogeneous groups within a dataset. According to the provenance postulate proposed by Weigand et al. (1977), these groups likely correspond to specific geographic sources. For ceramics, however, chemical compositions may also reflect the paste recipes used by potters. These recipes encapsulate a range of practices, from selecting and preparing raw materials to mixing temper and clay and firing the pottery, all of which influence the final chemical profile. Factors such as use and diagenesis can further alter elemental composition, and their effects should be evaluated and minimized during analysis.

Different types of artifacts require tailored approaches for sourcing. In ceramics, sourcing involves comparing unknown artifacts to known reference materials, such as clay samples, or employing indirect approaches like the "criterion of abundance" (Bishop et al. 1982) or geological and sedimentological reasoning (e.g., Steponaitis et al. 1996). Unlike lithic sources, which are often localized and compositionally uniform, ceramic raw materials are widespread, making it impractical to sample all potential sources comprehensively.

Compositional groups are mathematically represented as points within a multidimensional space defined by the measured elemental data. Each group is characterized by the position of its centroid and the unique correlations among its elements. Specimens are assigned to groups based on statistical probabilities, assessing whether their measured concentrations are consistent with those of the group.

Hypotheses regarding source-related subgroups may be informed by non-compositional factors, such as archaeological context or artifact attributes, and through computational methods applied to multivariate chemical data. Common pattern-recognition techniques include hierarchical cluster analysis (HCA) and principal components analysis (PCA). A relatively new data assessment method, the Uniform Manifold Approximation and Projection (UMAP) algorithm, was used in this study (see Chapter 4). Each method has specific strengths and limitations, which depend on the nature and volume of the data available for interpretation.

Initially it is helpful to examine datasets with a HCA or UMAP, which can reveal initial groupings to be tested by further methods such as PCA. Archaeological and geological datasets often involve numerous measured elements that are highly correlated, which can complicate the identification and interpretation of patterns. To address this, it is often beneficial to reduce the dataset to a smaller set of uncorrelated variables, simplifying the analysis. Principal Component Analysis (PCA) is a widely used method for achieving this transformation by converting correlated variables into a new set of uncorrelated components.

PCA generates a series of new reference axes, called principal components (PCs), ranked in order of the variance they explain. Each principal component is a linear combination of the original variables, allowing the data to be displayed using these new axes instead of the original variables. This transformation can serve two purposes: it can help identify subgroups within an undifferentiated dataset (pattern recognition) or evaluate the consistency of groups hypothesized based on other criteria. In general, specimens from different groups are expected to show larger compositional differences than those within the same group. As a result, distinct clusters of data points often emerge in plots of the first few principal components, which capture the greatest variance in the dataset.

The application of PCA to chemical datasets is scale-sensitive, as components are influenced disproportionately by variables with larger concentrations (Mardia et al. 1979). To mitigate this, it is common practice to log-transform the data, ensuring a more balanced contribution of elements across the analysis.

One of PCA's key strengths is its ability to function simultaneously in both R-mode and Q-mode analysis (Baxter 1992; Baxter and Buck 2000; Neff 1994, 2002). This means PCA can represent both variables (elements) and samples (analyzed artifacts) on the same set of principal component axes. When plotted using the first two principal components, the dataset achieves the best two-dimensional representation of its variance-covariance or correlation structure. Relationships between variables are visualized as vectors radiating from the origin, where small angles indicate strong positive correlations, orthogonal angles suggest no correlation, and angles approaching 180 degrees indicate strong negative correlations. Similarly, sample coordinates on these axes provide insights into their Euclidean relationships within log-transformed space.

Combining objects and variables on a single plot—commonly referred to as a "biplot"—offers a powerful tool for analyzing group separations and identifying the role specific elements play in defining group distinctions. Observations from biplots can be cross-validated by examining scatterplots of elemental concentrations, providing a more nuanced understanding of the underlying relationships.

The ability to distinguish a group from others can be assessed visually in two dimensions or quantitatively in multiple dimensions. A valuable statistical tool for this purpose is the Mahalanobis distance (also referred to as generalized distance), which measures separation either between groups or between individual specimens and group centroids in multivariate space. This metric accounts for variances and covariances within the dataset, making it analogous to expressing distance from a mean in univariate analyses using standard deviation units. For specimens, probabilities of group membership based on Mahalanobis distance can be calculated, with smaller distances indicating a higher likelihood of belonging to the group (Bieber et al. 1976; Bishop and Neff 1989). The Mahalanobis distance is defined as:

$$D^2_{y,X} = [y - \overline{X}]^t I_x [y - \overline{X}]$$

where y represents a $1\times m$ array containing the logged elemental concentrations of the specimen being evaluated. The group it is compared against is represented by X, an $n \times m$ matrix of logged concentrations, where $\overline{X}$ is the group's $1\times m$ centroid, and I_x is the inverse of the $m \times m$ variance-covariance matrix of the group. This method incorporates both variances and covariances of the group, making it analogous to the use of standard deviation units in univariate statistics. Just as standard deviation provides a measure of how far a value is from the mean, Mahalanobis distance quantifies how far a specimen lies from a group centroid in multivariate space.

Mahalanobis distances can also be translated into probabilities of group membership for individual specimens. For smaller sample sizes, it is more accurate to calculate these probabilities using Hotelling's T^2, a multivariate extension of the univariate Student's t-test. This approach adjusts for the limited sample size, ensuring that the probabilities reflect the underlying statistical relationships more reliably.

An issue known as "stretchability" can arise in small groups, as described by Harbottle (1976). When a specimen is included in the group it is compared to, it may disproportionately expand the group in the direction of its own location within the elemental concentration space. To address this, cross-validation is recommended: removing the specimen from its group before calculating its probability of membership. This method is conservative, reducing the risk of overestimating group membership probabilities, though it may occasionally exclude true members (Baxter 1994; Leese and Main 1994).

Small sample sizes pose additional challenges, particularly when the number of measured elements exceeds the number of specimens. In such cases, the group's variance-covariance matrix becomes singular, preventing the calculation of Mahalanobis distance. To resolve this, dimensionality must be reduced. One option is to exclude certain elements, but this risks introducing bias based on the researcher's assumptions about which elements are most relevant. Furthermore, this approach undermines the strength of multielement analysis—its ability to analyze a broad range of variables.

A more robust solution involves using scores from principal component analysis (PCA) instead of the original variables. By focusing on the principal components that explain the majority of variance (typically 90% or more), it is possible to approximate Mahalanobis distances in the full elemental concentration space while reducing dimensionality. This method is particularly effective when the dataset includes clear group separations, as the key differences between groups are often captured by the first few principal components.

Mahalanobis distance also offers practical solutions for handling missing data (Sayre 1975). In large datasets with many variables, it is common for some specimens to lack data for a few elements, often due to concentrations falling near the detection limit. Instead of excluding these specimens or variables, missing values can be replaced with estimates that minimize the Mahalanobis distance from the specimen to the group centroid. This allows specimens with minor missing data to remain part of the analysis without compromising the overall results.

Membership Probability Analysis

This section presents the results of the Mahalanobis distance membership probability analysis. Tables B.1, B.2, and B.3 present the results of the Early Preclassic, Early Middle Preclassic, and Late Middle Preclassic core membership groups respectively. Table B.4. presents the analysis specifically for the Late Middle Preclassic Fine Ware and Utilitarian 2 groups, as these groups were difficult to separate with PCA alone, but both groups contain enough elements to base the analysis on their elemental values. The Late Middle Preclassic Fine Ware group was further subdivided into 1, 2, and 3 based on UMAP clustering with the Early Middle Preclassic Fine Ware 1 ,2, and 3 groups. Unassigned samples are also presented, but many of these were added to groups as non-core members using PCA and CDA at a later stage of the analysis in accordance with the rules laid out in Chapter 4. Samples added using PCA and CDA are not indicated here, as this section focuses on defining the core members.

Table B.1. Early Preclassic Core Member Membership Probability Results. The results are based on PC1-PC5, explaining 86% of the sample variance.

ANID	EPC_BVDW1	EPC_BVDW2	EPC_CA	EPC_UTIL	Best Group
CHP068	94.79419	0.822917	0.005558	0.001351	EPC_BVDW1
CHP069	21.53786	0.688485	0.019573	0.008276	EPC_BVDW1
CHP077	78.34398	1.281937	0.00525	0.001513	EPC_BVDW1
JBD156	26.31915	1.879475	0.012765	0.006639	EPC_BVDW1
JBD160	7.817604	1.33423	0.010871	0.003769	EPC_BVDW1
JBD421	49.96166	0.422949	0.007823	0.00228	EPC_BVDW1
JBD422	65.68001	2.609204	0.014261	0.009604	EPC_BVDW1
CHP051	0.016568	93.35401	0.01339	0.018289	EPC_BVDW2
CHP055	0.019287	84.23767	0.012016	0.022238	EPC_BVDW2
CHP059	0.014495	23.66245	0.012166	0.013669	EPC_BVDW2
CHP060	0.019972	88.72233	0.01278	0.018436	EPC_BVDW2
CHP070	0.019467	13.92873	0.016652	0.027513	EPC_BVDW2
CHP076	0.017033	56.66648	0.01603	0.018718	EPC_BVDW2

JBD153	0.025605	10.89858	0.017058	0.008915	EPC_BVDW2
JBD392	0.032941	7.113039	0.016246	0.023265	EPC_BVDW2
JBD164	0.005562	0.02147	49.76995	0.000267	EPC_CA
JBD396	0.004517	0.060958	42.90044	0.000329	EPC_CA
JBD397	0.004572	0.027562	90.32704	0.000381	EPC_CA
JBD398	0.005992	0.093032	38.32047	0.000477	EPC_CA
JBD399	0.005469	0.048569	99.8932	0.000512	EPC_CA
JBD404	0.014393	0.270443	18.10499	0.00675	EPC_CA
JBD429	0.006064	0.032004	3.763863	0.000747	EPC_CA
JBD430	0.002337	0.012704	8.288879	0.000178	EPC_CA
CHP046	0.108026	0.219264	0.160555	86.47654	EPC_UTIL
CHP049	0.126033	0.173302	0.335994	22.08803	EPC_UTIL
CHP054	0.077634	0.278941	0.097209	47.13603	EPC_UTIL
CHP058	0.038302	0.043258	1.013235	63.45782	EPC_UTIL
CHP063	0.078435	0.143916	0.206324	88.72069	EPC_UTIL
CHP065	0.050737	0.134651	0.301912	53.77426	EPC_UTIL
CHP072	0.058573	0.099365	0.49141	24.56558	EPC_UTIL
CHP075	0.048058	0.031856	2.616291	39.5064	EPC_UTIL
JBD180	0.088553	0.062209	0.669684	32.80191	EPC_UTIL
CHP047	26.31796	5.616032	0.022788	0.020903	UNASSIGNED
CHP048	0.323359	0.078411	0.195243	2.060557	UNASSIGNED
CHP050	0.036824	0.079172	0.370387	1.381238	UNASSIGNED
CHP052	0.306105	0.404463	0.104048	3.905784	UNASSIGNED
CHP053	5.621201	0.517588	0.082617	0.170281	UNASSIGNED
CHP056	0.158386	0.134543	0.220901	8.74029	UNASSIGNED
CHP057	0.025482	0.110414	0.272394	1.696351	UNASSIGNED
CHP061	0.105784	2.011784	0.017287	0.00569	UNASSIGNED
CHP062	0.016357	1.552004	0.040095	0.013352	UNASSIGNED
CHP064	1.347359	0.044128	0.198185	0.093802	UNASSIGNED
CHP066	0.027037	0.093783	0.874506	0.306676	UNASSIGNED
CHP067	0.025123	0.037268	4.186615	0.693951	UNASSIGNED
CHP071	0.266344	1.515221	0.185481	2.974938	UNASSIGNED
CHP073	0.198548	1.488096	0.008925	0.008104	UNASSIGNED
CHP074	0.349422	1.450351	0.155174	7.050464	UNASSIGNED
JBD154	2.220018	1.151707	0.0121	0.00561	UNASSIGNED
JBD155	0.01843	0.357926	0.0131	0.006539	UNASSIGNED
JBD157	45.26918	3.857375	0.012684	0.004039	UNASSIGNED
JBD158	0.051888	7.43213	0.022957	0.00964	UNASSIGNED
JBD159	0.284112	4.399952	0.017948	0.005007	UNASSIGNED
JBD171	0.028448	0.099003	28.22922	0.026052	UNASSIGNED
JBD172	0.002045	0.015007	1.439474	9.37E-05	UNASSIGNED

JBD174	0.019402	0.052532	17.14196	0.023847	UNASSIGNED
JBD179	0.039535	0.049771	2.698362	5.94626	UNASSIGNED
JBD187	0.050053	0.084862	1.195808	0.144798	UNASSIGNED
JBD188	0.039749	0.028519	4.75134	1.94942	UNASSIGNED
JBD189	0.00114	0.006773	0.034862	3.13E-05	UNASSIGNED
JBD391	1.971669	1.637851	0.00956	0.002342	UNASSIGNED
JBD393	0.102933	2.467612	0.017348	0.036047	UNASSIGNED
JBD394	36.31153	3.784873	0.012153	0.007621	UNASSIGNED
JBD395	0.295987	1.833535	0.007942	0.003414	UNASSIGNED
JBD402	44.93705	3.829971	0.01869	0.015245	UNASSIGNED
JBD419	0.027368	0.152118	0.680243	0.297956	UNASSIGNED
JBD423	0.109262	1.354579	0.009106	0.002844	UNASSIGNED
JBD424	17.01147	3.510006	0.013285	0.004589	UNASSIGNED
JBD426	0.008682	0.05849	1.720236	0.025487	UNASSIGNED
JBD427	0.416392	12.40849	0.027293	0.033775	UNASSIGNED

Table B.2. Early Middle Preclassic Core Member Membership Probability Results. The results are based on PC1-PC8 explaining 90.7% of the sample variance.

ANID	EMPC ASH	EMPC CA	EMPC FW1	EMPC FW2	EMPC FW3	EMPC UTIL	Best Group
CHP013	71.3992	0.0004	0.1147	0.0012	3.5713	0.0000	EMPC ASH
CHP014	90.1078	0.0004	0.1334	0.0025	0.1632	0.0003	EMPC ASH
CHP015	74.0514	0.0005	0.0690	0.0009	0.2439	0.0000	EMPC ASH
CHP016	47.6199	0.0004	0.0716	0.0014	2.4080	0.0000	EMPC ASH
CHP019	83.4205	0.0030	0.0493	0.0031	0.3117	0.0000	EMPC ASH
CHP030	10.4168	0.0002	0.0496	0.0014	0.4479	0.0000	EMPC ASH
CHP031	81.2345	0.0010	0.0581	0.0025	2.0202	0.0001	EMPC ASH
CHP045	84.9341	0.0003	0.0591	0.0018	0.0864	0.0005	EMPC ASH
JBD151	90.0631	0.0114	0.0707	0.0057	0.4564	0.0000	EMPC ASH
JBD152	55.5120	0.0525	0.2147	0.0168	0.6557	0.0000	EMPC ASH
JBD161	42.5635	0.0054	0.0696	0.0056	1.0325	0.0000	EMPC ASH
JBD169	66.1395	0.0134	0.2219	0.0114	0.1855	0.0000	EMPC ASH
JBD213	12.8184	0.0031	0.2417	0.0059	0.0179	0.0000	EMPC ASH
JBD214	23.3858	0.0305	0.1306	0.0325	0.3340	0.0000	EMPC ASH
JBD215	80.8405	0.0040	0.7186	0.0052	0.6319	0.0000	EMPC ASH
JBD216	74.3415	0.0160	0.2327	0.0275	0.0685	0.0000	EMPC ASH
JBD271	32.6287	0.0382	0.0566	0.0406	0.0625	0.0000	EMPC ASH
JBD273	35.7924	0.0355	0.6425	0.0510	3.4511	0.0002	EMPC ASH
JBD275	43.7897	0.0185	0.0479	0.0267	0.0812	0.0000	EMPC ASH
JBD295	10.1004	0.0044	0.0032	0.0255	0.0036	0.0000	EMPC ASH
JBD296	20.9162	0.0030	0.0390	0.0036	0.0936	0.0000	EMPC ASH

JBD298	2.9070	0.0011	0.0207	0.0025	0.0607	0.0000	EMPC ASH
JBD301	22.0238	0.2834	0.4209	0.0056	0.0289	0.0000	EMPC ASH
CHP043	0.0002	43.1809	0.0122	0.0551	0.0076	0.0016	EMPC CA
CHP044	0.0000	8.1203	0.0000	0.0133	0.0018	0.0001	EMPC CA
JBD170	0.0000	28.3660	0.0001	0.0078	0.1369	0.0000	EMPC CA
JBD249	0.0000	72.9300	0.0000	0.0104	0.0003	0.0000	EMPC CA
JBD254	0.0018	73.9209	0.0355	0.0266	0.0093	0.0023	EMPC CA
JBD256	0.0001	37.1799	0.0056	0.0185	0.0019	0.0031	EMPC CA
JBD274	0.0000	69.5360	0.0001	0.0008	0.2306	0.0000	EMPC CA
JBD280	0.0000	78.5537	0.0001	0.0018	0.0153	0.0000	EMPC CA
JBD283	0.0000	60.0794	0.0000	0.0028	0.0157	0.0000	EMPC CA
JBD284	0.0002	33.9890	0.0003	0.0015	0.0076	0.0000	EMPC CA
JBD325	0.0000	21.1848	0.0002	0.0003	0.0734	0.0000	EMPC CA
JBD326	0.0000	45.5919	0.0000	0.0006	0.1232	0.0000	EMPC CA
JBD376	0.0000	44.9485	0.0000	0.0205	0.0003	0.0000	EMPC CA
JBD384	0.0000	28.8160	0.0000	0.0117	0.0003	0.0001	EMPC CA
JBD386	0.0000	35.8433	0.0006	0.0086	0.0010	0.0006	EMPC CA
JBD387	0.0000	91.8746	0.0003	0.0098	0.0011	0.0004	EMPC CA
JBD388	0.0000	95.5222	0.0000	0.0125	0.0012	0.0000	EMPC CA
JBD411	0.0000	51.9111	0.0001	0.0228	0.8737	0.0000	EMPC CA
JBD412	0.0000	28.9918	0.0000	0.0012	0.0636	0.0000	EMPC CA
JBD413	0.0005	74.1774	0.0038	0.0769	0.0270	0.0070	EMPC CA
JBD414	0.0000	12.2474	0.0005	0.0190	1.1396	0.0000	EMPC CA
JBD416	0.0000	86.7159	0.0009	0.0057	0.0374	0.0000	EMPC CA
JBD417	0.0000	86.5890	0.0000	0.0029	0.0173	0.0000	EMPC CA
JBD418	0.0000	56.7387	0.0000	0.0025	0.1441	0.0000	EMPC CA
JBD420	0.0000	3.8863	0.0000	0.0023	0.0580	0.0000	EMPC CA
ZPL026	0.0000	12.7479	0.0006	0.0106	0.0021	0.0007	EMPC CA
CHP012	0.0003	0.0042	54.9468	0.3311	0.0719	0.0008	EMPC FW1
CHP024	0.0031	3.2052	34.4994	0.0285	2.0247	0.0170	EMPC FW1
CHP033	0.0030	0.0070	77.5954	0.8304	0.0789	0.0010	EMPC FW1
JBD162	0.0009	0.1029	89.8471	0.0203	0.1437	0.0009	EMPC FW1
JBD178	0.0005	0.0001	19.3542	0.0363	0.0378	0.0009	EMPC FW1
JBD229	0.0004	0.0503	3.3608	0.1330	0.1094	0.0011	EMPC FW1
JBD233	0.0004	0.0381	32.0594	1.2534	0.5000	0.1499	EMPC FW1
JBD303	0.0036	0.0091	26.7672	0.0198	0.0188	0.0001	EMPC FW1
JBD305	0.0003	0.0000	20.8360	0.0036	0.0288	0.0000	EMPC FW1
JBD306	0.0002	0.0238	41.3893	0.0232	0.1966	0.0010	EMPC FW1
JBD316	0.0029	0.0028	72.6131	0.0670	0.1940	0.0220	EMPC FW1
JBD321	0.0003	0.0087	87.4603	0.0270	0.0734	0.0001	EMPC FW1
JBD323	0.0046	0.1732	18.1866	1.7236	0.0562	0.0008	EMPC FW1

JBD400	0.0002	0.0006	50.4725	0.0404	0.1283	0.0010	EMPC FW1
JBD403	0.0002	0.0016	46.0373	2.2119	0.9934	0.0178	EMPC FW1
JBD405	0.0002	0.0120	65.5728	0.1343	1.0387	0.0111	EMPC FW1
JBD406	0.0002	0.0028	37.3644	0.1844	0.0349	0.0001	EMPC FW1
JBD408	0.0001	0.0042	91.5799	0.1333	0.0956	0.0002	EMPC FW1
JBD410	0.0009	0.0408	98.6933	0.1114	0.0739	0.0004	EMPC FW1
JBD434	0.0008	0.0029	11.0228	0.0679	0.0547	0.0005	EMPC FW1
JBD217	0.0008	0.1367	0.3150	92.8357	0.1084	1.7719	EMPC FW2
JBD220	0.0001	0.0319	0.2923	95.9155	0.0674	0.0927	EMPC FW2
JBD224	0.0001	0.0259	0.1261	95.9882	0.0297	0.2581	EMPC FW2
JBD235	0.0002	0.0440	0.4695	85.8319	0.0287	4.1394	EMPC FW2
JBD236	0.0001	0.0525	0.2628	32.3982	0.0166	0.9743	EMPC FW2
JBD237	0.0001	0.0136	0.7698	13.5185	0.0746	0.2598	EMPC FW2
JBD238	0.0001	0.0228	0.6607	93.5428	0.0305	2.5737	EMPC FW2
JBD239	0.0001	0.0771	0.1610	23.9568	0.0151	0.2275	EMPC FW2
JBD240	0.0007	0.0975	2.7191	40.7449	0.1285	0.7668	EMPC FW2
JBD241	0.0003	0.1059	0.0115	3.2170	0.0095	0.2877	EMPC FW2
JBD243	0.0013	0.9775	0.1900	8.0431	0.0488	0.2917	EMPC FW2
JBD313	0.0003	0.0638	4.6550	44.5080	1.4693	0.0337	EMPC FW2
JBD318	0.0003	0.1435	0.6787	13.8074	0.3661	0.0008	EMPC FW2
JBD319	0.0005	0.6355	0.3330	20.2510	1.1321	0.0074	EMPC FW2
CHP001	0.0155	0.0080	0.3520	0.0320	92.7834	0.0221	EMPC FW3
CHP011	0.0199	0.0113	0.3507	0.0313	53.3276	0.0144	EMPC FW3
CHP021	0.0008	0.0029	0.4380	0.2162	4.3474	0.0011	EMPC FW3
CHP022	0.0025	0.0190	0.1581	0.0652	15.4833	0.0051	EMPC FW3
CHP027	0.9597	0.0374	0.5598	0.0397	47.7786	0.8224	EMPC FW3
CHP029	0.4397	0.1578	0.1069	0.0183	27.0656	0.2062	EMPC FW3
CHP032	0.2678	0.1795	1.2850	0.1298	71.6079	1.4237	EMPC FW3
CHP036	0.5740	0.1004	0.3808	0.0489	99.5379	0.2032	EMPC FW3
CHP038	0.7890	0.0087	0.3627	0.0168	64.2416	0.0081	EMPC FW3
CHP039	0.7003	0.0058	0.1256	0.0081	19.3532	0.2056	EMPC FW3
JBD211	2.7806	0.0231	0.3451	0.0317	63.3705	0.0004	EMPC FW3
JBD311	0.0905	0.0292	0.2062	0.0489	50.6560	0.0049	EMPC FW3
JBD315	0.4039	0.0591	0.1939	0.1469	17.5116	0.0031	EMPC FW3
CHP004	0.0004	0.0029	0.9404	1.3219	0.3243	22.1458	EMPC UTIL
CHP005	0.0026	0.0088	2.5431	0.5100	4.1155	91.2991	EMPC UTIL
CHP008	0.0049	0.0006	3.2342	0.1005	6.3078	22.6123	EMPC UTIL
CHP041	0.0147	0.0255	0.2248	0.1035	3.3116	48.7642	EMPC UTIL
JBD175	0.0033	0.0013	5.0937	0.2537	4.4091	71.6623	EMPC UTIL
JBD181	0.0024	0.0043	4.0301	0.7245	1.2166	83.5499	EMPC UTIL
JBD184	0.0034	0.0184	0.7577	0.5992	0.3921	7.8516	EMPC UTIL

JBD247	0.0019	0.0936	1.6819	8.6121	0.1604	17.2263	EMPC UTIL
JBD250	0.0069	0.0287	0.1011	0.1880	0.1611	37.3502	EMPC UTIL
JBD251	0.0021	0.0350	0.2005	0.4568	0.1724	7.1180	EMPC UTIL
JBD252	0.0007	0.0223	1.5112	1.0043	0.7056	65.5123	EMPC UTIL
JBD253	0.0037	0.1304	1.5731	2.3741	0.2520	16.9481	EMPC UTIL
JBD255	0.0013	0.0015	2.0493	0.1938	1.6760	20.9568	EMPC UTIL
JBD257	0.0003	0.0008	0.6766	0.1207	0.0977	41.2335	EMPC UTIL
JBD258	0.0002	0.0006	1.1104	0.2148	0.2751	17.5276	EMPC UTIL
JBD259	0.0019	0.0016	0.8707	0.0986	0.4388	84.9051	EMPC UTIL
JBD260	0.0005	0.0391	1.7727	1.4383	0.6648	73.9336	EMPC UTIL
JBD262	0.0004	0.0015	3.4636	0.2371	0.3985	47.2044	EMPC UTIL
JBD263	0.0007	0.0206	4.4742	3.5500	0.3111	47.4075	EMPC UTIL
JBD281	0.0028	0.0362	1.5869	1.0619	0.9703	95.5782	EMPC UTIL
JBD282	0.0023	0.0253	1.4329	1.4173	1.2835	68.0325	EMPC UTIL
JBD333	0.0057	0.0028	5.0344	0.2740	4.4785	79.2163	EMPC UTIL
JBD341	0.0033	0.0015	3.3966	0.1299	0.5505	30.7608	EMPC UTIL
JBD415	0.0026	0.0030	3.7902	0.6922	2.8579	84.8458	EMPC UTIL
CHP002	0.0085	0.0077	17.2778	1.2910	5.4780	7.1956	UNASSIGNED
CHP003	0.0019	0.0375	2.6984	0.6626	15.7085	0.2154	UNASSIGNED
CHP006	72.0640	0.0011	0.2247	0.0021	11.6353	0.0000	UNASSIGNED
CHP007	0.0084	0.0165	0.6524	0.2768	20.3799	0.5211	UNASSIGNED
CHP009	0.0011	0.1100	7.1583	14.8597	3.1043	0.5935	UNASSIGNED
CHP010	0.0005	2.2587	1.8330	0.0585	0.2587	0.3003	UNASSIGNED
CHP017	0.0224	0.0029	1.8960	0.1278	20.1512	40.3960	UNASSIGNED
CHP018	0.0008	0.0260	1.2050	0.9450	0.1883	4.9001	UNASSIGNED
CHP020	0.0000	0.0229	0.0000	0.0021	0.0308	0.0000	UNASSIGNED
CHP023	0.0061	0.2075	0.2865	0.2431	50.1063	0.0331	UNASSIGNED
CHP025	0.0388	0.0282	2.5834	0.8256	19.6248	0.4855	UNASSIGNED
CHP026	0.0451	0.0149	3.8616	0.2315	82.4004	1.7904	UNASSIGNED
CHP028	0.0008	0.0057	8.7371	6.6516	6.3196	0.1921	UNASSIGNED
CHP034	0.0038	0.0516	0.6125	0.2869	40.4937	2.7885	UNASSIGNED
CHP035	0.0291	0.0403	7.9611	1.2901	11.9965	4.2903	UNASSIGNED
CHP037	0.4176	0.2868	5.2634	4.5908	0.1623	0.0083	UNASSIGNED
CHP040	0.0019	0.3217	5.2341	0.8763	5.6682	19.0547	UNASSIGNED
CHP042	0.1011	0.0006	0.0138	0.0037	0.0303	0.0001	UNASSIGNED
JBD163	0.0008	0.0103	5.1603	9.9275	13.1564	0.0007	UNASSIGNED
JBD165	0.0005	0.3610	0.2531	2.2448	0.0307	5.8158	UNASSIGNED
JBD166	0.0009	0.0002	26.3875	0.2266	0.6353	0.0549	UNASSIGNED
JBD167	0.0005	0.1410	30.4017	0.3851	4.6362	0.4916	UNASSIGNED
JBD168	0.0003	0.0015	11.1830	3.0555	2.4165	1.8677	UNASSIGNED
JBD173	0.0115	1.8429	6.3763	3.2785	11.0388	2.3914	UNASSIGNED

JBD176	0.0001	0.0005	24.2358	0.9207	2.4337	0.3551	UNASSIGNED
JBD177	0.2517	0.6605	1.0156	0.4698	0.3328	0.0007	UNASSIGNED
JBD182	0.0013	0.0073	4.2247	1.4933	3.1871	13.5761	UNASSIGNED
JBD183	0.0687	1.1065	0.3434	0.2489	2.0242	0.1355	UNASSIGNED
JBD185	0.0014	0.0005	0.4012	0.0219	0.2256	1.0987	UNASSIGNED
JBD186	0.0108	0.0033	6.9096	0.3539	1.5878	6.0000	UNASSIGNED
JBD212	0.0753	0.0069	2.1197	0.0907	30.7804	1.8223	UNASSIGNED
JBD218	0.2555	0.3417	2.1109	0.8660	12.9470	0.7798	UNASSIGNED
JBD219	0.1253	0.1620	5.9465	1.4656	21.6275	1.4749	UNASSIGNED
JBD221	0.0001	0.2184	0.3823	0.0029	1.1387	0.0061	UNASSIGNED
JBD222	0.0032	0.1466	1.5691	7.4593	0.6887	0.1884	UNASSIGNED
JBD223	0.0068	0.0558	7.6569	22.8815	1.5945	4.5839	UNASSIGNED
JBD227	0.0011	0.2118	6.1163	7.6246	8.6018	0.6007	UNASSIGNED
JBD230	0.0000	0.0000	0.5085	0.0155	0.0962	0.0013	UNASSIGNED
JBD231	0.0000	0.0001	1.1560	0.0314	0.0405	0.0009	UNASSIGNED
JBD232	0.0002	0.0176	0.7294	31.2886	0.2031	3.0275	UNASSIGNED
JBD234	0.0335	0.0429	2.2828	0.2580	2.6630	4.1914	UNASSIGNED
JBD244	0.0000	0.0188	13.0068	1.1934	3.8546	0.0281	UNASSIGNED
JBD245	0.0027	0.7534	5.3316	3.1249	0.3399	32.8861	UNASSIGNED
JBD246	0.0003	3.6851	1.0198	0.2024	0.0493	1.5327	UNASSIGNED
JBD248	0.0064	0.0466	0.0583	2.8499	0.0687	0.0290	UNASSIGNED
JBD261	0.0000	0.0000	0.0403	0.0006	0.0436	0.0001	UNASSIGNED
JBD264	0.0004	0.0129	1.6474	5.7154	0.0511	0.3411	UNASSIGNED
JBD265	0.0015	0.0066	5.3835	0.1724	0.6030	0.4279	UNASSIGNED
JBD272	4.1843	0.2832	0.0581	0.0750	2.4485	0.0000	UNASSIGNED
JBD276	0.0001	0.0072	0.6878	8.3328	0.0216	1.0374	UNASSIGNED
JBD277	0.0002	0.0011	22.6006	1.8499	4.8978	4.3883	UNASSIGNED
JBD279	0.0025	0.1994	0.5461	3.5568	0.4344	0.0668	UNASSIGNED
JBD285	0.0037	0.0052	6.9552	1.5274	0.7405	8.6939	UNASSIGNED
JBD291	0.0160	0.0158	3.4474	0.2784	2.4046	0.8548	UNASSIGNED
JBD294	0.0054	0.1865	0.0104	0.0049	0.5183	0.0002	UNASSIGNED
JBD297	0.0000	0.0002	1.1402	0.0007	0.0050	0.0000	UNASSIGNED
JBD299	0.0137	3.7225	0.0150	0.1446	0.0388	0.0057	UNASSIGNED
JBD300	0.0674	0.2167	0.0503	0.2902	0.2956	0.0047	UNASSIGNED
JBD307	0.0008	0.5809	7.9482	7.5930	1.4146	0.2153	UNASSIGNED
JBD312	0.0025	0.4342	1.1749	32.9100	1.2709	0.0063	UNASSIGNED
JBD314	0.0036	3.8213	3.1161	3.4889	0.4304	0.8111	UNASSIGNED
JBD317	0.0193	0.0307	3.1225	1.5297	38.4183	0.3216	UNASSIGNED
JBD320	0.0070	0.0077	0.8138	0.2459	1.7014	0.2247	UNASSIGNED
JBD322	0.0292	0.0563	4.3098	4.1571	26.4970	0.2926	UNASSIGNED
JBD324	6.2953	0.0148	0.0973	0.0761	0.1209	0.0001	UNASSIGNED

JBD330	0.0007	0.0010	2.4842	0.3174	1.0806	17.4476	UNASSIGNED
JBD331	0.0077	0.0113	19.8740	2.4663	9.5259	28.8214	UNASSIGNED
JBD332	0.0011	0.0100	1.7616	1.8411	3.1254	7.1134	UNASSIGNED
JBD334	0.0036	0.0127	4.3869	2.0436	5.1169	0.2083	UNASSIGNED
JBD335	0.0009	0.0003	0.8833	0.0061	2.2116	1.3699	UNASSIGNED
JBD336	0.0001	0.0000	19.9282	0.0274	0.5256	0.0015	UNASSIGNED
JBD337	0.0028	0.0046	0.2307	0.1465	2.0376	8.7429	UNASSIGNED
JBD338	0.0278	0.0014	0.7967	0.0258	10.5842	2.0391	UNASSIGNED
JBD339	0.0002	0.0005	1.6150	0.0041	0.5059	0.0092	UNASSIGNED
JBD340	0.0008	0.0238	1.5957	1.8435	3.7358	1.3010	UNASSIGNED
JBD342	0.0002	0.0002	2.9922	0.0028	0.8392	0.0588	UNASSIGNED
JBD343	0.0345	0.5595	0.2948	0.5848	0.3761	2.4509	UNASSIGNED
JBD344	0.0010	0.0039	2.7916	0.2146	0.4804	0.3387	UNASSIGNED
JBD352	0.0025	0.2784	4.1542	22.4045	5.6011	0.0936	UNASSIGNED
JBD375	36.5879	0.0379	0.3620	0.0493	34.3166	0.0001	UNASSIGNED
JBD378	0.0002	0.0041	1.3465	4.5104	12.0192	0.0004	UNASSIGNED
JBD382	0.0002	0.0066	32.2516	9.9475	0.9761	0.0466	UNASSIGNED
JBD383	0.0058	0.2430	6.9716	0.2002	1.8996	0.5595	UNASSIGNED
JBD385	0.0444	0.0000	0.0001	0.0001	0.0013	0.0000	UNASSIGNED
JBD401	0.9278	0.0014	0.6564	0.0146	1.4281	0.0341	UNASSIGNED
JBD407	0.0382	0.0001	1.2918	0.0074	1.2713	0.0333	UNASSIGNED
JBD409	0.0022	0.0023	33.7239	2.1005	7.1903	3.1949	UNASSIGNED
JBD439	0.0031	0.0048	2.6742	0.6650	0.5239	2.4575	UNASSIGNED
ZPL023	6.9409	0.0833	0.0034	0.0047	0.0689	0.0001	UNASSIGNED
ZPL024	1.8689	0.0057	0.1716	0.0095	0.5813	0.0023	UNASSIGNED
ZPL025	7.7819	0.0102	0.0673	0.0051	2.0384	0.0036	UNASSIGNED
ZPL027	0.0191	0.0107	0.0787	0.0203	0.3017	8.0352	UNASSIGNED

Table B.3. Late Middle Preclassic Core Member Membership Probability Results. The results are based on PC1-PC8 explaining 92% of the sample variance. Samples assigned to the LMPC FW and LMPC UTIL 2 groups are not presented in this table.

ANID	LMPC AS	LMPC CA	LMPC FW	LMPC JOV	LMPC UTIL1	LMPC UTIL2	Best Group
JBD302	80.9441	0.4086	0.0819	4.1265	0.0298	0.0000	LMPC AS
JBD308	7.6859	0.2196	0.0000	0.6432	0.0186	0.0000	LMPC AS
JBD309	22.6004	0.2188	0.0526	1.8040	0.0458	0.0000	LMPC AS
JBD310	18.0595	0.2046	0.0530	1.6494	0.0426	0.0000	LMPC AS
JBD328	53.7735	0.2916	0.0612	0.9550	0.0174	0.0000	LMPC AS

JBD329	12.3099	0.2427	0.0000	0.4134	0.0838	0.0005	LMPC AS
JBD345	84.3282	0.2967	0.0223	0.9292	0.1555	0.0137	LMPC AS
JBD346	63.1638	0.1773	0.0087	0.4050	0.0504	0.0000	LMPC AS
JBD347	81.9515	0.1728	0.0082	0.2950	0.0480	0.0001	LMPC AS
JBD348	74.7673	0.2125	0.0200	0.1776	0.0624	0.0380	LMPC AS
JBD349	74.7787	0.2203	0.0058	0.1630	0.1701	0.0694	LMPC AS
JBD030	0.0086	78.3030	0.0000	7.2931	0.0821	0.0000	LMPC CA
JBD071	0.0088	81.6022	0.0000	8.9930	0.1574	0.0000	LMPC CA
JBD089	0.0136	82.1688	0.0000	0.5044	0.2702	0.0000	LMPC CA
JBD092	0.0205	85.3031	0.0000	0.4518	0.2126	0.0000	LMPC CA
JBD148	0.4493	47.2027	0.0000	1.5509	0.1304	0.0000	LMPC CA
JBD206	0.0177	26.3417	0.0000	4.5512	0.1024	0.0000	LMPC CA
JBD208	0.0731	45.5628	0.0000	4.5656	0.0574	0.0000	LMPC CA
JBD288	0.0035	44.6901	0.0000	6.5328	0.2178	0.0000	LMPC CA
ZPL020	0.0054	30.3458	0.0000	6.1356	0.3865	0.0001	LMPC CA
ZPL021	0.0031	57.4543	0.0000	2.2461	0.5642	0.0000	LMPC CA
CHP104	0.1071	0.0843	0.0000	70.1320	0.1175	0.0000	LMPC JOV
CHP117	0.0126	0.0541	0.0000	41.2752	0.0334	0.0000	LMPC JOV
CHP118	0.0046	0.1634	0.0000	19.3393	0.5701	0.0000	LMPC JOV
CHP119	0.0550	0.0944	0.0000	3.7747	0.4963	0.0000	LMPC JOV
JBD011	0.0049	0.1344	0.0000	12.7464	0.0430	0.0000	LMPC JOV
JBD109	0.0030	0.0835	0.0000	69.0571	0.0099	0.0000	LMPC JOV
JBD110	0.0031	0.0828	0.0000	78.2529	0.0134	0.0000	LMPC JOV
JBD200	0.0010	0.0702	0.0000	16.2639	0.1323	0.0000	LMPC JOV
JBD201	0.0046	0.1191	0.0000	89.4475	0.0309	0.0000	LMPC JOV
JBD202	0.0004	0.0678	0.0000	91.7204	0.0056	0.0000	LMPC JOV

JBD203	0.0005	0.0576	0.0000	21.6425	0.0083	0.0000	LMPC JOV
JBD204	0.0004	0.0843	0.0000	17.1319	0.0045	0.0000	LMPC JOV
JBD205	0.0006	0.0873	0.0000	97.7168	0.0078	0.0000	LMPC JOV
CHP098	2.0945	0.4567	0.6626	1.2269	82.9704	0.1735	LMPC UTIL1
CHP099	1.7575	0.4282	0.6228	0.9465	26.0322	0.1211	LMPC UTIL1
CHP100	1.3297	0.4413	0.3993	1.1507	57.1171	0.0782	LMPC UTIL1
CHP101	0.1576	0.3558	0.1661	0.2507	65.4023	2.5205	LMPC UTIL1
CHP102	0.2717	0.3144	0.0997	0.1236	33.0105	3.0994	LMPC UTIL1
CHP103	0.2718	0.3041	0.0137	0.0897	52.7805	0.3975	LMPC UTIL1
CHP116	0.0499	0.4413	0.6423	0.3618	85.9072	3.1923	LMPC UTIL1
JBD020	0.1993	0.3028	0.1275	0.1544	37.1488	0.0207	LMPC UTIL1
JBD081	0.0113	0.2158	0.0301	0.1269	12.2130	0.3287	LMPC UTIL1
JBD115	0.9415	0.4840	1.4636	0.7088	81.6970	0.0860	LMPC UTIL1
JBD116	7.7414	0.3557	0.2902	0.5005	59.9992	0.0021	LMPC UTIL1
CHP113	0.1947	0.2765	7.1115	0.6077	2.9731	0.7168	UNASSIGNED
CHP078	0.0587	0.3446	3.5917	0.2014	4.9946	15.9142	UNASSIGNED
CHP079	0.0706	0.4718	0.1013	0.3609	34.1374	4.4853	UNASSIGNED
CHP080	0.0718	0.5156	2.3846	0.9358	34.2592	16.4255	UNASSIGNED
CHP081	0.0785	0.4256	4.3724	0.3965	9.1830	12.1811	UNASSIGNED
CHP082	3.8101	36.0950	0.0000	9.6121	0.1103	0.0001	UNASSIGNED
CHP085	3.6172	0.2600	2.3821	0.5255	0.1610	0.0008	UNASSIGNED
CHP086	0.0278	0.4442	91.1332	0.4598	0.8749	0.4338	UNASSIGNED
CHP087	0.0200	0.3861	26.3215	0.5977	0.3662	0.1178	UNASSIGNED
CHP090	0.0143	0.3476	57.8908	0.3121	0.4599	0.3708	UNASSIGNED
CHP095	7.4857	0.2860	6.0638	0.0698	0.0368	0.0000	UNASSIGNED
CHP096	0.0100	0.1441	0.0000	0.0436	0.0042	0.0000	UNASSIGNED

CHP097	0.0215	0.1868	0.0000	0.0984	0.0051	0.0000	UNASSIGNED
CHP105	9.0982	0.2759	0.0971	1.7964	0.2069	0.0000	UNASSIGNED
CHP106	0.1710	0.3784	22.6968	3.6567	0.2519	0.0013	UNASSIGNED
CHP107	2.9664	0.4285	69.8313	1.7619	0.2938	0.0006	UNASSIGNED
CHP108	0.0779	0.3367	21.5424	0.6774	0.1849	0.0011	UNASSIGNED
CHP109	0.0179	0.6217	34.1450	0.9707	0.1494	0.0009	UNASSIGNED
CHP111	0.0273	0.1502	1.0289	0.0804	0.7437	2.9821	UNASSIGNED
CHP112	6.4804	0.5785	28.6355	1.8311	3.1976	9.9898	UNASSIGNED
CHP114	13.3417	0.3567	13.2456	0.6177	0.9358	2.2274	UNASSIGNED
CHP120	0.0400	0.4333	11.2753	0.8674	1.0854	0.0393	UNASSIGNED
CHP122	0.0138	0.1750	19.4740	0.5319	0.2708	0.0000	UNASSIGNED
CHP124	0.3952	0.3420	23.8564	0.4009	2.0565	6.0455	UNASSIGNED
CHP125	0.0173	0.4039	1.4654	0.6388	2.4547	1.9892	UNASSIGNED
JBD001	0.0202	0.3485	25.5447	1.6367	0.3958	0.0227	UNASSIGNED
JBD002	7.8058	0.4639	29.1794	0.9404	1.3354	1.2205	UNASSIGNED
JBD003	0.0374	0.5922	2.0225	2.6070	0.5397	0.0006	UNASSIGNED
JBD005	1.5355	0.4130	45.5630	1.7351	0.7788	0.1440	UNASSIGNED
JBD006	0.7086	0.1370	0.4366	0.0418	0.7562	9.2558	UNASSIGNED
JBD007	1.0469	0.3155	64.1077	0.6438	0.3296	0.0938	UNASSIGNED
JBD009	0.0117	0.2293	29.6555	0.2960	0.2458	0.2881	UNASSIGNED
JBD012	0.0196	0.2413	0.0194	0.5699	0.1977	0.0078	UNASSIGNED
JBD017	8.9687	0.1676	0.0311	0.0568	0.4860	21.0359	UNASSIGNED
JBD018	1.8628	0.2470	0.5185	0.1516	2.7047	32.0580	UNASSIGNED
JBD021	0.1064	0.5472	28.1909	3.1663	0.4612	0.0006	UNASSIGNED
JBD022	0.0250	14.3940	0.0000	9.4629	0.0979	0.0000	UNASSIGNED
JBD024	17.3628	0.2797	1.8709	0.0789	0.0363	0.0000	UNASSIGNED

JBD031	0.1630	0.4801	0.0000	50.4501	0.0944	0.0000	UNASSIGNED
JBD032	9.5034	0.4901	0.3415	2.1065	0.5081	1.5580	UNASSIGNED
JBD033	0.0058	10.6335	0.0000	3.2762	0.0488	0.0000	UNASSIGNED
JBD034	0.0049	59.1237	0.0000	11.0558	0.3488	0.0006	UNASSIGNED
JBD035	0.0069	0.1822	0.0030	0.1399	3.1575	0.4001	UNASSIGNED
JBD036	0.0295	0.2050	0.0017	0.2424	2.8591	0.4119	UNASSIGNED
JBD041	0.5066	0.5434	36.2249	1.2966	1.0130	0.3709	UNASSIGNED
JBD042	0.1627	0.1739	49.0430	0.1137	0.5489	0.3011	UNASSIGNED
JBD043	10.4789	0.2613	0.2157	0.2611	0.0787	0.0000	UNASSIGNED
JBD044	0.0290	0.2281	2.5665	0.2177	1.5524	24.3959	UNASSIGNED
JBD046	0.1063	0.2869	91.3845	0.4966	0.3886	0.1987	UNASSIGNED
JBD049	5.0799	0.2190	91.1124	0.1973	0.2730	0.2460	UNASSIGNED
JBD050	0.2553	0.2568	3.5090	1.3712	0.4419	0.0000	UNASSIGNED
JBD052	0.0070	4.2070	0.0000	8.0443	0.1164	0.0000	UNASSIGNED
JBD055	0.0554	0.1936	0.0000	0.1127	3.6775	0.9287	UNASSIGNED
JBD056	0.0297	0.2642	0.1029	0.1554	26.2890	6.6355	UNASSIGNED
JBD058	0.0339	0.5441	0.0662	1.8773	8.7366	55.4579	UNASSIGNED
JBD059	0.0081	0.8783	0.0000	18.7979	0.0585	0.0000	UNASSIGNED
JBD060	0.0065	20.7302	0.0000	3.1568	0.0674	0.0000	UNASSIGNED
JBD067	0.1364	0.2354	0.7517	1.0379	0.4321	0.0008	UNASSIGNED
JBD068	0.1032	0.3341	5.7967	0.0681	0.0259	0.0000	UNASSIGNED
JBD069	1.4833	1.7601	0.0000	4.1481	0.0247	0.0000	UNASSIGNED
JBD070	0.1514	0.2611	94.5241	0.2733	0.1169	0.0041	UNASSIGNED
JBD072	0.0035	12.4595	0.0000	2.8774	0.1296	0.0000	UNASSIGNED
JBD073	0.0148	1.9479	0.0000	15.7768	0.0502	0.0000	UNASSIGNED
JBD074	0.2648	0.3079	0.9567	0.1328	19.0701	8.8832	UNASSIGNED

JBD075	0.0687	0.1270	0.0000	0.0097	0.0443	0.0002	UNASSIGNED
JBD076	4.3180	0.3326	0.2721	0.2704	0.6125	1.2809	UNASSIGNED
JBD077	0.3289	0.2508	0.1891	0.1829	0.7845	34.2468	UNASSIGNED
JBD078	1.9975	0.3242	0.0191	0.2452	10.0516	32.2851	UNASSIGNED
JBD079	0.0004	0.0673	0.0000	0.4631	0.1115	0.0000	UNASSIGNED
JBD080	0.0240	1.2329	0.0858	3.6009	1.9466	0.2015	UNASSIGNED
JBD083	0.0402	0.3443	7.9998	0.2111	4.6731	2.3868	UNASSIGNED
JBD084	0.0170	0.3285	7.8390	0.5486	0.2718	0.1575	UNASSIGNED
JBD085	0.0070	0.3100	0.0000	17.4593	0.0605	0.0000	UNASSIGNED
JBD087	0.0135	3.3075	0.0000	3.4646	0.0783	0.0000	UNASSIGNED
JBD088	0.3685	0.2954	0.0114	2.1718	0.4043	0.0002	UNASSIGNED
JBD091	0.0097	1.7229	0.0000	4.7522	0.1686	0.0000	UNASSIGNED
JBD093	0.0026	0.9178	0.0000	2.0898	0.0479	0.0000	UNASSIGNED
JBD094	0.0289	0.2350	0.1512	0.1275	15.8052	4.2987	UNASSIGNED
JBD095	0.0136	0.3899	11.2447	0.3922	1.8755	2.6901	UNASSIGNED
JBD097	0.0136	0.1474	0.0628	0.8021	0.3498	0.0000	UNASSIGNED
JBD099	0.7594	0.2112	19.9480	1.1173	0.1233	0.0000	UNASSIGNED
JBD100	0.0778	0.2012	0.2860	0.3508	1.1524	0.0019	UNASSIGNED
JBD101	1.3821	0.2315	4.1127	0.2680	0.6121	17.2384	UNASSIGNED
JBD102	0.0078	0.2847	2.3955	1.1752	0.0439	0.0000	UNASSIGNED
JBD103	3.6038	0.1366	0.0667	0.9598	0.1555	0.0000	UNASSIGNED
JBD106	0.0047	0.1908	31.8689	0.4992	0.2323	0.0058	UNASSIGNED
JBD107	0.0123	0.1405	0.0683	0.9205	0.1534	0.0000	UNASSIGNED
JBD108	0.0146	0.1396	0.0000	0.5715	0.3744	0.0000	UNASSIGNED
JBD111	0.0009	0.0608	0.0000	4.6182	2.8594	0.0000	UNASSIGNED
JBD113	5.7559	0.2245	1.1520	0.2237	0.9084	67.2158	UNASSIGNED

JBD117	0.0059	0.1158	0.0000	0.0311	1.2929	0.5471	UNASSIGNED
JBD119	1.1103	0.3290	20.7566	0.5220	1.2164	37.1111	UNASSIGNED
JBD123	0.1624	0.2315	3.7774	0.3199	1.6395	0.3148	UNASSIGNED
JBD126	0.2502	0.6562	0.5396	2.4151	0.8105	15.6995	UNASSIGNED
JBD127	0.0076	0.2131	0.2098	0.2613	0.2257	0.0331	UNASSIGNED
JBD128	0.1386	0.1989	3.6627	0.3456	0.1604	0.0012	UNASSIGNED
JBD129	0.0249	0.1991	29.4211	0.4303	0.2599	0.0530	UNASSIGNED
JBD130	0.6541	0.4847	3.5094	1.7648	0.3279	0.0161	UNASSIGNED
JBD131	0.0730	0.4000	53.3498	1.1927	0.6788	0.1220	UNASSIGNED
JBD132	0.0610	0.1665	13.4232	0.1389	0.3779	0.5326	UNASSIGNED
JBD133	9.1317	0.2673	90.8248	0.9568	0.3445	0.0726	UNASSIGNED
JBD134	0.0062	0.1659	0.4632	0.2523	0.1685	0.0035	UNASSIGNED
JBD135	15.8703	0.4148	20.4870	1.4042	0.8673	0.2510	UNASSIGNED
JBD136	1.9810	0.2342	63.8358	0.1962	0.5625	5.0816	UNASSIGNED
JBD138	0.4134	0.1898	35.4908	0.1622	0.4584	1.5569	UNASSIGNED
JBD139	0.0043	0.3331	0.0113	2.3035	0.1622	0.0003	UNASSIGNED
JBD143	4.5885	0.8223	1.3880	6.4440	0.9944	0.1234	UNASSIGNED
JBD144	0.2600	0.2232	63.0285	0.2415	0.4076	2.0655	UNASSIGNED
JBD145	0.3789	0.1944	0.0000	0.0398	0.0076	0.0000	UNASSIGNED
JBD146	0.0396	0.2315	0.0000	0.1006	0.0054	0.0000	UNASSIGNED
JBD147	0.0334	0.6970	0.1796	4.9428	1.2468	0.0168	UNASSIGNED
JBD149	0.0021	0.0738	0.0000	1.3646	0.0102	0.0000	UNASSIGNED
JBD191	0.2610	0.3087	36.4916	0.4747	0.4476	0.1149	UNASSIGNED
JBD192	30.4312	0.1666	0.0713	0.0659	0.0304	0.0000	UNASSIGNED
JBD194	0.6947	0.1742	22.8310	0.0786	0.1022	0.0004	UNASSIGNED
JBD196	0.0418	0.1493	0.0000	0.0224	0.0121	0.0000	UNASSIGNED

JBD198	0.7153	0.2815	75.5004	0.5584	0.1417	0.0032	UNASSIGNED
JBD199	0.3816	1.9915	0.0016	3.2296	0.5368	0.0075	UNASSIGNED
JBD207	0.0025	0.1442	0.0000	0.0110	0.0043	0.0000	UNASSIGNED
JBD209	0.0102	61.2123	0.0000	1.9366	0.0236	0.0000	UNASSIGNED
JBD210	0.0239	4.1610	0.0000	15.9334	0.1210	0.0000	UNASSIGNED
JBD226	0.0109	0.3964	29.3109	0.6008	0.0344	0.0000	UNASSIGNED
JBD266	2.6434	0.2675	78.0843	0.2890	0.4251	0.4731	UNASSIGNED
JBD278	0.6509	0.2613	98.7326	0.5358	0.3003	0.2721	UNASSIGNED
JBD289	0.0209	0.2204	0.0000	26.2204	0.0197	0.0000	UNASSIGNED
JBD290	0.0323	0.2890	0.0000	13.3701	0.0615	0.0000	UNASSIGNED
JBD292	0.0051	11.7786	0.0000	8.1961	0.0871	0.0000	UNASSIGNED
JBD293	0.0026	0.0529	0.0000	0.0021	0.0033	0.0000	UNASSIGNED
JBD304	1.8496	0.3086	0.0764	2.4658	0.0399	0.0000	UNASSIGNED
JBD327	0.4796	0.6766	0.1562	5.5006	0.0538	0.0000	UNASSIGNED
JBD350	1.0106	0.2294	0.0058	0.9343	0.0744	0.0001	UNASSIGNED
JBD351	2.4513	0.2277	0.0001	0.3072	0.0544	0.0041	UNASSIGNED
JBD380	0.1095	0.2594	95.4922	0.2211	0.2857	0.5965	UNASSIGNED
JBD389	0.0218	0.1926	0.0003	0.0361	0.0107	0.0000	UNASSIGNED
JBD390	0.0593	0.3003	0.5643	1.9472	0.1496	0.0001	UNASSIGNED
JBD435	0.0851	0.2469	27.0850	1.3339	0.4045	0.0008	UNASSIGNED
JBD437	1.8470	0.2672	44.5453	0.4507	0.2269	0.0125	UNASSIGNED
JBD438	12.7040	0.2331	77.9234	0.2424	0.3685	6.7446	UNASSIGNED
ZPL015	0.1526	13.1346	0.0000	12.5284	0.1771	0.0001	UNASSIGNED
ZPL017	0.0948	0.2044	23.8315	0.4443	0.2241	0.0511	UNASSIGNED
ZPL019	0.0055	35.7896	0.0000	4.1024	0.1356	0.0000	UNASSIGNED
ZPL022	0.0819	25.0119	0.0000	13.9352	0.1335	0.0000	UNASSIGNED

Table B.4. Late Middle Preclassic Core Member Membership Probability Results for LMPC FW and LMPC UTIL2 Groups. These results are based on 31 elements.

ANID	LMPC FW	LMPC UTIL2	Best Group
CHP084	98.6318	0.3921	LMPC FW
CHP088	49.1022	1.7350	LMPC FW
CHP089	70.3307	0.1563	LMPC FW
CHP091	58.6182	0.3761	LMPC FW
CHP092	91.1744	0.1736	LMPC FW
CHP093	65.4289	7.5963	LMPC FW
CHP094	3.7724	0.5474	LMPC FW
CHP110	12.0141	3.1911	LMPC FW
CHP121	39.1107	0.3424	LMPC FW
CHP123	46.5980	0.5084	LMPC FW
JBD004	98.4569	0.2830	LMPC FW
JBD008	28.1855	0.8941	LMPC FW
JBD010	42.8935	3.2704	LMPC FW
JBD023	6.8429	1.2371	LMPC FW
JBD025	16.4505	0.5159	LMPC FW
JBD026	58.0474	2.1881	LMPC FW
JBD027	15.6422	3.7724	LMPC FW
JBD028	47.7172	0.0931	LMPC FW
JBD029	7.4050	0.4685	LMPC FW
JBD045	55.0876	3.4002	LMPC FW
JBD047	87.5523	0.4333	LMPC FW
JBD048	30.2255	0.2823	LMPC FW
JBD061	71.0547	0.8244	LMPC FW
JBD062	16.7227	5.2460	LMPC FW
JBD063	32.7849	0.5733	LMPC FW
JBD064	15.6064	0.1560	LMPC FW
JBD065	64.9517	1.5023	LMPC FW
JBD066	94.0945	0.3048	LMPC FW
JBD096	20.0656	0.1760	LMPC FW
JBD098	44.4132	0.1677	LMPC FW
JBD104	40.9821	1.4640	LMPC FW
JBD105	18.5918	0.7149	LMPC FW
JBD137	52.6673	6.4586	LMPC FW
JBD140	19.7519	0.3440	LMPC FW
JBD141	53.9806	0.2756	LMPC FW
JBD142	49.9463	0.2631	LMPC FW

JBD150	26.3819	8.0585	LMPC FW
JBD190	97.4376	0.6160	LMPC FW
JBD193	50.5856	1.1601	LMPC FW
JBD195	94.0542	4.5702	LMPC FW
JBD197	94.7031	0.6183	LMPC FW
JBD225	27.8577	1.2790	LMPC FW
JBD228	87.1195	3.6767	LMPC FW
JBD242	63.9546	1.7130	LMPC FW
JBD267	25.0561	0.0706	LMPC FW
JBD268	68.7749	6.0842	LMPC FW
JBD377	20.0742	0.2126	LMPC FW
JBD379	60.5077	5.1855	LMPC FW
JBD381	32.7977	2.4416	LMPC FW
ZPL014	82.3677	1.9899	LMPC FW
ZPL016	64.4595	1.1031	LMPC FW
ZPL018	11.2997	0.1994	LMPC FW
CHP083	0.0003	14.1116	LMPC UTIL2
CHP113	0.0386	12.7849	LMPC UTIL2
CHP115	0.0002	14.8443	LMPC UTIL2
JBD013	0.0000	49.0655	LMPC UTIL2
JBD014	0.0000	36.1760	LMPC UTIL2
JBD015	0.0001	32.3871	LMPC UTIL2
JBD016	0.0495	27.8257	LMPC UTIL2
JBD019	0.0014	81.4360	LMPC UTIL2
JBD037	0.0149	94.6275	LMPC UTIL2
JBD038	0.0000	57.9422	LMPC UTIL2
JBD039	0.0000	34.5745	LMPC UTIL2
JBD040	0.0000	82.0731	LMPC UTIL2
JBD051	0.0000	81.7616	LMPC UTIL2
JBD053	0.0004	17.5316	LMPC UTIL2
JBD054	0.0000	54.4726	LMPC UTIL2
JBD057	0.0002	65.1086	LMPC UTIL2
JBD082	0.3692	77.6833	LMPC UTIL2
JBD086	0.0312	46.5048	LMPC UTIL2
JBD090	0.0001	31.0461	LMPC UTIL2
JBD112	0.0000	87.0697	LMPC UTIL2
JBD114	0.0003	85.5401	LMPC UTIL2
JBD118	0.0001	17.1720	LMPC UTIL2
JBD120	0.0001	63.6044	LMPC UTIL2
JBD121	0.0000	30.9126	LMPC UTIL2
JBD122	0.0123	28.4245	LMPC UTIL2

JBD124	0.0000	29.0278	LMPC UTIL2
JBD125	0.0000	96.8661	LMPC UTIL2
JBD269	0.0458	27.9541	LMPC UTIL2
JBD270	0.0000	51.1507	LMPC UTIL2
JBD286	0.0000	61.8772	LMPC UTIL2
JBD287	0.0010	80.9265	LMPC UTIL2
JBD433	0.0000	96.0998	LMPC UTIL2
JBD436	0.0003	55.1918	LMPC UTIL2

Description of Groups

The remainder of this appendix is concerned with the identified chemical groupings presented in Chapter 4. Tables B.5, B.6, and B.7 present the mean and standard deviation for each element of every group observed with NAA. Each group is described in chemical detail.

Table B.5. Early Preclassic Ceramic Compositional Group Descriptive Statistics. This table includes the mean and standard deviation for each group based only on core members of the group. Bold indicates heightened levels of an element.

	EPC_BVDW1		EPC_BVDW2		EPC_CA		EPC_UTIL		EPC_XUN	
Element	Mean	St Dev	Mean	St Dev	Mean	St Dev	Mean	St Dev	Mean	St Dev
Na	**12436.38**	2399.41	**11294.22**	1362.01	1661.44	703.80	3874.59	363.35	4832.70	1117.51
Al	82995.04	6687.05	78990.05	6816.29	64445.38	11428.86	85267.67	4230.16	56642.00	2354.67
K	24247.10	4545.07	20983.02	3342.91	12198.33	5047.91	22027.07	1514.05	9105.40	463.01
Ca	11737.62	3631.92	16261.30	4643.94	**101633.13**	51648.34	8819.75	2059.61	177410.00	5133.60
Sc	8.92	1.88	8.11	1.34	11.47	2.05	13.74	0.95	6.20	0.12
Ti	2689.55	856.44	2284.88	247.00	4445.11	854.83	3653.66	459.97	1768.50	45.25
V	40.15	14.62	26.83	5.69	**70.12**	19.91	**74.77**	7.14	28.38	10.66
Cr	34.52	12.19	39.43	17.92	58.50	9.37	62.76	3.15	33.71	1.22
Mn	422.46	101.53	485.26	133.20	236.90	160.17	130.40	15.25	253.49	41.61
Fe	20764.24	4299.37	19124.04	3522.67	**28422.25**	6638.89	**30546.58**	2128.65	18744.00	1124.30
Co	4.24	0.93	5.25	1.37	6.66	3.51	6.04	0.62	4.06	0.27
Ni	0.00	0.00	22.20	0.00	56.69	5.60	23.83	2.38	0.00	0.00

Zn	83.55	24.58	63.50	17.88	71.97	10.06	73.51	12.21	44.47	2.70
As	**13.12**	2.45	8.15	3.16	7.03	1.94	6.57	1.37	4.32	0.14
Rb	**174.13**	12.44	104.63	18.12	93.67	33.53	**146.46**	5.06	38.58	2.89
Sr	49.35	7.58	72.57	10.85	83.22	24.82	50.73	7.24	65.08	19.06
Zr	156.87	31.64	105.41	13.83	139.99	32.66	117.32	29.08	97.27	14.25
Sb	1.71	0.28	1.14	0.15	0.91	0.23	1.46	0.23	0.59	0.03
Cs	**10.30**	1.66	5.53	0.94	5.33	1.61	6.52	0.50	0.88	0.41
Ba	463.15	101.47	**759.88**	96.74	**710.34**	405.99	542.54	119.10	342.52	23.15
La	28.17	3.22	18.68	3.37	29.53	10.25	39.27	12.00	10.68	0.48
Ce	63.56	10.39	43.75	12.13	65.84	31.11	88.59	28.51	21.75	1.43
Nd	26.84	2.48	17.52	2.95	30.00	12.89	36.47	13.35	9.73	0.14
Sm	5.76	0.59	3.91	0.63	5.92	2.72	7.50	2.57	1.76	0.08
Eu	0.74	0.16	0.64	0.05	1.07	0.51	1.21	0.40	0.34	0.04
Tb	0.76	0.12	0.59	0.08	0.81	0.39	0.89	0.12	0.26	0.03
Dy	4.97	0.61	3.69	0.51	4.76	2.04	5.05	0.40	1.51	0.12
Yb	3.04	0.32	2.65	0.18	2.74	0.99	3.10	0.29	1.06	0.12
Lu	0.46	0.04	0.38	0.03	0.38	0.14	0.44	0.04	0.16	0.02
Hf	6.41	0.50	5.51	0.49	5.95	1.34	5.43	0.62	4.66	0.32
Ta	1.23	0.20	0.79	0.15	1.36	0.24	1.58	0.24	0.56	0.02
Th	**17.75**	3.27	10.49	1.80	11.44	1.84	**17.88**	1.66	8.02	0.65
U	**4.87**	0.68	2.26	0.86	2.16	0.53	2.46	0.44	1.41	0.14

Early Preclassic

EPC_BVDW1 is characterized by very high sodium (Na) and potassium (K) indicating a strongly alkali-rich composition. Calcium (Ca) is moderate, and iron (Fe) is present at intermediate levels. Rubidium (Rb), cesium (Cs), thorium (Th), and uranium (U) are relatively elevated, and rare earth element (REE) concentrations are moderate to high. Overall, this group reflects an alkali-enriched silicate paste.

EPC_BVDW2 is chemically similar to BVDW1 but slightly less enriched overall. Sodium and potassium remain high, though lower than in BVDW1, and calcium is somewhat elevated. Iron and transition metals are moderate. Barium (Ba) is particularly high in this group relative to BVDW1, while Rb and Cs are lower. REE concentrations are moderate but consistently below those of BVDW1 and UTIL.

EPC_CA is strongly defined by extremely high calcium (Ca ~101,633 ppm), far exceeding all groups except XUN. Aluminum and alkalis (Na, K) are comparatively low, and many trace and rare earth elements occur at diluted levels relative to other groups. However, Fe, Sc, Ti, V, and Cr are elevated compared to BVDW groups. This chemistry indicates a highly calcareous paste, where carbonate content strongly influences overall elemental concentrations.

EPC_UTIL displays the highest iron (Fe) concentrations among the non-calcareous groups and elevated Sc, Ti, V, and Cr, suggesting a relatively mafic composition. Potassium is high, while calcium is modest. REEs (La, Ce, Nd, Sm) are notably elevated compared to BVDW1 and BVDW2, and Th is also high. Rubidium is strongly enriched. Overall, UTIL reflects a trace-element–rich, iron-rich composition distinct from the more alkali-dominant BVDW groups.

EPC_XUN is chemically the most distinct group. It exhibits extremely high calcium (Ca ~177,410 ppm), the highest of all groups, along with very low aluminum, potassium, scandium, titanium, and transition metals. Rare earth elements are consistently the lowest across all groups. Rubidium, cesium, thorium, and uranium are also comparatively low. This composition reflects a highly calcareous, trace-element–poor matrix, strongly separated from the other groups.

These groups differ primarily along two major chemical axes. First is calcium enrichment: EPC_CA and especially EPC_XUN are strongly calcareous, with carbonate dilution of trace elements. Second is the degree of iron and transitional element enrichment:

EPC_UTIL shows the strongest Fe–Sc–Ti–V–Cr and REE enrichment, BVDW1 is characterized by high alkalis and elevated Rb–Cs–Th–U, BVDW2 represents a slightly less enriched but Ba-rich variant, and XUN is strongly depleted in most trace and rare earth elements.

Table B.6. Early Middle Preclassic Ceramic Compositional Group Descriptive Statistics. This table includes the mean and standard deviation for each group based only on core members of the group. Bold indicates heightened levels of an element.

	EMPC_ASH		EMPC_CA		EMPC_FW1		EMPC_FW2		EMPC_FW3		EMPC_UTIL	
Element	Mean	St Dev	Mean	St Dev	Mean	St Dev	Mean	St Dev	Mean	St Dev	Mean	St Dev
Na	**11379.22**	2583.48	985.32	712.99	2575.82	1001.20	1674.06	459.87	**7266.31**	1994.05	2774.11	639.90
Al	90237.35	15527.39	72685.35	14367.27	120978.19	19941.11	122460.00	10828.04	107381.53	9980.21	94038.75	8898.77
K	17405.49	5036.42	7139.92	3939.36	20202.04	4073.39	16655.36	2134.07	24006.41	5861.37	17284.12	2740.06
Ca	**19822.95**	11780.11	**146114.57**	47412.36	8900.69	5227.53	12022.51	2425.08	13572.89	5347.14	10449.57	2930.79
Sc	8.69	1.70	11.36	2.49	**19.25**	2.23	**20.91**	2.25	15.41	1.93	14.96	1.50
Ti	2788.14	622.56	3692.21	1060.54	5151.46	944.39	4843.16	529.33	3661.49	570.89	4163.08	472.51
V	35.82	15.18	71.98	23.42	98.99	17.25	115.39	13.38	79.84	16.17	92.97	17.76
Cr	33.12	8.60	63.33	22.07	**98.66**	15.51	**96.93**	9.07	65.60	11.22	73.16	7.94
Mn	**623.76**	321.01	206.66	173.83	391.37	166.95	120.72	50.39	179.29	52.13	110.50	24.47
Fe	22772.29	6183.89	29537.46	7399.63	**52413.96**	8314.76	**53740.86**	4667.77	32624.88	7294.46	33363.49	5144.41
Co	5.84	2.34	5.89	2.92	**21.97**	7.20	6.75	1.69	3.75	0.92	5.70	0.68
Ni	27.70	12.35	24.00	14.55	63.70	24.77	50.57	22.10	37.79	24.54	38.56	17.07
Zn	72.80	17.38	58.11	12.88	**114.10**	24.57	95.62	16.81	71.27	8.29	75.74	14.10
As	12.15	5.61	8.10	3.62	12.22	3.41	16.80	5.95	11.46	5.54	9.19	3.11
Rb	121.17	45.16	53.26	39.50	151.19	35.77	**244.07**	51.18	167.82	37.40	135.82	23.38
Sr	78.96	21.97	79.27	47.31	66.31	13.59	51.26	3.22	59.33	16.68	45.52	13.51
Zr	171.70	39.83	159.77	71.92	189.43	42.61	187.30	30.07	139.50	39.72	158.92	36.12
Sb	1.44	0.51	0.98	0.25	2.05	0.65	1.82	0.53	1.53	0.25	1.11	0.23
Cs	7.42	3.22	3.86	2.99	8.84	2.60	**15.30**	4.44	8.85	1.38	7.48	1.42
Ba	768.10	298.33	514.39	221.61	662.66	190.44	636.39	121.66	954.79	227.71	447.23	94.17
La	28.96	9.71	21.48	8.96	**48.86**	7.51	31.47	3.14	29.00	4.13	36.74	6.17
Ce	68.95	21.67	55.25	22.26	**151.47**	51.47	86.90	17.42	63.48	9.16	77.93	14.95
Nd	27.75	9.44	19.84	8.13	**46.24**	7.96	31.58	2.74	25.72	3.78	33.97	7.22
Sm	6.11	1.91	4.21	1.65	**10.09**	1.63	6.73	0.63	5.63	0.85	6.93	1.19

Eu	0.92	0.31	0.79	0.30	1.73	0.28	1.21	0.11	0.93	0.11	1.15	0.21
Tb	0.88	0.32	0.64	0.23	1.54	0.26	1.07	0.13	0.79	0.19	0.93	0.19
Dy	5.47	1.59	3.79	1.25	**8.93**	1.09	6.65	0.53	5.15	0.75	5.48	0.72
Yb	3.49	0.85	2.50	0.69	**5.42**	0.65	4.31	0.21	3.27	0.43	3.45	0.48
Lu	0.50	0.12	0.35	0.09	0.72	0.10	0.60	0.04	0.47	0.07	0.48	0.07
Hf	6.80	1.40	6.30	2.33	7.92	1.42	7.60	1.08	5.84	1.10	5.97	0.97
Ta	1.12	0.31	1.07	0.29	2.06	0.32	2.01	0.32	1.51	0.24	1.72	0.18
Th	15.88	5.17	11.62	2.90	22.70	4.90	23.90	8.98	18.96	2.90	19.51	3.48
U	3.05	1.43	1.56	0.58	3.32	0.61	2.73	0.32	2.55	0.73	2.37	0.45

Early Middle Preclassic

EMPC_ASH is characterized by very high sodium (Na) and elevated calcium (Ca), along with unusually high manganese (Mn) relative to the other groups. Iron (Fe) is moderate compared to the FW groups, and trace elements such as Sc, Ti, V, and Cr are comparatively low. Rare earth element (REE) concentrations are modest. Overall, this group reflects a sodium-rich, moderately calcareous matrix with limited mafic enrichment.

EMPC_CA is defined by extremely high calcium (Ca), far exceeding all other groups, and comparatively low sodium (Na), potassium (K), and manganese (Mn). Most transition metals (Sc, V, Cr, Ni) and REEs occur at lower concentrations than in the FW groups. This chemistry indicates a strongly calcareous paste in which carbonate content likely dilutes the trace element fractions, making it the most chemically distinct group.

EMPC_FW1 exhibits very high iron (Fe), scandium (Sc), titanium (Ti), vanadium (V), chromium (Cr), nickel (Ni), and zinc (Zn), along with strong enrichment in rare earth elements (e.g., La, Ce, Nd, Sm). Thorium (Th), tantalum (Ta), and uranium (U) are also elevated. Calcium is comparatively low. This group represents an iron-rich composition consistent with a mafic or volcaniclastic signature.

EMPC_FW2 closely resembles FW1 in its very high Fe, Sc, Ti, V, and Cr concentrations, indicating a similarly mafic geochemical signature. However, it is distinguished by especially high rubidium (Rb) and cesium (Cs), and slightly lower cobalt (Co) than FW1. REE concentrations are elevated but generally somewhat lower than in FW1. Overall, FW2 is a strongly iron-rich, trace-element–rich group.

EMPC_FW3 is intermediate in composition. Iron, Sc, Ti, and transition metals are elevated but not as high as in FW1 and FW2. Sodium is relatively high, and barium (Ba) reaches the highest levels of all groups. REE concentrations are moderate. FW3 separates out from the other two FW groups based on sodium. Calcium remains modest compared to EMPC_CA. This group reflects a paste distinct from both the highly mafic FW1/FW2 groups and the strongly calcareous EMPC_CA group.

EMPC_UTIL also displays an intermediate chemistry, with moderate Fe, Sc, Ti, and REE concentrations. Calcium is modest, sodium is lower than in FW3 and ASH. Trace elements such as Rb and Cs are elevated but not to the levels observed in FW2. Overall, UTIL represents a compositionally distinct but chemically moderate group.

The groups differ primarily along three geochemical axes: (1) calcium enrichment (with EMPC_CA representing a strongly calcareous composition); (2) degree of iron and mafic trace element enrichment (with EMPC_FW1 and FW2 showing the strongest Fe–Sc–Ti–V–Cr signatures and highest REEs); and (3) alkali and incompatible element variation (with EMPC_ASH high in Na and Mn, FW2 high in Rb and Cs, and FW3 notable for elevated Na and Ba).

Table B.7. Late Middle Preclassic Ceramic Compositional Group Descriptive Statistics. This table includes the mean and standard deviation for each group based only on core members of the group. Bold indicates heightened levels of an element.

	LMPC_AS		LMPC_CA		LMPC_FW1		LMPC_FW2		LMPC_FW3		LMPC_JOV		LMPC_UTIL1		LMPC_UTIL2	
Element	Mean	St Dev	Mean	St Dev	Mean	St Dev	Mean	St Dev	Mean	St Dev	Mean	St Dev	Mean	St Dev	Mean	St Dev
Na	2641.21	940.96	1326.33	1364.27	3110.61	2250.17	2071.16	641.11	**5489.17**	2329.85	585.45	394.96	1878.80	493.24	2644.64	300.24
Al	108225.82	16982.86	69906.18	9236.32	113854.64	15296.02	116968.91	10794.36	108723.08	6855.64	69930.28	14088.75	90753.77	7132.11	88597.93	9308.12
K	16904.64	2536.72	8101.08	1726.48	18427.80	3125.80	18281.68	2777.92	20929.79	2875.34	2182.72	1830.82	12634.11	3561.26	19117.97	3604.95
Ca	9590.33	3878.51	**153131.50**	27585.54	9553.03	4210.03	11556.45	2809.89	10424.97	1853.33	**186675.08**	60900.78	13041.07	2341.38	9574.61	4291.28
Sc	16.21	2.98	12.33	1.80	18.34	2.80	19.66	1.73	16.45	1.27	10.60	3.01	14.13	0.96	14.03	1.53
Ti	4558.05	885.55	3956.06	1744.84	5627.55	849.83	4829.42	535.93	4220.14	583.19	2818.50	1195.40	4221.78	519.63	4347.02	537.62
V	**137.81**	25.06	74.62	14.04	93.87	13.05	112.39	13.91	88.74	12.71	45.31	14.93	72.36	6.73	88.80	13.63
Cr	81.32	13.35	61.81	9.51	96.54	11.35	95.07	8.17	78.07	9.26	41.86	8.82	78.85	10.10	71.86	7.88
Mn	**1050.26**	1232.37	138.30	102.45	254.60	176.47	123.86	57.19	220.91	86.78	196.71	85.34	105.33	27.08	162.30	51.63
Fe	**42161.73**	10745.03	28851.73	4482.78	**48252.17**	7862.03	**50619.06**	6079.23	**41233.12**	6723.57	22322.59	7338.69	32456.83	2967.20	30544.29	3522.65
Co	**14.15**	6.44	4.62	1.83	**14.34**	7.70	6.63	2.28	5.60	1.51	5.13	2.12	4.92	0.72	7.28	1.26
Ni	55.61	28.49	43.12	15.08	55.75	24.86	63.45	26.73	37.47	16.28	31.05	8.71	50.09	20.94	48.04	23.36
Zn	94.75	23.02	58.42	10.85	107.67	17.22	92.52	16.28	82.64	13.82	46.37	15.24	68.44	5.75	91.44	13.30
As	**29.87**	6.95	8.19	3.45	7.62	2.66	12.79	2.64	9.79	1.91	3.89	1.80	7.46	1.21	7.64	2.15
Rb	167.81	52.42	81.62	13.80	140.53	33.02	250.77	75.92	168.42	31.86	10.10	8.32	106.91	37.40	146.11	27.18
Sr	62.62	22.75	56.40	23.29	67.45	30.26	53.33	31.05	57.92	33.11	50.89	16.91	41.55	0.00	48.77	13.33
Zr	174.83	30.91	132.17	57.62	204.85	23.86	186.79	38.62	159.96	26.45	144.82	86.81	152.60	30.99	157.89	26.11
Sb	1.80	0.65	0.89	0.18	2.00	0.33	1.79	0.35	1.66	0.21	0.99	0.36	1.16	0.20	1.09	0.20

Cs	8.67	3.21	5.86	2.03	8.65	2.58	**14.63**	3.57	9.74	1.90	0.82	0.66	5.89	1.87	7.20	1.41
Ba	750.10	206.61	584.43	402.06	643.66	197.98	761.69	114.90	933.96	328.26	726.85	364.58	630.89	102.60	508.94	139.30
La	30.19	5.34	25.95	8.33	**45.65**	10.16	28.85	3.94	30.26	5.02	9.69	3.85	30.15	4.18	**40.76**	10.48
Ce	87.29	29.95	60.40	22.26	**123.60**	45.56	82.21	21.13	67.82	11.94	38.17	19.93	67.04	8.75	88.44	21.99
Nd	30.65	5.09	24.35	6.98	42.54	11.42	28.98	4.44	28.25	4.36	8.67	3.17	28.93	3.91	37.09	9.81
Sm	6.62	1.18	5.01	1.32	9.08	2.74	6.13	0.86	5.97	0.91	2.03	0.64	5.97	0.53	7.51	1.79
Eu	1.13	0.21	0.90	0.25	1.61	0.47	1.11	0.18	1.04	0.15	0.38	0.12	1.00	0.09	1.25	0.27
Tb	1.05	0.14	0.77	0.17	1.30	0.34	1.02	0.16	0.93	0.13	0.29	0.07	0.83	0.14	0.98	0.13
Dy	6.96	2.37	4.53	1.23	7.89	1.88	6.14	0.67	5.76	0.65	2.00	0.48	5.28	0.54	5.84	0.55
Yb	4.07	0.62	2.77	0.64	4.86	1.02	4.01	0.27	3.69	0.29	1.56	0.40	3.19	0.26	3.57	0.42
Lu	0.55	0.09	0.39	0.08	0.66	0.14	0.57	0.04	0.52	0.04	0.23	0.06	0.44	0.03	0.50	0.06
Hf	7.02	1.02	5.22	1.89	8.24	0.80	7.52	0.91	6.90	0.69	6.36	3.46	6.21	1.24	5.98	0.57
Ta	1.84	0.34	1.35	0.36	1.96	0.30	1.75	0.26	1.53	0.18	0.74	0.28	1.58	0.14	1.80	0.22
Th	20.53	3.78	14.17	3.16	20.07	3.91	19.46	4.11	17.37	3.25	12.29	2.66	19.23	3.35	17.17	3.59
U	2.66	0.53	1.80	0.47	3.12	0.51	2.89	0.41	3.09	0.56	1.19	0.56	2.06	0.33	2.61	0.85

Late Middle Preclassic

LMPC_AS is defined by high aluminum (Al ~108,000 ppm), iron (Fe ~42,000 ppm), titanium, vanadium, and chromium, indicating a mafic composition. Potassium is elevated, and trace metals (Co, Ni, Zn) are comparatively high. Rare earth elements (REEs) are consistently enriched (La, Ce, Nd, Sm), as are Th and U. Calcium is modest. Overall, this group reflects a trace-element–rich, arsenic- and iron-rich silicate paste.

LMPC_CA is clearly defined by extremely high calcium (Ca ~153,000 ppm), far exceeding most other LMPC groups. Iron, potassium, and trace elements are comparatively lower, reflecting dilution by carbonate content. REEs are present but at lower concentrations than in other groups. This chemistry indicates a strongly calcareous paste.

LMPC_FW1 exhibits very high iron (~48,000 ppm), and elevated Sc, Ti, V, and Cr, marking it as one of the more mafic and trace-element–enriched groups. Potassium and sodium are moderate to high. REEs (especially La, Ce, Nd) are strongly enriched, and Th and U are elevated. Zr and Hf are also high.

LMPC_FW2 is chemically similar to FW1 but shows even higher iron (~50,600 ppm) and very high Rb and Cs. Aluminum remains high, and transition metals (V, Cr, Ni) are elevated. REEs are moderately enriched, though generally lower than FW1. Calcium remains modest. FW2 can be characterized as iron and alkali-enriched with particularly strong Rb–Cs enrichment.

LMPC_FW3 has high iron (~41,000 ppm), but it is distinguished by the highest sodium (~5,500 ppm) among the LMPC groups. Potassium and barium are also elevated. REEs are moderately enriched, and Th and U remain high. Calcium is moderate. This group represents a sodium-enriched composition distinct from FW1 and FW2.

LMPC_JOV is the most chemically distinct group. It is extremely calcareous (Ca ~186,000 ppm), the highest in the dataset, with correspondingly low iron (~22,000 ppm), and strongly depleted trace and rare earth elements. Rb, Cs, Th, and U are notably low, and REEs are dramatically reduced compared to other groups. This composition reflects a highly carbonate-dominated paste with substantial dilution of silicate and incompatible elements.

LMPC_UTIL1 shows moderate iron (~32,500 ppm) and elevated potassium relative to many groups. Trace elements and REEs are moderately enriched, though generally lower than FW1 and FW2. Calcium is moderate (~13,000 ppm).

LMPC_UTIL2 variant has slightly lower iron (~30,500 ppm) and somewhat higher potassium (~19,100 ppm). REEs (La, Ce, Nd) are comparatively enriched relative to the first UTIL variant, and Th and U remain elevated. Calcium is moderate (~9,600 ppm).

The LMPC groups separate primarily along two compositional axes. The first is calcium enrichment: LMPC_CA and especially LMPC_JOV are strongly calcareous, with very high Ca and corresponding depletion in aluminum, iron, trace metals, and REEs due to carbonate dilution. The second axis concerns iron and REEs. FW1 and FW2 are the most iron- and trace-element–rich silicate groups, with strong REE and high field strength element enrichment; FW2 is especially enriched in Rb and Cs. LMPC_AS is also highly enriched but slightly less extreme than FW1/FW2. FW3 is distinguished by elevated sodium, while the UTIL variants are compositionally intermediate. LMPC_JOV stands apart as the most chemically distinct, representing an extremely calcareous and trace-element–poor paste.