

DIET AND MIGRATION IN COASTAL OAXACA:
IDENTIFYING EFFECTS OF POLITICAL AND SOCIAL COLLAPSE THROUGH THE
UTILIZATION OF STABLE ISOTOPE ANALYSIS

by

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ABSTRACT

This study involves the investigation of diet and mobility among people living in the lower Río Verde Valley, Oaxaca, Mexico, during the Late Classic (AD 500-800) and Early Postclassic (AD 800-1200) periods. Specifically, this research focuses on how political and social collapse affected subsistence practices and diet, particularly maize agriculture and consumption, as well as human migration. Archaeological evidence suggests that Río Viejo, the region's largest urban center before AD 800, experienced multiple periods of political fragmentation and instability during its long history, specifically during the Early Classic (AD 250 - 500) and Early Postclassic periods, making it an ideal place to test these relationships. Stable carbon, nitrogen, and oxygen isotopic analyses of human bone and tooth samples were used to reconstruct diet and create a life history for sampled individuals. Samples were extracted from the skeletal remains of individuals dating to the Late Classic (n=11) and Early Postclassic (n=11) periods. Stable carbon and nitrogen isotope values provide insight into maize consumption; in addition stable nitrogen isotope values also indicate the extent that aquatic resources were being exploited. Stable oxygen isotope values are used to determine if any of the individuals were foreigners and had migrated to the valley during their lifetime. Results demonstrate collapse following the Classic period led to a slight dietary shift that included a wider variety of resources, possibly aquatic. Human mobility also increased during this time as oxygen values display a wider range and indicate movement within the valley and along the coast.

*To my father, who chose to pursue a vocation that was never his passion so his children could;
and to my mother, who gave us the joy of reading always knowing
the doors and worlds it would open.*

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CHAPTER 1: INTRODUCTION

Major avenues of research within the field of archaeology have focused on the rise and subsequent collapses of ancient civilizations (Yoffee and Cowgill 1988). Spengler (1919), working under a social evolutionary model, argued that the decline of cultures is inevitable and is the destiny of complex societies. Toynebee (1933) suggested that societal growth is selected for when civilizations are faced with obstacles that they overcome, and collapse is selected for when civilizations are unable to overcome said obstacles. Rappaport (1977: 49-73), on the other hand, saw complex societies as too rigid and therefore unable to adapt to stress; furthermore, since the systems in place are so interconnected, a change in one component will lead to change in all. For example, Rappaport (1977) assents that societal collapse is immanent when the demand for resources is unable to be met. Since the 1970's, societal collapse has been attributed to environmental degradation through the process of resource production and consumption (Odell 1977), and is one of the main eleven themes given by Tainter (1988) for the explanation of collapse. The remaining themes include: establishment of a new source for material goods, a natural catastrophe, inadequate response to changing cultural or physical environment, interaction with other societies, outside conflict, internal conflict, social dysfunction, religious influences, interconnectedness of events, and economic factors (Tainter 1988).

Collapse in Mesoamerica and the Aftermath

Within the study of Mesoamerican history, period designations—Archaic, Formative/Preclassic, Classic, and Postclassic— have been used to define the progression of society (Table 1) (King 2003). Period designations, however, while useful in categorizing transitions in the development of sociopolitical complexity, can be problematic in that periods of

transition within Mesoamerica can vary from region to region. For example, the transition between the Classic and Postclassic in the Maya region is often separated into another period, the Terminal Classic (AD 750-1050), which roughly correlates with the Early Postclassic period in Oaxaca and other parts of Mesoamerica (AD 800-1100) (Hodell et al. 2005). For this thesis, the term Early Postclassic will be used to discuss this period; however, previous isotopic research focused on collapse comes from the Maya region where the Terminal Classic is used to define the same centuries.

Table 1: Ceramic Sequence, Time Periods, and Associated Uncalibrated Radiocarbon Dates for the lower Río Verde Valley (adapted from Joyce 2010; Hepp 2015)

Phase	Time Period	Dates
Yucadzaa	Late Postclassic	AD 1100-1522
Yugüe	Early Postclassic	AD 800-1100
Yuta Tiyoo	Late Classic	AD 500-800
Coyuche	Early Classic	AD 250-500
Chacahua	Late Terminal Formative	AD 100-250
Miniyua	Early Terminal Formative	150 BC- AD 100
Minizundo	Late Formative	400-150 BC
Charco	Late Middle Formative	700-400 BC
No Data	Late Early-Middle Formative	1350-700 BC
Tlacuache	Initial Early Formative	1600-1350 BC

Collapse during the transition between the Classic and Postclassic period is seen as a pan-Mesoamerica phenomenon, as major political centers such as Teotihuacan, Monte Albán, and Tikal declined dramatically in population or were abandoned altogether (Joyce et al. 2001). During the Early Postclassic, new major centers did rise such as Tula, El Tajin, Xochicalco, Uxmal, and Cacaxtla; however, smaller, sprawling, autonomous sites generally characterized the

period (Feinman 1999; Blomster 2008:6). For example, following the collapse of Teotihuacan six major sites rose to power in the Valley of Mexico; however, none reached the size or exerted the same influence throughout Mesoamerica as Teotihuacan (Diehl and Berlo 1989:4; Sanders et al. 1979; Blomster 2008). These widespread centers located in areas previously considered peripheral zones led to a decentralization of trade (Blomster 2008). While debates over the cause of collapse are ongoing, archaeological, iconographic, and epigraphic evidence suggests that polities experienced interpolity warfare, changes in political structure, the end to ruling ideologies and dynastic lines, and depopulation of site cores (Culbert 1973; Demarest et al. 1997; Diehl and Berlo 1989; Inomata 1997; Sabloff and Andrews 1996; Sabloff and Henderson 1993; Sharer 1994). Warfare models postulate that widespread conflict among polities at the end of the Classic period led to political instability, fragmentation, and collapse of political centers of control (Demarest et al. 1997; Freidel 1986; Sharer 1994:338-357). The anthropogenic landscape change model argues that increases in population and agricultural intensification at the end of the Classic period led to environmental degradation causing intensive subsistence strategies to fail (Abrams and Rue 1988). The failing of intensive agriculture is cited as the reason for major population shifts away from site centers and the breakdown of political structures (Abrams and Rue 1988; Fash 1991:179-181; Paine and Freter 1996). The final and most recent model has centered on climate change, which would have caused drought and famine leading to an inability to support large centralized populations (Huag et al. 2003; Shaw 2003). Collapse, despite the initial causes, leads to the disruption of many facets of society. Political administration becomes fragmented, ruling dynasties are overthrown or lose power; economic systems morph and trade routes shift, investment in agricultural systems may experience a change especially as centers experience major demographic shifts in population, and access may be gained to previously elite-

controlled resources (Blanton 1978; Byland and Pohl 1994; Feinman 1999; Marcus 1983; Smith and Berdan 2000; Spores 1984).

The Early Postclassic Collapse in Oaxaca

Similar to other regions in Mesoamerica, the Early Postclassic in Oaxaca is marked by the collapse Classic period centers and the appearance of smaller polities (Byland and Pohl 1994; Diehl and Berlo 1989; Marcus 1983; Paddock 1983a; Spores 1984; Joyce 2010). The cause for collapse of these major centers is still under debate and include warfare, economic and political restructuring, factionalism, internal conflict, and the economic consequences of the collapse of Teotihuacan (Winter 1994; Marcus 1983, 1989; Paddock 1983b). Regardless of the cause, these smaller polities displayed a major shift in settlement patterns throughout the region and a lack of regional incorporation. Furthermore, the increase of small and competing polities suggests that there was not only a collapse of large, urban political centers but also of their corresponding economic and political networks (King 2003).

Typically, Oaxacan archaeology is associated with the Valley of Oaxaca where archaeological excavations have primarily focused on the rise and growth of social complexity at Formative period centers (see Figure 1). Monte Albán, the Zapotec capital located in the Valley of Oaxaca, remains an exception due to the extensive archaeological work conducted at the site. The collapse of Monte Albán at the end of the Classic period led to rippling economic, political, and social effects throughout all of Oaxaca; however, there is considerable difficulty identifying Early Postclassic diagnostic material markers leading most comparisons to be between the Late Classic and Late Postclassic in the Valley of Oaxaca (Byland and Pohl 1994; Feinman 1999). Considering they are primarily used for period designations, problems associated with the

ceramic sequence during the Classic to Postclassic transition remain an ongoing debate within the field (Markens 2003). Furthermore, problems in archaeological chronologies are also apparent in the Mixteca Alta since ceramic sequences were founded based on imported Valley of Oaxaca ceramics (King 2003).



Figure 1: The modern state of Oaxaca, Mexico with geographical regions and the archaeological sites of Río Viejo, Monte Albán, and Teotihuacan

Contrary to the Valley of Oaxaca and Mixteca Alta, the coastal region of the lower Río Verde Valley provides strong Early Postclassic data (see Figure 1). Survey by the Río Verde Archaeological Project and excavations of neighborhoods at the urban center of Río Viejo provide information about this period and the transitions that occurred following the Classic period collapse (Joyce et al. 2001; King 2003; Joyce et al. 2014). Radiocarbon dates from these excavations place the Río Viejo neighborhoods between A.D. 975 and 1220 during the Early

Postclassic period (Joyce et al. 2001; King 2003). These two neighborhoods showed little to no difference in social roles and status based on the similarities in architecture, domestic assemblages, and the lack of luxury items. The presence of non-local items, such as greenstone beads, pumice, and obsidian, along with artifacts used in a specialized economy, such as spindle whorls, bone needles, and bone spindles, suggest the people living at Río Viejo during this time were active participants in trade networks extending outside the lower Verde (Joyce et al. 2001; King 2003). Survey of the valley by the Río Verde Archaeology Project indicates there was a major settlement shift away from large centers like Río Viejo, possibly indicating internal conflict. Furthermore, the individuals of the Early Postclassic actively deprecated former symbols of power indicating there was a change in rulership or political authority. An example of this is a stela portraying a ruler with an elaborate feather headdress being used both as a *metate* and as a building block in a house (Joyce et al. 2001:361; Joyce et al. 2014:394).

A cultural shift in the region is indicated in the beginning of the Early Postclassic as archaeological, iconographic, and ethnohistoric records show evidence of Mixtec peoples from the Mixtec Alta invading and settling the coast (Byland and Pohl 1994; Smith 1973; Spores 1993). Mixtec codices and ethnohistoric records discuss the coast being conquered by Lord 8 Deer Jaguar Claw, a Mixtec cultural hero, from Tilantango. During his adult life, he migrated to the lower Verde for a brief period and founded a capital for the growing Mixtec empire at Tututepec, a polity located 12 kilometers from Río Viejo (Byland and Pohl 1994). Lord 8 Deer Jaguar Claw is said to have reached the valley in A.D. 1083 during the Early Postclassic; the conquest of the valley which continued for generations after Lord 8 Deer returned to the highlands reached its height, covering an estimated 25,000 km² by the beginning of the Late Postclassic in A.D. 1100 (Byland and Pohl 1994). Whether the legendary Lord 8 Deer existed is

still in question, however, there is considerable agreement between codical and archaeological evidence. For instance, both indicate a fairly large group migrated to the lower Verde from the Mixteca Alta (Levine 2007:91). Glottochronological research evaluated the Mixtec dialect spoken on the coast and determined it diverged from the highland dialect around AD 900-1000 (Josserand et al. 1984; Joyce et al. 2004b) which falls within the time period of 8 Deer's migration to the coast. Finally, archaeological evidence supports that Tututepec became a regional capital and player in political activity throughout the lower Río Verde Valley and resisted Aztec invasion during the end of the Late Postclassic (Davies 1968; Gerhard 1972; Joyce et al. 2004:287). Tututepec also remained autonomous for a short time during the Colonial period until it was taken under Spanish control in A.D. 1522 by Pedro de Alvarado (Gerhard 1972:380; O'Mack 1990; Smith 1973).

The lower Río Verde Valley provides a wealth of information in relation to the Postclassic including the Early Postclassic, a period poorly dated and discussed in other areas of Oaxacan archaeology. This information allows for a deeper analysis of the effects of social and political change directly following the Classic period collapse.

Research Questions

This thesis presents an investigation of diet and human mobility in the lower Río Verde Valley through the analysis of stable carbon, nitrogen, and oxygen isotopes from human bone and teeth during the Late Classic and Early Postclassic time periods at Río Viejo, the valley's political center before AD 800. Archaeological evidence suggests that Río Viejo experienced periods of political fragmentation and instability during the Early Classic (AD 250 - 500) and Early Postclassic (AD 800-1200) periods (Joyce et al. 2001). These multiple periods of collapse

at Río Viejo provide a context to evaluate larger questions on how political and social changes affected diet and human mobility in Mesoamerica. Theories surrounding collapse in the Maya region have focused heavily on environmental degradation and climate change that could have led to drought and famine. Isotopic studies focused on collapse periods have analyzed whether dietary changes from the Classic to Postclassic period reflect a strain on resources caused by these factors (White 1997; Wright 1997). Archaeological evidence from Río Viejo suggests collapse was due to political and social turmoil, most likely internal and possibly caused by a rift between the ruling elite and commoners (Joyce et al. 2001; Joyce et al. 2014). The assumption underlying this research is that non-environmental factors led to collapse and therefore the ability to continue producing resources through intensive agriculture was possible. Therefore changes observed in diet would be the result of social, political, or economic factors rather than climate change or environmental degradation.

H₁: I hypothesize that collapse at the end of the Classic period led to an increase in movement within the lower Río Verde Valley. Survey and archaeological evidence suggests that Río Viejo along with other major centers in the area experienced a population drop from the Late Classic to the Early Postclassic. This hypothesis will be tested through the analysis of stable oxygen isotope analysis conducted on individuals interred during the Late Classic and Early Postclassic at Río Viejo. If collapse led to greater movement throughout the lower valley, then results will demonstrate a wider range of values for the Early Postclassic compared with a smaller range of values for the Late Classic. A similar range in values for both the Late Classic and Early Postclassic would refute the hypothesis and suggest that collapse had no bearing on human mobility patterns.

H₂: I also hypothesize that collapse at the end of the Classic period led to a more varied diet due to changes in the social and political landscape. Dietary shifts could be an indicator of greater access to resources, disruption of food production, or a choice to focus less on agricultural production and instead exert energy and time on another economic pursuits. This hypothesis will be tested through the analysis of stable carbon and nitrogen isotopes. Changes in $\delta^{13}\text{C}$ values from both bone and dental collagen and enamel apatite may indicate a decreased or increased reliance on maize, while changes in $\delta^{15}\text{N}$ values can indicate new or greater emphasis on an existing protein source.

Secondary H₂: The population at Río Viejo had access to a wide variety of aquatic resources because of its location on the Río Verde River, near a series of lagoons and other river systems, and in close proximity to the Pacific Ocean. Therefore, analyses will be conducted to determine whether it is possible to distinguish maize from aquatic resources isotopically. I hypothesize that this should be possible by comparing the sample data to food web data that was compiled from modern, historical, and archaeological Oaxaca, archaeological sites in the Caribbean, and the archaeological coastal sites of San Pedro and San Marcos Gonzalez in Belize (Keegan and DeNiro 1988; Williams et al. 2009; Warinner et al. 2013).

Thesis Summary

The first chapter of this thesis will provide the geographical and archaeological context for the site of Río Viejo and the surrounding lower Río Verde Valley. It will also outline the physiological and histological characteristics of bone and teeth that allow for stable isotope analysis. Furthermore, it will discuss the foundations of stable isotopic research and provide an in depth discussion on the isotopes being researched for this study: nitrogen, carbon, and oxygen.

Finally, the chapter will provide an overview for previous isotopic studies relating to periods of collapse in Mesoamerica and details all past isotopic analysis in the lower Río Verde Valley.

The second chapter of this thesis provides the materials and methods used in this study. The archaeological context is provided for the individuals who provided adequate results. Further details on each individual such as skeletal and dental analyses, preservation details, associated grave goods, and mortuary context are provided in Appendix 1. The rest of chapter two details the methods used to process the bone and teeth for analysis of stable carbon, nitrogen, and oxygen isotope analysis.

The third chapter in this thesis discusses the results of the isotopic analysis. First it will cover sample preservation and then the precision and accuracy of the results. The chapter will detail how resources were distinguished and how a flora and faunal food web was created for the lower Río Verde Valley. Next, the chapter will outline how isotopic results from dentition are utilized to discuss human mobility. Finally, the results are presented and outliers are discussed. The fourth chapter presents a discussion about the isotopic results, specifically reviewing changes and continuities in diet and migration between the Late Classic and Early Postclassic. Specifically highlighting how changes in the sociopolitical landscape may have affected diet and human movement on a large scale and within the valley. The concluding chapter summarizes the findings of the research; discusses challenges faced with isotopic analysis in the region; and suggest future directions to continue isotopic analysis in the lower Río Verde Valley.

CHAPTER 2: BACKGROUND AND LITERATURE REVIEW

Geography

The state of Oaxaca is located in southwestern Mexico with the state of Chiapas to the south, Puebla to the north, Veracruz to the east, and Guerrero to the west (Figure 1). The Oaxacan state is home to highland mountains, highland valleys, and coastal plains, which stretch from the southwest corner of the state and to the east where the Isthmus of Tehuantepec begins. The lower Verde Valley is nestled between the Pacific Ocean to the southwest and the Sierra Madre Del Sur to the northeast. The Sierra Madre Del Sur sits between the Oaxacan highlands and the coast; the mountain range drops off steeply on the coastal side creating a series of high cliffs (West 1964:65). Rivers such as the Río Verde begin in the mountain range and funnel through narrow valleys to the coastline, creating alluvial plains while the rest of the coast is fairly rocky and dry (Gay 1998:2; Joyce et al. 1998:3). The site of Río Viejo is located in one of these fertile alluvial plains, which makes it a perfect place for cultural development to flourish (Joyce and Mueller 1992, 1997).

Environment and Climate

Within the lower Río Verde Valley, a diverse set of environmental zones exist including coastal plains; beach; brackish water lagoons and estuaries; salt flats; alluvial plains; freshwater rivers, streams, and lagoons; mountains; and piedmont valleys (Joyce 2010). Climate can change based on a variety of things such as topography, altitude, atmospheric pressure, wind movements, and humidity. On the coast, the temperature is normally very warm and humid while the mountain valleys and highlands can be cooler and drier. The tropical climate of the lower Verde is home to semi-deciduous forests, dry scrub, and chaparral with acidic, clay soil and

mangroves that flourish along the shores of the rivers, lagoons, and estuaries (Joyce et al. 1998:3; Rodrigo Alvarez 1998:18). Natural vegetation however has been mainly eliminated through intensive agricultural practices (Joyce 1991a:45).

Fauna

A variety of large mammals were available in the Precolumbian lower Río Verde Valley including species of canids, felids, tapirs, peccary, and cervids (Rodrigo Alvarez 1998:204-209, 211; Fernandez 2004:19). White-tailed deer were one of the more popular proteins along with the pronghorn antelope, which is now extinct in the region from being over-hunted (Fernandez 2004:21). A variety of medium-sized mammals were present and consumed including armadillo, rabbit, agouti, opossum, raccoon, and mustelids (Rodrigo Alvarez 1998:191, 194, 195, 199-201; Fernandez 2004:21). A variety of small mammal species were present; however they were most likely not readily consumed due to the little amount of meat they would have produced.

Turtles, lizards, iguana, snakes, and crocodile are among the types of reptiles found in the lower Río Verde Valley (Rodrigo Alvarez 1998:248, 250, 258). Turtles could be found along the ocean shoreline, the rivers, streams, and lagoons and turtle eggs in particular were favored (Fernandez 2004:23).

Along with a large variety of terrestrial animals, the ancient peoples of coastal Oaxaca had access to a wide range of aquatic resources. Freshwater fish are found in rivers, streams, ponds, and lagoons and the most important freshwater fish include catfish, mojarra, sardine, and eel (Fernandez 2004:24). Brackish water fish are found in the estuaries and include catfish, mullet, mojarra, snook, white snapper, and eel. Marine fish such as southern flounder, jackfish, tuna, seatrout, snapper, mullet, creolefish, and grouper and shellfish such as mollusks and

crustaceans inhabit the ocean waters (Fernandez 2004:25). Shellfish in particular make up part of the faunal samples found at the archaeological sites in the lower Río Verde Valley; samples include mussels, chione, hornsnail, barnacle, and crab (Rodrigo Alvarez 1998:275). Research has indicated that these species were gathered from estuaries, tidal flats, mud flats, and mangroves (Quitmyer 1991:6).

While ancient peoples living in coastal Oaxaca had access to an abundance of terrestrial and aquatic resources, archaeological evidence suggests certain species were chosen more readily over others. Recent faunal analyses of 7,000 vertebrate and invertebrate remains recovered from middens at the site of Río Viejo provide a more detailed view of diet at Río Viejo and throughout the lower Verde (Cunningham-Smith and Barber 2015). The assemblage was collected from ten archaeological midden contexts that date to the Early Terminal Formative, Late Terminal Formative, and Late Classic. Thirty percent of the faunal assemblage recovered from middens was marine and brackish water mollusks (Cunningham-Smith and Barber 2015). Marine invertebrates, such as barnacles and crabs, and fish, such as snook and snapper, also made up part of the assemblage; however these aquatic species are found less frequently compared with mollusks. Furthermore, the assemblage also included the following reptiles and amphibians: frogs, toads, crocodiles, iguanas, turtles, and snakes. As discussed earlier, a variety of mammals ranging in size inhabited the area. The most common mammals found among the assemblage were white-tailed deer, rabbit, opossum, and dog— dog being the most common. The majority of the mammals from the sample indicate coastal peoples were actively exploiting resources found in savannah and forested areas.

Río Viejo

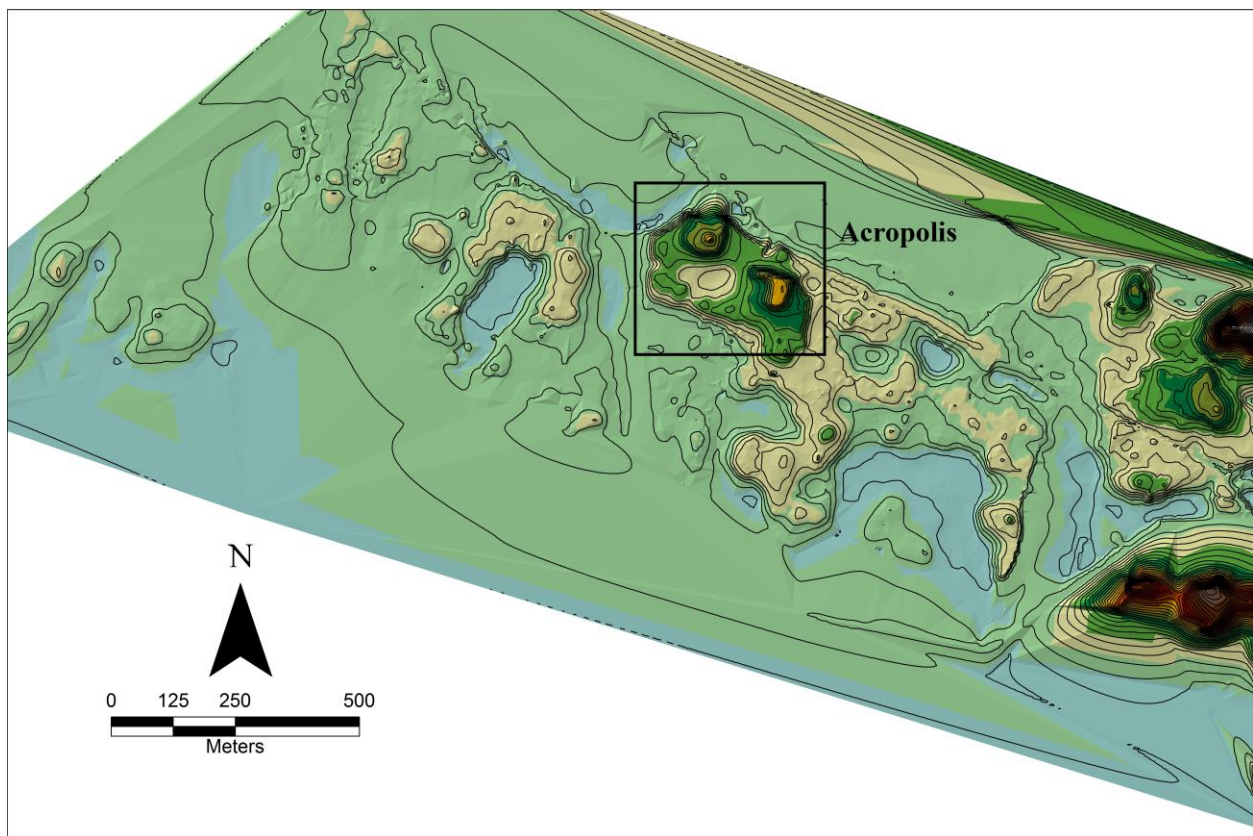


Figure 2: Topographic map of Río Viejo noting the acropolis

Archaeological investigations in the lower Río Verde Valley began in the mid-1980s, and the continuation of this research has provided a large body of knowledge about the area and the site of Río Viejo (Figure 2). Río Viejo, as evident from redeposited ceramics, was first settled during the Middle Formative (700-400 BC) (Joyce and King 2000). The site continued to flourish into the Late Formative while remaining small at 2 hectares. Individuals participated in trade and it appears the site was relatively egalitarian (Joyce and King 2000; Joyce and Workinger 1996).

During the Terminal Formative, Río Viejo grew rapidly in size, reaching 225 hectares, and became not only the largest site in the region but also the most important urban center in the

lower Verde and one of the largest along the Oaxacan coast (Joyce and Barber 2015). At this time large-scale mound construction began and Mound 9, reaching 12 meters above the floodplain, most likely served as the center for ceremonial activity until around A.D. 50 (Joyce and Barber 2015). Furthermore, social complexity began to increase as evident from mortuary patterns, residential data, and the previously mentioned growth of public ceremonial and monumental structures (Barber 2005, 2013; Barber and Joyce 2007; Joyce 1991a, 1991b, 2003, 2005; Workinger 2002). Community identity was established at Río Viejo through feasting, caching, and mortuary practices (Barber 2005, 2013; Barber and Joyce 2007). Political authority during this period was likely held by a corporate political organization.

Entering the Early Classic, however, Río Viejo began to drop in both population and size, from 225 to 75 hectares (King 2003; Joyce and Workinger 1996; Workinger 2002; Joyce 2008). Settlement data indicate this decline was seen throughout the lower Verde as multiple larger sites declined in size or were abandoned altogether. Settlements shifted from the floodplains to the piedmont zones of the lower Verde. During this time Río Viejo was no longer the dominant urban center in the region, rather, at least eight major centers competed for power during the Early Classic (Joyce 2008). The causes behind the Early Classic collapse are still in the process of investigation; however, some theories suggest collapse may have been caused by interactions with Teotihuacan or tensions between ruling institutions and commoners over ideology and forms of authority. Archaeological evidence of burnt structures and floors, and the abandonment of the entire acropolis, tends to suggest the later (Joyce 2003, 2008; Joyce and Barber 2015).

Transitioning into the Late Classic, political centralization once again culminated with Río Viejo as the political and urban center in the region and settlement shifted back to the

floodplains (Joyce et al. 2001). Civic-ceremonial activities resumed at the acropolis, with some of the most important activity occurring on Mound 1; excavations and surface collections indicate a majority of the acropolis was in use during the Late Classic. The Río Viejo polity became an urban center boasting art, monumental architecture, writing, dynastic rule, and craft specialization. The site once again increased in size, reaching 250 hectares, and was built up above the floodplain by a series of artificially raised platforms. Furthermore, political authority during this period completely changed compared to earlier periods and Río Viejo was no longer controlled by corporate political organization, but rather, by individual rulers (Urcid and Joyce 2001; Joyce 2008).

During the Early Postclassic, the Río Viejo polity experienced a second collapse. The site like many others in the region, declined in size. Río Viejo dropped to 140 hectares but still remained one of the largest communities in the region. It appears that no monumental construction occurred at Río Viejo during this time; furthermore, there is a steep decline in the creation of monumental art (Urcid and Joyce 2001; Joyce 2008). Excavations dating to this time period are limited to two residences in Operations RV00 A, located on Mound 1-Structure 2, and RV00 B, located on Mound 8. These structures were both on low platforms and made of wattle-and-daub architecture; artifacts and features uncovered in both excavations were very similar and indicated residential usage. Modest burials found in both structures suggest commoner status (Joyce and King 2000; King 2003); however, the small sample size and lack of comparative data must be considered. These excavations coupled with survey data from the region indicate that the Early Postclassic was a period with little disparity of wealth and power (Joyce et al. 2014). Commoner residential structures located in the acropolis indicate this area was no longer a center of civic-ceremonial activity; Early Postclassic residents of Río Viejo did not view the symbolism

of authority and political power associated with the acropolis in the same way as their Late Classic counterparts (Joyce et al. 2001).

While the Early Postclassic may be poorly understood in many areas of Oaxaca, the Late Postclassic boasts a wealth of information from archaeological, epigraphic, and ethnohistorical resources. In the lower Río Verde Valley, the Late Postclassic period ushered in the establishment of a powerful political center at Tututepec which served as the capitol of an empire on the Oaxaca coast. Tututepec's founding is best outlined in the Mixtec codices *Nuttall*, *Bodley*, and *Colombino-Becker* which recount the founding of Tututepec by Lord 8 Deer "Jaguar Claw" from the highland Mixtec site of Tilantongo (Joyce et al. 2004). Codices recount that Lord 8 Deer arrived in the lower Verde during the latter part of the eleventh century, established a Mixtec political center at Tututepec, and then shortly after returned to the highlands. Tututepec continued to grow after and came to control an empire that covered roughly 25,000 km² on the Oaxaca coast (Joyce et al. 2014). Lord 8 Deer in this way effectively paved the way for a powerful economic and political relationship to flourish between the coast and the highlands. While there is not direct archaeological evidence for the cultural hero Lord 8 Deer or his arrival to the lower Verde, archaeological data does support that the region was dominated by Mixtecs during the Late Postclassic and was held by this group until the time of Spanish Conquest (Joyce 2011; Levine 2007:277).

Background on Stable Isotope Analysis

Stable isotope analysis, used to reconstruct diet and migration among past societies, is based on the fact that the chemical signature of substances consumed through eating and drinking during life is converted metabolically into chemical markers (Lambert 1997). These

markers are isolated and extracted for analysis by researchers. Since carbon and nitrogen make up important elements of food, and oxygen signatures differ from water source to water source, bioarchaeologists can utilize stable carbon, nitrogen, and oxygen isotopes of bone and teeth to reconstruct ancient diet and movement patterns (Lambert 1997:216). Therefore, the ratios of stable carbon and nitrogen present in skeletal remains will be a reflection of an individual's consumed diet and the ratio of stable oxygen present in skeletal remains will be a reflection of the water source used by an individual and will represent where the majority of their life was spent (Price et al. 1985).

These premises are based on the fact that isotopes are atoms of a chemical element that have the same number of protons but a different number of neutrons than the other atoms of the same element. This leads to different nucleonic and mass numbers, the latter of is calculated by finding the sum of the protons and neutrons in the nucleus. For example, carbon atoms all have six protons in the nucleus, so a carbon atom with six neutrons would have a mass of 12, displayed as ^{12}C , and a carbon atom with seven neutrons would have a mass of 13, displayed as ^{13}C . Therefore, ^{13}C is heavier than ^{12}C due to the extra neutron; but both isotopes are stable nonetheless because they will not decay over time due to the placement of protons and neutrons in the nucleus.

The weight of the isotopes and their weight in comparison with others isotopes is the premise of isotopic study within bioarchaeology. These ratios of different isotopes within a sample are very small and therefore they display the difference between the sample material and the international standard of the known isotopic ration. The standard ration of expression is calculated using the following equation:

$$\delta = \frac{R_{Sample}}{R_{Standard}} * 1000\text{‰} \quad (1)$$

The “R” represents the ratio of one stable isotope to the other and the ratios are expressed as delta values (δ). These ratios are so small that the values are reported in per mil values (‰) rather than percentages (Lambert 1997:220).

Bone and teeth are comprised of different components that contain the carbon, nitrogen, and oxygen used in dietary and migration reconstruction research (Schoeninger and Moor 1992; Hedges et al. 2005). The main component of bone, collagen, comprises up one fourth of the bone’s weight and molecular structure and commonly survives well through the deterioration process (Hedges et al. 2005). Collagen is therefore the ideal component of bone for the analysis of carbon and nitrogen values for isotopic research. Furthermore, bone is constantly being remodeled throughout an individual’s life, with a general consensus being that 0.05 mm³ of bone is remodeled every four months (Hollinger 2005). Therefore, studies utilizing bone normally represent the last 10-20 years of an individual’s life, depending on their sex and age (Hedges et al. 2007; Katzenberg 2008).

Apatite, the mineral portion of the bone, can also be utilized in stable isotopic research. This portion is also preserved in deteriorative conditions due to its placement within the bone collagen matrix (Hedges et al. 2007). The isotopic carbon value taken from bone apatite is representative of the whole diet, including carbohydrates, lipids, and proteins; this is unlike the carbon extracted from bone collagen, which solely represents the protein portion of the diet (Lee-Thorp et al. 1989; Schoeninger and Moore 1992; Ambrose and Krigbaum 2003; Mays and Beavan 2012). Teeth on the other hand have two primary components— enamel and dentin

(Hilson 2014:146-229). Dentin, a dull, yellow, and porous material, is found in the roots and the internal portion of the tooth's crown (Hilson 2014). Enamel, a shiny, white nonporous material and also the strongest part of the human skeleton, protects the pulp chamber and forms the crown of the tooth, which is the portion above the gum line (Hilson 2014). Collagen makes up part of the structure of dentin and can provide information on the carbon and nitrogen from the protein portion of the diet (Hilson 2005). Apatite makes up the majority of enamel and can provide information on oxygen and carbon from the entirety of the diet (Hilson 2005). Teeth, unlike bone, are fully formed at known ages during childhood and do not remodel throughout life (Hedges et al. 2005). Therefore, analysis of diet based on teeth reflects particular periods in an individual's life and when paired with bone can provide a life history approach to studying the diet and migration of an individual (Chenery et al. 2010).

Stable Carbon Isotope Analysis

During photosynthesis, plants absorb ^{12}C and ^{13}C (DeNiro 1987). Plants obtain carbon dioxide during photosynthesis and utilize the carbon to create larger molecules of carbon-carbon bonds. These molecules have a greater enrichment of ^{12}C compared with the atmosphere the carbon is taken from because the lighter ^{12}C tends to form bonds at a faster pace. This process is called isotopic fractionation and is not identical for every plant, meaning the fractionation varies changing the ration of ^{12}C and ^{13}C (Lambert 1997). Wheat, rice, legumes, fruits, and nuts absorb in greater quantities the lighter isotope of carbon while maize, sugarcane, sorghum, and some millets absorb in greater quantities the heavier isotope of carbon (Wickman 1952; Bender 1968). Plants that display a higher ^{12}C value do so because the enzyme ribulose bisphosphate carboxylase is utilized during photosynthesis to fix atmospheric CO_2 (Lambert 1997). The end

result of this process is a compound with 3 carbon atoms; therefore, plants using this photosynthetic pathway are known as C₃ plants. Plants that display a higher ¹³C value do so because their process of photosynthesis has evolved to use the enzyme phosphoenol pyruvate carboxylase to fix atmospheric CO₂ (Cerling et al. 1993). The end result of this process is a compound with four carbon atoms; therefore, plants using this photosynthetic pathway are known as C₄ plants. Plants that display intermediate values follow an alternative photosynthesis pathway known as crassulacean acid metabolism or CAM. CAM plants include cacti, succulents, and other desert plants. These plants have a similar process to C₄ plants in that they have the same two carbon-fixing steps; however these enzymes are not separated but held within the same cell and used during different times of the day. The enzyme phosphoenol pyruvate carboxylase is used during the day while the enzyme ribulose biphosphate carboxylase is used at night. This cycle allows for the internal concentration of CO₂ to reach high levels with minimal CO₂ leakage resulting in greater ¹³C enrichment when compared with C₄ plants (O'Leary 1981).

International standards for stable isotopic analysis are determined by the International Union of Pure and Applied Chemistry (IUPAC). As of 1995, the standard for stable carbon isotope analysis was NBS 19 calcite at +1.95‰ (Bulletin of Volcanology, 1995). Values, however, for isotopic analysis are most commonly reported in Vienna Pee Dee Belemnite (VPDB) standard and will be displayed in this manner for this research. Since most organisms are less enriched in ¹³C than the VPDB standard, δ¹³C values are usually negative. The δ¹³C values associated with C₃ plants range from -32 to -21‰ with an average value being -26‰; while, the δ¹³C values associated with C₄ plants range from -15 to -8‰ with an average value of -11.5‰ (DeNiro 1987; Katzenberg 2008). δ¹³C values increase by about +1‰ for every trophic level; it is generally accepted that the isotopic enrichment from diet to human bone collagen is

+5‰, however this is still debated (van der Merwe and Vogel 1978; Ambrose 1991). $\delta^{13}\text{C}$ values from apatite experience a large enrichment between food and consumer and the literature has debated the values to be either 12.0‰ (Lee-Thorp et al. 1989; Garvie-Lok 2001) or 9.4‰ (Ambrose and Norr 1993; Ambrose et al. 1997; Harrison and Katzenberg 2003; Kellner and Schoeninger 2007). For this study the fractionation of 9.4‰ will be used due to a greater body of literature supporting this value. Furthermore, the determination of this value is based on the concept that digestive physiology plays a greater role in the fractionation process than body size (Kellner and Schoeninger 2007). The following equation is used to calculate the $\delta^{13}\text{C}$ values for a sample:

$$\delta^{13}\text{C}_{(PDB)} = \left[\frac{{}^{13}\text{C}/{}^{12}\text{C}_{\text{Sample}}}{{}^{13}\text{C}/{}^{12}\text{C}_{\text{PDB}}} \right] \times 1000\text{‰} \quad (2)$$

Significant variations will therefore be found in populations that rely heavily on C_3 or C_4 foods. The approximate percentage of C_4 plants (PC4) will be used to estimate diet since maize is considered one of the largest staples within a Mesoamerican diet. The following formula from Schwarcz et al. (1985) will be used to determine this percentage with δ_c representing the measured value of the collagen sample, Δ_{dc} representing the accepted fractionation factor of -5, δ_3 representing the average value of C_3 plants (-26.5), and δ_4 representing the average value of archaeological maize (-9.5).

$$PC4 = \frac{\delta_c - \delta_3 + \Delta_{dc}}{\delta_4 - \delta_3} \times 100 \quad (3)$$

Stable Nitrogen Isotope Analysis

Nitrogen isotopes are found in the collagen of bone and teeth and are related to the isotopic composition of dietary protein, making them ideal for determining trophic level of an organism (Pate 1994). For the majority of mammalian species, there is an increase of 2‰ to 3‰ in $\delta^{15}\text{N}$ values for every trophic level. This increase is due to the way nitrogen is metabolized and recycled within the body and based on the placement of an organism within the food chain. The longer the food chain the more enriched nitrogen becomes as it is transferred from food resource to consumer. The consumer then excretes nitrogen as waste, or urea, inside the body (Dupras and Schwarcz 2001). The theoretical concepts of $\delta^{15}\text{N}$ analysis are the same as those for $\delta^{13}\text{C}$ analysis in that plants are divided into legumes and non-legumes; however, the division is based on the source from which nitrogen is taken. Legumes for instance take in nitrogen gas (N_2) from the atmosphere and nitrates from the soil; while non-legumes only take in nitrogen from the soil because they are unable to fix nitrogen from the atmosphere (Virginia and Delwiche 1982; DeNiro 1987).

The international standard for stable nitrogen is AIR (atmospheric N_2), which is 0‰. Legumes utilize nitrogen from the atmosphere as well as the soil and therefore have similar $\delta^{15}\text{N}$ values to the AIR standard. Non-legumes on the other hand have higher $\delta^{15}\text{N}$ values closer to an average of +6.5‰. $\delta^{15}\text{N}$ values increase by about +3‰ for every trophic level. The following equation is used to calculate the $\delta^{15}\text{N}$ value for a sample:

$$\delta^{15}\text{N}_{(AIR)} = \left[\frac{{}^{15}\text{N}/{}^{14}\text{N}_{\text{Sample}}}{{}^{15}\text{N}/{}^{14}\text{N}_{\text{AIR}}} \right] \times 1000\text{‰} \quad (4)$$

While there is generally a 3‰ enrichment from resource to consumer, nitrogen enrichment is also affected by other factors which can change the way nitrogen is enriched and retained within an organism. Nutritional stress, pregnancy, pathology, and environment have all been cited as factors that can influence nitrogen enrichment (see Table 2) (Cormie and Schwarcz 1996; Katzenberg and Lovell 1999; Fuller et al. 2004; Olsen et al. 2014). Organisms that live in dry, arid environments with little rainfall experience higher nitrogen values than their counterparts that live in areas with more rainfall; this difference is attributed to water stress (Dupras and Schwarcz 2001; Hedges and Reynard 2007; Lambert 1997; Pollard 2007). Ambrose (1991) studied this process by observing the physiological basis for nitrogen enrichment via urea waste deposits during the metabolic process. Urea is excreted in relation to the urine volume under conditions of water stress; this in turn causes the light ^{14}N isotope to be lost and the heavier ^{15}N isotope to be retained, giving an organism a higher nitrogen value (Ambrose 1991; Dupras and Schwarcz 2001). This process can therefore make it difficult to distinguish between terrestrial and marine food resources in drier, coastal environments (Lambert 1997). Protein stress, related to water stress, can also lead to enriched nitrogen levels. When an organism does not intake an inadequate amount of protein, the body then begins to breakdown and reutilize existing tissues which are enriched in ^{15}N (Katzenberg 2008). During pregnancy, the body enters a state of positive nitrogen balance where it increases protein synthesis and decreases nitrogen excretion (Fuller et al. 2004). This leads to a 0.5 to 1‰ depletion of $\delta^{15}\text{N}$ values in pregnant women and an increase in nitrogen retention (Duggleby and Jackson 2002). Furthermore, $\delta^{15}\text{N}$ values are also affected by diseases and trauma. Katzenberg and Lovell (1999) found that $\delta^{15}\text{N}$ values were depleted in healed fractions by 0.8‰ and enriched in bone with osteomyelitis by 2‰.

Table 2: Summary of environmental, physiological, and metabolic factors that influence $\delta^{15}\text{N}$ values

Factor	Enrichment/Depletion in $\delta^{15}\text{N}$	Known $\delta^{15}\text{N}$ Change (‰)
Trophic Level	Enrichment	3.0
Dry, arid climates	Enrichment	N/A
Protein Stress	Enrichment	N/A
Pregnancy	Depletion	0.5 to 1.0
Healed Fracture	Depletion	0.8
Osteomyelitis	Enrichment	2.0

Adapted from Ambrose 1991; Duggleby and Jackson 2002; Dupras and Schwarcz 2001; Fuller et al. 2004; Katzenberg 2008; Katzenberg and Lovell 1999

Stable Oxygen Isotope Analysis

Oxygen also has different stable isotopes such as ^{16}O , ^{17}O , and ^{18}O and these enter the body through respiration, diet, and liquids. Through metabolism, oxygen binds with other chemicals to form essential compounds for the body. One compound mentioned earlier is hydroxyapatite or apatite ($\text{Ca}_{10}(\text{PO}_4)_6(\text{OH})_2$) that is formed by blood bicarbonate and comprises the enamel of teeth and the inorganic portion of bone. Tooth enamel, unlike bone, is never remodeled after formation, and therefore the $\delta^{18}\text{O}$ values of the carbonate are permanently recorded and represent that specific period of time in the individual's life (Longinelli 1984; Luz et al. 1984; Dupras and Tocheri 2007). The chemical composition of water is variable based on geographical location, climate, and water source. For the most part, $\delta^{18}\text{O}$ values decrease in environments farther from ocean coasts that increase in latitude and altitude; this is due to a higher amount of ^{18}O in precipitation in these areas (Dansgaard 1964). This is not the only factor that affects $\delta^{18}\text{O}$ values; humidity and food consumption also play a role (Luz and Kolodny 1989). Oxygen isotopes are absorbed in the body through drinking water, water from within

foods, and through the atmosphere; however, the values metabolically derived are impacted the most by $\delta^{18}\text{O}$ values taken in through drinking (Luz et al. 1984). The type of plant food, whether C_3 , C_4 , CAM, also contributes as C_4 and CAM plants often lend to higher $\delta^{18}\text{O}$ values (White et al. 2004). This is attributed to the way in which C_4 plants are able to continue the process of photosynthesis in dry conditions, leading to an enrichment of ^{18}O (White et al. 2004). $\delta^{18}\text{O}$ values in sample material can be compared to the $\delta^{18}\text{O}$ values in the water samples collected from the different geographical locations to determine where the individuals were obtaining their water during dental formation and bone remodeling.

The standard for $\delta^{18}\text{O}$ values are either the Vienna Standard Mean Ocean Water (VSMOW) or Vienna Pee Dee Belemnite (VPDB). This research is presented in VSMOW, which is the more commonly used standard to measure the ratios of ^{18}O and ^{16}O . The following equation is used to calculate the $\delta^{18}\text{O}$ value for a sample:

$$\delta^{18}\text{O}_{(VSMOW)} = \left[\frac{{}^{18}\text{O}/{}^{16}\text{O}_{\text{sample}}}{{}^{18}\text{O}/{}^{16}\text{O}_{VSMOW}} \right] \times 1000\text{‰} \quad (5)$$

Previous Isotopic Research within Mesoamerica

Very little isotopic research has been conducted within the state of Oaxaca. Migration studies have focused on the relationship between Monte Albán and Teotihuacan and dietary reconstruction has focused mainly on identifying use of aquatic resources in the lower Río Verde Valley (White et al. 2004a, b; White and Spence 1998). This represents a common trend in isotopic research within Mesoamerica since the majority of research surrounding migration involves the relationship between Teotihuacan and other major sites such as Tikal, Guatemala;

Copan, Honduras; and Kaminalijuyu, Guatemala. Dietary reconstruction has only been investigated isotopically in Oaxaca in the lower Río Verde Valley. Stable barium and strontium data from this region were included in a large study to identify use of marine resources (Burton and Price 1990). More recently Taylor et al. (2009) utilized stable carbon isotopes to identify change in diet over time and aquatic resource consumption. The majority of research in relation to reconstructing past diet, particularly during periods of collapse, have focused on Maya populations that inhabited the regions of modern day Belize, Guatemala, parts of Mexico, Honduras, and El Salvador (White et al. 1993; Wright 1997; White 1997; Somerville et al. 2013). While not located in Oaxaca, these populations share many similarities in diet and forms of subsistence strategies.

Teotihuacan's Foreign Barrios

Prompted by the findings of the Oaxaca barrio Tlailotlacan at Teotihuacan, stable oxygen isotope analysis has been used to extensively explore the relationship between Teotihuacan and Monte Albán in the Valley of Oaxaca (Spence 1992:60; White et al. 1998; White et al. 2004). The barrio itself was inhabited for roughly 400 years and the residents maintained Oaxacan cultural identity, evident through ceramic style, architecture, and burial type (White et al. 2004). While the barrio is unique at Teotihuacan, Oaxacan barrios at Los Teteles, Puebla, and Chingú and El Tesoro in central Mexico show that a Zapotec diaspora from the Valley of Oaxaca was not unique (White et al. 2004). Baselines for this study were first established from 25 individuals buried in the Tlanjinga 33, a barrio of local Teotihuacan's, and 16 individuals interred at Monte Albán (White et al. 1998; White et al. 2004). These baseline results demonstrated a significant difference in oxygen values between the two areas. Twenty-eight individuals, both adults and

children, from the Oaxacan barrio were then sampled for comparison. Samples were taken when possible from both bone and tooth enamel phosphate in order to look at the life history of the individuals. Bone samples showed that the barrio's adult residents had values consistent with the baseline established from Tlanjinga 33; this suggests that if they were migrants they had resided in the city for at least the last 10-20 years of their life. Individuals whose bones and teeth were analyzed revealed an interesting discovery. Many of the individuals who were born in the barrio left the city at some point and then returned later; this pattern occurs most frequently among females and children (White et al. 2004:400). However, these pilgrimages were not back to Monte Albán but rather to other Oaxacan barrios such as Los Teteles. This isotopic data has suggested that there was continual interaction among the barrio's residents, the Oaxacan region, and other diaspora barrios that were formed by the initial Zapotec migration (White et al. 2004).

Another barrio at Teotihuacan where stable oxygen isotope analysis was used to determine relationships among groups in Mesoamerica is the Merchant's Barrio. Its nickname originated because of the diverse variety of regional style goods similar to those found in the Maya region and on the Gulf Coast. Many have speculated that the individuals residing here were involved in long distance exchange or that the barrio displays a diaspora of goods obtained from another source within the city (Spence et al. 2005). The burials within the barrio are also unique in that the majority appear to be secondary in nature or a single internment containing multiple individuals (Spence et al. 2005:160). While this barrio is a distinct area within Teotihuacan, it does not represent a group of people who share a single ethnic identity like that of the Oaxaca barrio. Isotopic evidence indicates that all immigrants were male except for one female, and generally all females and children displayed local values while males displayed foreign isotopic values (Spence et al. 2005:16-17). Since males were most likely the ones

participating in long distance trade, the isotopic evidence may support the hypothesis that the barrio's residents were merchants.

Migration among the Maya

The Maya epigraphic record has strongly suggested that central Mexico played a role in founding Tikal's dynastic line and marriage alliances were formed between Tikal elites and individuals from central Mexico during the Early Classic (Martin 2003; Martin and Grube 2008; Stuart 2000). Isotopic analysis of both strontium and oxygen isotopes from tooth enamel of 134 individuals were used to test these relationships. Wright (2012) found that between 11-15% of the population was non-local, with the highest frequency of migrations occurring during the Early Classic (27.5%) compared to the Late Classic (10.2%). However, the comparison of these two samples is difficult because the Early Classic samples are from elite and ceremonial contexts while the Late Classic samples are from mainly domestic contexts. This analysis demonstrates that people migrated to Tikal from highland Guatemala, central Mexico, the Maya Mountains, the Gulf Coast, and the Belize River Valley (Wright 2012:341). A few individuals had values similar to those of Kaminaljuyu and Teotihuacan. Samples taken from Yax Num Ahiin, whom the epigraphic record describes as the son of Teotihuacan's ruler Spearthrower Owl, were of particular interest and displayed values of a local resident (Martin and Grube 2008:32). Furthermore, the majority of sampled individuals dating to the Preclassic or Early Classic had values consistent with central Mexico, suggesting that Teotihuacan did not play a role in creating dynastic lines and relations between the two polities was most likely built economically rather than through marriage alliances.

Similar theories have been tested at Copan, where isotopic analysis has been used to understand the relationship between Copan, Teotihuacan, and other Maya lowland polities. Thanks to Linda Schele's (1986) detailed work, Copan's epigraphic record is one of the best understood among all Maya sites. The record recounts a coup by foreigners who invested ethnic Maya as rulers over the local population, and Schele (1986) and Sharer (2003:143-165) suspected these rulers came from Tikal. Oxygen samples from 11 individuals, including the dynastic founder K'inich Yax K'uk Mo were taken to determine their place of origin (Price et al. 2010:35). Some individuals appeared to have migrated from central Mexico and the southern Maya lowlands. K'inich Yax K'uk Mo had some of the most interesting isotopic values; values from tooth enamel and bone displayed three migrations through the course of his life: first from the Maya mountains, likely Caracol; then to Tikal in the Peten region; and finally to Copan (Price et al. 2012:41). The authors concluded from these data that the founder of Copan's dynasty came to Copan from Caracol via Tikal.

Finally, isotope analysis has been utilized to understand the extent of Teotihuacan's influence at Kaminaljuyu during the Early Classic, much of which has previously been discussed through shared ceramic and architecture styles (Braswell 2003). Carbonate samples of bone and tooth enamel were both utilized in this study. Individuals interred in the Early Classic tombs of Mounds A and B had values consistent with foreigners from various areas (Wright et al. 2010). Out of all the migrants, only two displayed values similar to the baseline at Teotihuacan; the majority better matched values from the Maya lowlands (Wright et al. 2010). The authors concluded that a relationship between Teotihuacan and Kaminaljuyu was most likely indirect and probably facilitated merely through trade while sociopolitical relationships were fostered between Kaminaljuyu and the Maya lowlands.

Dietary Reconstruction in the lower Río Verde Valley, Oaxaca



Figure 3: Río Viejo, Cerro de la Cruz, and Barra Quebrada are all sites within the lower Río Verde Valley which were included in previous isotopic studies; Tututepec is another major center during the Postclassic period (courtesy of Sarah Barber).

Burton and Price (1990) evaluated samples from the lower Río Verde Valley as part of a larger study investigating whether the ratio of barium (Ba) to strontium (Sr) could be used as an indicator of marine resource consumption. Fourteen different sites were compared based on known or assumed subsistence. Paloma (Peru), Rolling Bay (Alaska), Kiavak (Alaska), Three Sts Bay (Alaska), Chaluka (Alaska), and Port Moller (Alaska) were all categorized as coastal sites subsisting mainly on marine resources. Río Viejo and Cerro de la Cruz, Mexico (Figure 3) were both categorized as coastal sites subsisting mainly on terrestrial resources. Pirincay, Ecuador; Pueblo Grande, Arizona; Carson Sink, Nevada; multiple sites in Poland; Monte Albán, Mexico; and Frabrica San Jose, Mexico were all categorized as inland sites subsisting mainly on

terrestrial resources. Data demonstrates a clear difference between populations consuming a marine versus terrestrial diet, except for the case of populations living in a desert environment (Table 3). The populations from Pueblo Grande and Carson Sink are both known to consume a terrestrial diet and have no access to marine resources however their Ba/Sr values are very similar to populations consuming a marine based diet. This difference was attributed to the enrichment of strontium in desert basin soils.

Table 3: Stable Barium and Strontium Isotope Values (Burton and Price 1990)

Site	N	Location	Subsistence	Ba/Sr with SD
Paloma, Peru	53	Coastal	Marine	-1.583 ± 0.13
Rolling Bay, Alaska	10	Coastal	Marine	-1.714 ± 0.23
Kiavak, Alaska	8	Coastal	Marine	-1.518 ± 0.18
Three Sts Bay, Alaska	12	Coastal	Marine	-1.397 ± 0.26
Chaluka, Alaska	4	Coastal	Marine	-1.397 ± 0.26
Port Moller, Alaska	3	Coastal	Marine	-1.456 ± 0.16
Río Viejo, Mexico	8	Coastal	Terrestrial	-0.184 ± 0.14
Cerro de la Cruz, Mexico	12	Coastal	Terrestrial	-0.288 ± 0.16
Pirincay, Ecuador	9	Inland	Terrestrial	-0.026 ± 0.38
Pueblo Grande, Arizona	12	Inland	Terrestrial	-1.274 ± 0.36
Carson Sink, Nevada	18	Inland	Terrestrial	-1.266 ± 0.26
Poland (multiple sites)	15	Inland	Terrestrial	-0.216 ± 0.18
Monte Albán, Mexico (Oaxaca)	3	Inland	Terrestrial	-0.280 ± 0.22
Fabrica San Jose, Mexico	4	Inland	Terrestrial	-0.305 ± 0.13

Joyce (1991a, b) expanded further on this study by including zinc along with barium and strontium and focused more locally on diet within the lower Río Verde Valley. Data was collected from twenty-five Late and Terminal Formative individuals at Cerro de la Cruz and Río Viejo, seven Early Classic individuals at Río Viejo, and five individuals from Barra Quebrada (see Table 4 for results). While Río Viejo, Cerro de la Cruz, and Barra Quebrada are considered

coastal sites, the first two are geographically situated in the valley's flood plain while Barra Quebrada is located on a barrier island near the ocean, estuaries, and the mouth of the Río Verde River (see Figure 3). Formative values were compared with a "control sample" of individuals from the inland sites from the Valley of Oaxaca who had no access to marine resources. The Late/Terminal Formative coastal Ba/Sr sample was significantly lower than the highland control sample as demonstrated by a Mann-Whitney U test; this suggested that coastal populations were consuming larger amounts of marine resources than their inland counterparts. Early Classic samples from Río Viejo demonstrated no significant difference from the Late/Terminal Formative sample from Río Viejo and Cerro de la Cruz, indicating diet remained consistent. A comparison of individuals from Early Classic Río Viejo and Barra Quebrada does show a significant difference. Individuals from Barra Quebrada consumed a much higher quantity of marine resources compared to populations living in the valley's flood plain. Zinc data were used to identify meat consumption. Data suggest that individuals from the Late/Terminal Formative period from the lower Río Verde had significantly higher meat consumption than individuals from the Valley of Oaxaca. The Early Classic sample from Río Viejo shows a slight but not significant decrease in meat consumption when compared with its earlier counterpart. Barra Quebrada on the other hand has values significantly higher zinc values than at Río Viejo; further supporting that the population at Barra Quebrada ate a diet much higher in marine resources. Both chemical and archaeological evidence (freshwater fish and estuarine shellfish found in middens) suggest that aquatic resources were exploited. However the small assemblages of these food resources and the Ba/Sr data from flood plain sites demonstrates that plant foods made up the majority of the diet.

Table 4: Stable Barium, Strontium, and Zinc Isotope Values for sites with the lower Río Verde Valley and the Valley of Oaxaca (Joyce 1991)

Time Period	Location	N	Ba/Sr with SD	Zn with SD
Late/Terminal Formative	Cerro de la Cruz & Río Viejo	25	-0.260 ± 0.139	180.1 ± 42.1
	Valley of Oaxaca	19	-0.140 ± 0.314	147.3 ± 29.5
Early Classic	Río Viejo	7	-0.191 ± 0.149	154.1 ± 31.7
	Barra Quebrada	5	-0.568 ± 0.167	201.8 ± 53.6

More recently stable carbon isotope analysis and dental wear analysis was conducted on individuals from the sites of Río Viejo, Yugué, and Cerro de la Cruz in the lower Río Verde Valley (Taylor et al. 2009). These analyses were used to investigate human diet from the Late Formative to Early Postclassic (see Table 5 for results). The study demonstrated that the carbon values for the lower Río Verde sample had a mean of -5.2‰ with a range of -1.5‰ to -8.3‰; this differs greatly from North and South American populations that did not consume maize (Tykot et al. 2009). A Fisher PLSD test revealed that Early Postclassic samples (-2.6‰) differed statistically from all previous time periods. Furthermore, Late Formative and Late Terminal Formative samples were also significantly different suggesting there was a large increase in C₄ consumption at the end of the Formative. Overall, the mean carbon values become less negative throughout time, except for the samples dating to the Early Classic. Taylor et al. (2009) note this may be due to the small sample size for that time period (n=4). In addition, a dental microwear texture study was also conducted and is stated to further support the conclusions drawn from the isotopic portion of the study. The paper argued that because tooth surfaces experienced less abrasive wear in later time periods individuals could likely be eating a diet high in processed maize. This argument is problematic since maize was processed using large *manos* and *matates* made of abrasive stone material which becomes deposited in the finished food product and consumed by the individuals.

Table 5: $\delta^{13}\text{C}$ Apatite (adapted from Taylor et al. 2009)

Time Period	N	Mean	Minimum	Maximum	Range	Standard Deviation	Standard Error	Variance
Late Formative	36	-5.73	-7.90	-3.30	4.60	1.18	0.19	1.39
Early Terminal Formative	3	-5.60	-8.30	-3.80	4.50	2.38	1.37	5.67
Late Terminal Formative	13	-4.07	-6.80	-2.90	3.90	1.15	0.31	1.33
Early Classic	4	-6.25	-7.70	-4.40	3.30	1.41	0.70	2.00
Early Postclassic	3	-2.56	-4.60	-1.50	3.10	1.76	1.01	3.10

Dietary Reconstruction in the Maya Region

White et al. (1993) investigated dietary change over time at the site of Pacbitun, Belize (Figure 4). Their sample included thirty-three individuals total; however, due to status differences not all individuals were used when comparing temporal dietary shifts. Three individuals dating to the Late Classic (A.D. 550-700) and eight dating to the Terminal Classic (A.D. 700-900) were used to compare dietary shifts in reference to social and political collapse at the end of the Classic period. The site reached its height during the Terminal Classic before being abandoned shortly afterward (Campbell-Trithart 1990; Richie 1990). The percentage of C_4 plants within an individual's diet was calculated using the bone collagen formula (Schwarcz et al. 1985). During the Late Classic, maize-based foods appear to represent 77% of the diet for the three individuals ($\delta^{13}\text{C} = -8.46 \pm 1.29$), while maize-based foods appear to represent 68% of the diet for eight individuals dating to the Terminal Classic ($\delta^{13}\text{C} = -9.91 \pm 1.36$). These data suggest to the authors that there was decrease in maize consumption because Pacbitun was unsuccessful in meeting the demand for their growing population (White et al. 1993). Unlike the shifting plant portion of the diet, protein resources as evident from $\delta^{15}\text{N}$ values remain stable from the Late

Classic to the Terminal Classic. This evidence supports the idea that abandonment of Maya centers was due to intensive agriculture and exploitation that led to a degradation of the local environment.

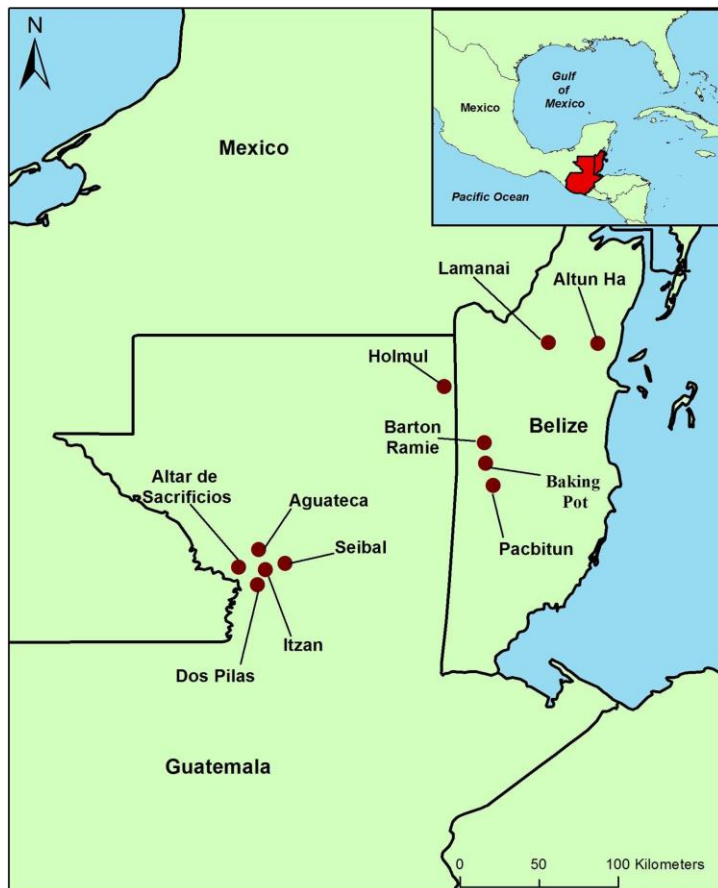


Figure 4: Maya sites discussed in articles by White (1993; 1997), Wright (1997), and Somerville et al. (2013)

White (1997) investigated diet as a way to answer questions about the cause of collapse at the Maya site of Lamanai, Belize (Figure 4). Specifically, the study analyzed stable isotope data alongside dental pathology to test the ecological model for collapse. These data were also compared to the study by White et al. (1993) discussed above that focused on the nearby site of Pacbitun, Belize. Unlike Pacbitun, maize reliance drastically increased during the collapse period with $\delta^{13}\text{C}$ values averaging at -14.2 ± 1.1 for the Late Classic and -9.3 ± 0.9 for the Postclassic.

Similarly to Pacbitun, the $\delta^{15}\text{N}$ values indicate that the protein sources being exploited remained consistent through time. The ability for maize production and consumption to not only increase following collapse but remain consistent until Spanish conquest argues against an ecological model for collapse.

Wright (1997) also conducted a regional study by investigating diet from five Maya sites in the Pasion region (Figure 4) of Guatemala as a way to investigate whether collapse was ecological or social in nature. The current hypothesis for collapse in the southern lowlands centers on an ecological model with the ancient Maya populations growing beyond the carrying capacity of the ecosystem and an increase in extensive agricultural systems leading to soil erosion and deforestation. The results of the study along with the previous two from Pacbitun and Lamania (White et al. 1993; White 1997) are summarized in the following table:

Table 6: Mean $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ Values from studies investigating Maya dietary change during periods of collapse (Wright 1997)

Site	N	Time Period	Mean $\delta^{13}\text{C}$ ‰	SD	Mean $\delta^{15}\text{N}$ ‰	SD
Pacbitun, Belize	1	Early Classic	-9.17	-	8.12	-
	3	Late Classic	-8.46	1.29	9.34	0.60
	8	Terminal Classic	-9.91	1.36	9.24	0.58
Lamania, Belize	5	Preclassic	-12.4	0.30	10.2	0.60
	2	Early Classic	-12.3	1.6	10.9	1.5
	5	Late Classic	-14.2	1.1	10.3	0.1
	6	Terminal Classic	-15.0	1.2	9.9	0.4
	50	Postclassic	-9.3	0.8	9.5	0.9
	42	Historic	-9.9	0.9	9.7	0.6
Altar de Sacrificios,	9	Preclassic	-10.7	1.17	8.2	0.95
	6	Early Classic	-9.7	1.65	8.3	0.62

Site	N	Time Period	Mean $\delta^{13}\text{C}$ ‰	SD	Mean $\delta^{15}\text{N}$ ‰	SD
Guatemala	7	Late Classic	-8.3	1.03	9.0	1.04
	16	Terminal Classic	-9.0	0.88	8.8	1.14
Seibal, Guatemala	7	Preclassic	-9.6	0.95	9.7	0.81
	11	Late Classic	-9.4	1.34	9.9	0.86
	16	Terminal Classic	-9.4	1.15	8.9	0.94
Dos Pilas, Guatemala	14	Late Classic	-9.0	1.03	9.8	0.93
	4	Terminal Classic	-9.4	0.77	8.8	1.21
Aguateca, Guatemala	8	Late Classic	-9.6	0.69	9.4	1.16
Itzan, Guatemala	5	Late Classic	-9.2	0.30	8.0	0.98

At Altar de Sacrificios there was an increase in maize consumption throughout time from the Preclassic to the Late Classic. During the Terminal Classic period, the site stopped the construction of ceremonial structures, population remained high, and $\delta^{13}\text{C}$ values dropped while $\delta^{15}\text{N}$ remained consistent suggesting a decrease in maize consumption during this period (Wright 1997:188). The $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values from Dos Pilas were similar to values from Altar and suggested a similar decrease in maize consumption during the Terminal Classic (Wright 1997:190). Data from Seibal differ from both Dos Pilas and Altar. Maize reliance appears to start much earlier during the Preclassic and remains consistent through time. A dietary shift is observed in $\delta^{15}\text{N}$ values suggesting a decline in meat consumption or a tradeoff in protein sources (Wright 1997:190). Itzán and Aguateca only have individuals sampled from the Late Classic and therefore cannot be used to discuss change over time but can be compared isotopically to individuals dating to the same period at other sites. Both sites have $\delta^{13}\text{C}$ values consistent with Dos Pilas but $\delta^{15}\text{N}$ indicate little reliance on animal protein and aquatic

resources. This is especially surprising for Aguateca since the site is located on a river (Wright 1997:192). These data indicate that even within a particular region dietary practices are site-specific and influenced by environmental and cultural factors. Maize was clearly an important and relied-upon staple food; however, its persistence at multiple sites during the Terminal Classic contradicts the ecological model for collapse.

More recently, Somerville et al. (2013) utilized a multivariate statistical model to evaluate dietary change in status groups from the Classic to Postclassic Period using a meta-analysis of previously published isotopic data from the Maya sites of Seibal, Pacbitun, Barton Ramie, Baking Pot, Homul, Altun Ha, and Lamanai. Isotope values from both bone apatite and collagen from one hundred and two individuals were analyzed using both simple carbon isotope and multivariate isotope models. Twenty-six individuals were sampled from the Early Classic, fifty-five from the Late Classic, and twenty-one from the Terminal Classic; the total sample is further divided into two equal-sized status groups, elite (N=51) and commoner (N=51). ANOVA tests demonstrated that elite diet changed from the Classic period to the Terminal Classic while commoner diet remained stable (Somerville et al. 2013:1544). This was attributed to the probability that commoners were utilizing several forms of food procurement such as slash-and-burn agriculture, terracing, raised fields, forest foraging, and kitchen gardens, while elite subsistence strategies were more likely tied to political and economic conditions, in which food resources were dependent on intensive agriculture and continually changing trade routes (Somerville et al. 2013:1551).

Summary

Migration studies within Mesoamerica have mainly focused on political relationships between major Maya polities and relationships between Maya or Oaxaca polities and Teotihuacan. Furthermore, the majority of samples are taken from individuals located in the epicenter of Maya polities, focusing on only the elite or higher status members of society. This existing research has also focused heavily on movement during the Classic period. The next step in more fully understanding human mobility is to investigate migration among commoners and expand data to include Preclassic and Postclassic time periods. Expanding this set of data will answer questions about mobility in reference to the emergence and collapse of complex societies and the possible reasons for commoners to move towards or away from larger centers.

Diet reconstruction studies within Mesoamerica, particularly among the Maya, have focused on understanding how diet changes through time and many have even utilized stable isotope analysis to test models for collapse. Many studies indicate no basis for an ecological model of collapse (White 1997; Wright 1997), but dietary shifts indicate that collapse did affect diet in different ways at different places. This suggests that while there may be a pan-Mesoamerican trend of collapse, collapse could be caused for a multitude of reasons or rather there were a diverse set of responses to collapse.

CHAPTER 3: MATERIALS AND METHODS

Materials: Samples and Archaeological Context

The materials for this thesis project were excavated under the Proyecto Archaeologia Río Verde, directed by Drs. Arthur Joyce and Sarah Barber, during the 2000 (Joyce) and 2012 (Joyce and Barber) field seasons. The samples were from individuals interred at the site of Río Viejo, which is located in the lower Río Verde Valley in the Mexican state of Oaxaca. In the summer of 2014, I collected bone and tooth samples from skeletal remains of 17 individuals dating to the Late Classic period and 12 individuals dating to the Early Postclassic period. All samples were processed according to the procedures explained in this chapter. A total of 12 individuals from the Late Classic and 11 individuals from the Early Postclassic produced acceptable results (see Chapter 4 for further detail) and this chapter will only discuss the context of those 23 individuals.

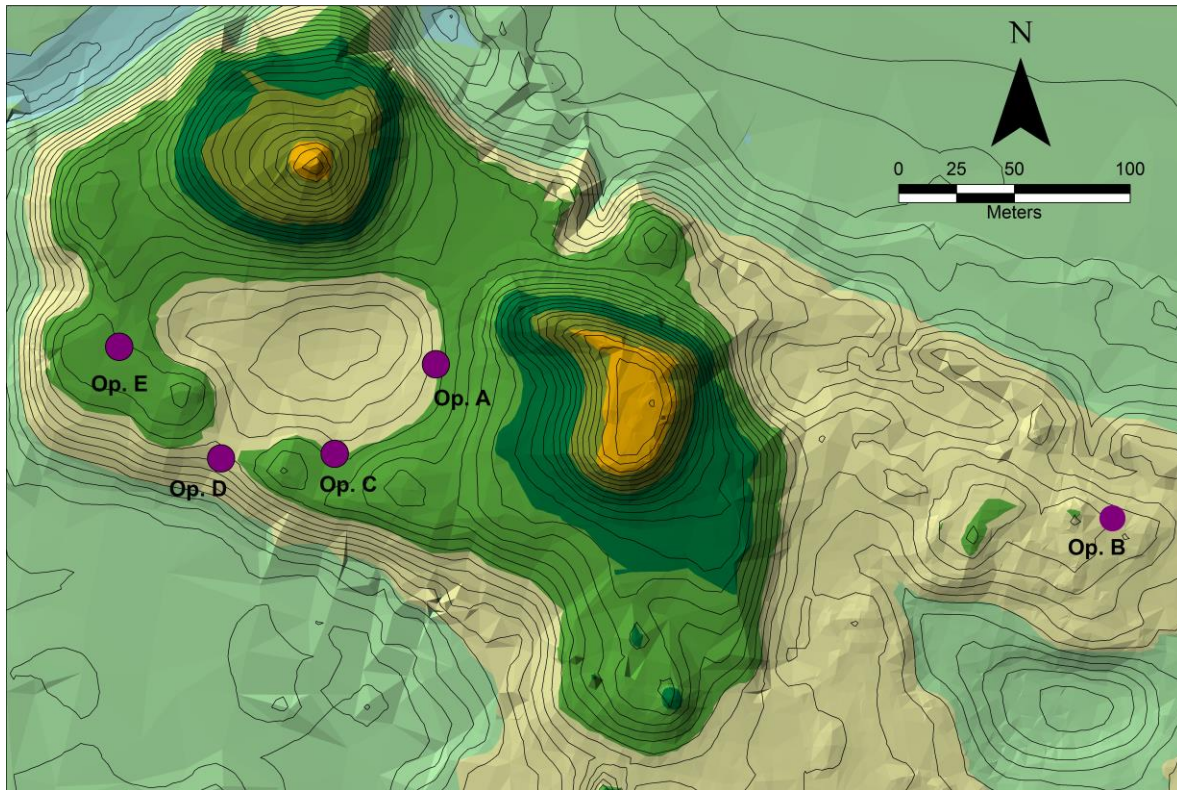


Figure 5: Topographic map of Río Viejo and the operations where burials used in this study were excavated

The individuals sampled from the Late Classic at Río Viejo were recovered from Operations A, B, C, D, and E (see Figure 5) (see Appendix for excavation reports). Individuals 73 and 103 were both uncovered from Burial 64 in Operation A. The burial was considered an offering because of its placement within a pit and due to the high concentration of ash, charcoal, and burned daub with burned bones placed over top. These individuals along with two others were interred at the bottom of the pit with individual 73 being situated in the center with the remaining individuals located in the northwest corner. Despite the overlying material appearing to be burned in situ none, of the four individuals were burned. Individual 102 from burial 93 in Operation A was located in the fill above a layer of sediment with a dense concentration of rocks. The individual was a possible adolescent male, placed face down with his head placed inside a Late Classic orange ware conical bowl. The final individual from this sample, individual

107 burial 97, was an adult male interred inside a large brown ware vessel and had probably been bundled. The vessel was a part of a placement of two large coarse brown ware vessels that represented one of the first Late Classic activities found in the Operation A area, the other of which also contained a bundled burial. Individual 48 from burial 40, individual 51 from burial 42, individual 53 from burial 44, individual 56 from burial 47, and individual 60 from burial 51 were all excavated in Operation B during the excavation of the Early Postclassic Structures 8-3, 8-4, 8-7, 8-8, 8-9, and 8-10. Individual 96 from burial 87 was uncovered within a unit in Operation C that had eleven stratigraphic layers, two burials, and a burial pit. The individual was a male, extended in the prone position, and had one gray ware bowl over the head, an orange ware pot with incising and motifs over the chest, and a gray ware pot with incising and motifs over the pelvis. Individual 65 from burial 74 was uncovered in the excavations of the Late Classic acropolis in Operation D. These Late Classic occupation phases are found within a large pit or channel erosion on the southern side of Mound 1 in the acropolis. Five burials were uncovered directly above or possibly within the deposit of a thick layer of fill labeled as E4, however, not all were excavated. B65 I74 was placed underneath this layer and cut into the earlier Formative fill; however, the burial was identified as Late Classic because of the Late Classic vessels found directly above the body and in the same associated layer. Individual 85 from burial 76 was also uncovered from excavations in Operation E, a Late Classic occupation of Mound 1. The burial was a part of the E11 fill layer, which covered a large area (40 meters), on the west platform of the mound. Two other burials were in close proximity but remained unexcavated. The burials discussed as part of the Late Classic sample from Río Viejo display a range of offerings and public space deposits; this makes it difficult to ascertain these individual's positions within society as it is unclear why they were chosen for special burial.

All individuals dating to the Early Postclassic were recovered from Operation A and B at Río Viejo. Only burials from Operation B were included in this study (see Appendix for excavation reports). All were single internments and buried underneath the floor of residential Structure 8-8b and residential Structure 8-7. The placement of these internments is unusual compared to burials from earlier time periods. The individuals placed underneath the floors during the Early Postclassic were purposefully and carefully placed as to not disturb other already buried individuals. This demonstrates knowledge of past burials, and possibly suggests a continual remembrance and respect for those interred. Burials from previous periods show quite the opposite, individuals were placed either atop or adjacent to one another purposefully or burials were being reentered by accident. All the individuals from the Postclassic were buried with their heads facing south, a trend normally associated in this region with burials underneath floors (King 2003). Furthermore, all the individuals except one were buried with offerings placed near the feet of an individual. Maize phytoliths were also present in one of the vessels and indicate that maize-based food was either consumed during mortuary ritual or presented to the deceased. Structure 8-8b and Structure 8-7 appear to represent two household groups that shared similar traditions based on mortuary practice and indicate the burials present here are domestic in nature and are likely of individuals who resided in these households.

Methods for Collagen and Apatite Extraction

Bone samples were collected from the femur when possible. If the femur was not available, another long bone such as the humerus or tibia was selected. Samples were collected using a Dremel© rotary tool with a circular blade. If the bone was already fragmented, the sample was collected from existing fragments to avoid any further destruction to the whole bone.

The third molar was collected for analysis when possible. If the third molar was not available, then the second molar or premolar was chosen. Molars that were no longer attached to the maxilla or mandible were selected first to prevent any further destruction. If there were no loose molars present, the Dremel® or tweezers were used to remove the molar from the mandible or maxilla. Maxillary molars were easier to remove with less damage so when possible those were chosen first. The bone and tooth samples were then processed according to the following procedures at the University of Central Florida's Bioarchaeological Laboratory.

Bone Collagen

The methods used to process bone collagen for this thesis was derived from the work of Longin (1971) which was later modified by the Laboratory for Stable Isotope Science (LSIS) at the University of Western Ontario in Canada. Following these methodologies, bone samples were processed in the following way:

1. The entire bone sample was cleaned to remove excess soil, roots, and foreign material using a toothbrush and then rinsed in distilled water using an ultrasonicator.
2. After being rinsed, the samples were dried for 24 hours at 90°C and then the pieces were broken into 2-5 millimeter pieces using a mortar and pestle.
3. The samples were then placed in 15 milliliters of 2:1 chloroform methanol to remove any lipids from the bone; this step was repeated three times.
4. Following the chloroform methanol process, the samples were rinsed with distilled water for 5 minutes and then placed in 15 milliliters of 0.25 M HCl, following White et al. (1993). The HCl was exchanged out every 24 hours until all the mineral content was dissolved and collagenous isomorphs were acquired.

5. The samples were then rinsed with distilled water for 5 minutes and then placed in 15 milliliters of 0.10 M NaOH to remove any humic and fulvic acids.
6. The samples were then rinsed with distilled water for 5 minutes at least six times and placed in 15 milliliters of 0.25 M HCl to remove any remaining trace materials and bring the pH to a level of neutrality.
7. The HCl was removed and replaced with 5 milliliters of distilled water and put in the oven at 90°C for approximately 16 hours in order to become gelatinized.
8. The gelatinized collagen was pipetted into a 15 milliliter glass dram vial and placed in the oven to dry at 90°C for 24 hours.

Following drying, the vials with the dried gelatinized collagen were weighed and the percentage of collagen in the bone, or the percentage yield of collagen (% collagen), was calculated. This was calculated following the equation used by the University of Central Florida Bioarchaeology Lab's protocol:

$$\text{Collagen yield \%} = \frac{\text{weight of vial with treated sample (g)} - \text{weight of empty vial (g)}}{\text{weight of dry sample (g)}} \times 100 \quad (6)$$

This is important in order to determine if the collagen was preserved in the samples in accordance with C:N ratios and atomic C and N percentages (DeNiro 1985). After the collagen extraction process was completed, dried collagen from each sample weighing between 1.0 and 1.2 micrograms was powdered and placed in a 3x3.5 millimeter tin capsule. The samples were then packaged in trays and sent to the Stable Isotope Facility at the University of California,

Davis for analysis of ^{13}C and ^{15}N isotopes using a PDZ Europa ANCA-GSL elemental analyzer interfaced to a PDZ Europa 20-20 isotope ratio mass spectrometer.

Dental Collagen

Methods for extracting dental collagen are derived from Wright and Schwarcz (1999); however, the process is similar to that used for bone samples. Dentin samples were processed in the following way:

1. Each tooth was cleaned using a toothbrush to remove excess soil, roots, and foreign material and then rinsed in distilled water using an ultrasonicator.
2. The teeth were then dried in the oven at 90°C for 24 hours. Following this the dentin was separated from the enamel using a Plattner's steel mortar and pestle, dental picks, and tweezers.
3. The dentin samples were placed in 2 milliliters of 0.25 M HCl; the solution was exchanged every 24 hours until any trace inorganics were dissolved and a collagenous isomorphs were acquired.
4. The samples were rinsed in distilled water for 5 minutes and placed in 15 milliliters of 0.10 M NaOH in order to remove any humic and fulvic acids.
5. The samples were then rinsed in distilled water and placed in an oven at 90°C for 16 hours to become gelatinized and then the gelatinized mixture was placed in 15 milliliter glass dram vials to dry in the oven at 60°C for approximately 24 hours.

Following this process, the percentage of collagen present in each dentin sample or percentage of yield of collagen (% collagen) was calculated. This was calculated following the equation used by the University of Central Florida Bioarchaeology Lab's protocol:

$$\text{Collagen yield \%} = \frac{\text{weight of vial with treated sample (g)} - \text{weight of empty vial (g)}}{\text{weight of dry sample (g)}} \times 100 \quad (7)$$

This is important in order to determine if the collagen was preserved in the samples in accordance with C:N ratios and atomic C and N percentages (DeNiro 1985). After the collagen extraction process was completed, dried collagen weighing between 1.0 and 1.2 micrograms was powdered and placed in a 3x3.5 millimeter tin capsule. The samples were then packaged in trays and sent to the Stable Isotope Facility at the University of California, Davis for analysis of ¹³C and ¹⁵N isotopes using a PDZ Europa ANCA-GSL elemental analyzer interfaced to a PDZ Europa 20-20 isotope ratio mass spectrometer.

Enamel Carbonate

Carbonate is derived from the enamel apatite in teeth and is more resilient to diagenetic processes, especially when compared with its bone counterpart. Therefore, is considered to produce more reliable isotopic data for carbon and oxygen (Lee-Thorp et al., 1989; Blondel et al., 1997). The method used for processing the enamel apatite is derived from Sullivan and Kruegar (1983). Enamel apatite samples were processed in the following way:

1. Samples were first cleaned using a toothbrush to remove any excess soil, roots, or foreign material and then rinsed with distilled water in an ultrasonicator.
2. The teeth were then dried in the oven at 90°C for 24 hours. Following this the enamel was separated from the dentin using a Plattner's steel mortar and pestle, dental picks, and tweezers.

3. The enamel was ground into a powder and sifted through a 180-micron sieve to achieve a fine ground for each sample.
4. Between 20-30 milligrams were then placed into plastic microcentrifuge vials and submersed in a 2% diluted bleach solution for 24 hours. The amount of bleach solution used was dependent on the sample and calculated using the following equation:
*weight of sample (mg) * 0.04 = 2% bleach solution needed (mL)*
5. The samples were then rinsed in distilled water for 10 minutes five times and placed into a 1.0 M acetic acid solution for four hours. Similar to the bleach solution, the amount of acetic acid solution was calculated based on sample weight using the formula above.
6. The samples were rinsed five more times in distilled water for 10 minutes, covered with a Kimwipe, and placed in the freezer at -60°C for 24 hours followed by a vacuum chamber at <200 mTorr for 24 to 48 hours, or until all samples were completely dry, to undergo lyophilization, or freeze drying.

Following this process, the percentage of apatite present in each enamel sample or percentage of yield of apatite (% carbonate), was calculated. This was calculated following the equation used by the University of Central Florida Bioarchaeology Lab's protocol:

$$\text{apatite yield \%} = \frac{\text{weight of vial with treated sample (mg)} - \text{weight of empty vial (mg)}}{\text{weight of dry sample}} \times 100 \quad (8)$$

Finally, between 1.0-1.5 milligrams of each sample was weighed out and placed in plastic microcentrifuge vials and sent to the Light Stable Isotope Mass Spec Lab at the University of

Florida to be run on a Finnigan-MAT 252 isotope ratio mass spec with a Kiel III carbonate preparation device.

CHAPTER 4: RESULTS

Sample Preservation

Taphonomic and diagenetic changes begin once an organism has transitioned from life to death. These changes influence how well skeletal material preserves in the archaeological record (Christensen et al. 2014). Diagenesis describes the chemical, physical, and biological changes in bone after death; this specifically relates to the isotopic study of bone collagen in that microorganisms invade the matrix surrounding the body and feed off the protein sources (Hedges 2002).

Skeletal remains from Mesoamerica are generally in poor condition due to the hot, humid, tropical environment. Coastal Oaxaca's clay soil is alkaline, heavy, sticky, and can become extremely hard. Much of the excavated skeletal material is crushed by the soil or badly molten together, making it very difficult to conduct bioarchaeological analysis. Because of this, hardened clay is removed from skeletal material with acetone as recommended by the conservation department at the Smithsonian Institute; this allows for detailed osteological analysis to be completed, giving us information on age, sex, and pathology of ancient individuals. This, however, can also lead to further challenges with chemical analyses since acetone can destroy collagen material. Despite how poorly bone tends to preserve in this context, teeth preserve remarkably well and therefore are relied upon heavily for bioarchaeological analyzes.

Ninety percent of the organic component of bone is collagen and normally samples should provide at least 5.0% collagen yield to be viable for study (Price et al. 1985; Schoeninger et al. 1989; White and Schwarcz 1989). Recent studies however have demonstrated that a 1.0-

3.5% collagen yield is acceptable for study but may contain organic contaminants (Schoeninger et al. 1989; Ambrose 1990). Therefore the quality of the preservation for this study was determined by a collagen yield of greater than 1%. The majority of samples with less than a 1% yield were not sent for further analysis; some with yields close to 1% were sent to determine whether acceptable carbon and nitrogen values from collagen could be extracted from these samples.

Acceptable collagen preservation for isotopic research is also determined by percent weight of the carbon and nitrogen concentrations (Ambrose 1990; Ambrose and Norr 1992). While these values indicate sample preservation they are the least relied upon due to the wide ranges and overlap. Bone collagen with acceptable preservation has a carbon concentration of 15.3-47.0% and a nitrogen concentration 5.5-17.3% (Ambrose 1990; Ambrose and Norr 1992). Forty-five bone and dentin samples were taken and twenty-five demonstrated satisfactory preservation as their carbon and nitrogen concentrations fall within the limits. Percent of weight of carbon and nitrogen concentrations was calculated by converting the weights in micrograms to milligrams and dividing by the sample weight.

Lastly, one of the most commonly used indicators of collagen preservation is the atomic C:N ratio. Collagen preservation acceptable for study based on atomic C:N ration should fall between 2.9-3.6 (DeNiro 1985; DeNiro 1987; Schoeninger et al. 1989; Ambrose 1990; Ambrose and Norr 1992; van Klinken 1999). According to Katzenberg (2008), modern mass spectrometers calculate C:N ratios that are approximately 1.16667 lighter than atomic ratios from previous studies (DeNiro 1985; Ambrose 1990). Atomic rations from Colorado Plateau Stable Isotope Laboratory (CPSIL) are therefore calculated using the following equation:

$$C:N \text{ ratio} = (14 \div 12) \times \left(\frac{C\% \text{weight}}{N\% \text{weight}} \right) \quad (9)$$

The samples in Table 7 demonstrates that overall bone collagen was not well preserved as only 11 out of 29 samples provided acceptable yields; these individuals are highlighted in the table. Two samples (B42 I51 and B87 I96) provided yields which fell right under 1% and were run and chosen to use in the study; both these samples failed to produce acceptable % weights but did produce an acceptable C:N ratio and produce results which fell in line with the averages for the rest of the sample average. Furthermore, two samples (B44 I53 and B97 I107) that did provide acceptable yields did not produce an acceptable % weight; these results were still included in the final analysis due to acceptable C:N ratio and results which fell within the average or the rest of the sample. The samples used in the analysis of this study are presented in Table 16 with the correlating carbon and nitrogen values.

Table 7: Summary of Preservation Values for Bone Collagen in Study Sample

Sample ID	Bone Collagen Yield (%)	%C Weight	%N Weight	C:N Ratio
Accepted Values	>1%	15.3-47	5.5-17.3	2.6-3.9
B26 I34	0.6	-	-	-
B27 I35	0.49	-	-	-
B28 I36	0.68	-	-	-
B29 I37	3.85	40.10	14.68	3.18
B30 I38	1.19	1.24	3.74	0.38
B31 I38	0.5	-	-	-
B32 I40	1.3	6.23	1.94	3.74
B33 I41	0.4	-	-	-
B35 I43	1.22	39.18	14.29	3.19
B42 I51	0.84	12.74	4.44	3.34
B41 I50	0.45	-	-	-

Sample ID	Bone Collagen Yield (%)	%C Weight	%N Weight	C:N Ratio
B44 I53	1.0	1.73	0.57	3.5
B45 I54	0.7	-	-	-
B46 I55	0.45	-	-	-
B47 I56	3.79	25.81	9.25	3.25
B50 I59	0.99	9.82	2.4	4.77
B51 I60	3.44	38.80	14.06	3.21
B64 I73	2.15	40.38	14.69	3.20
B64 I103	2.62	39.80	14.02	3.31
B65 I74	3.48	38.81	14.13	3.20
B67 I76	0.61	-	-	-
B76 I85	2.27	40.62	14.81	3.19
B81 I90	0.03	-	-	-
B87 I96	0.89	5.16	1.9	3.16
B88 I97	0.41	-	-	-
B93 I102	1.47	24.06	8.47	3.31
B94 I104	0.67	-	-	-
B97 I107	1.3	11.37	4.09	3.24
B98 I108	0.49	-	-	-

Table 8 demonstrates that dental collagen on the other hand has excellent preservation as 15 of the 16 samples produced acceptable yields; these individuals are highlighted in the table. However, not all these samples produced acceptable %C and %N weights and C:N ratios. B27 I36 while producing excellent yield did not produce acceptable % weights and C:N ratio; however, the results were included due to the individuals values falling within the sample's average. B30 I38, B42 I51, and B46 I55 all did not produce acceptable % weights but did produce acceptable C:N ratio; these were all included in the final analysis for this study.

Table 8: Summary of Preservation Values for Dental Collagen in Study Sample

Sample ID	Dental Collagen Yield (%)	%C Weight	%N Weight	C:N Ratio
Accepted Values	>1%	15.3-47	5.5-17.3	2.6-3.9
B26 I34	5.05	25.91	9.01	3.35
B27 I36	6.99	12.10	4.40	1.67
B28 I36	4.1	26.43	9.47	3.25
B29 I37	9.3	36.85	13.36	3.21
B30 I38	5.87	11.65	4.05	3.35
B31 I39	8.3	40.52	14.63	3.23
B32 I40	7.53	37.22	12.93	3.35
B33 I41	6.35	40.77	14.39	3.30
B42 I51	3.3	12.18	4.36	3.25
B41 I50	3.4	7.15	3.47	2.40
B43 I52	4.9	31.58	11.38	3.23
B46 I55	2.1	13.05	4.67	3.26
B47 I56	7.8	31.23	11.16	3.26
B51 I60	4.22	28.79	10.20	3.29
B87 I96	3.15	28.59	10.19	3.27
B93 I102	3.3	20.96	13.77	1.77

For this study, apatite from enamel was used. While enamel is inorganic and considered the hardest substance in the human body, it can still be susceptible to diagenic changes. The effects of diagenesis in apatite are the possible transferring of minerals from nearby sediment and groundwater (Hedges 2002; Katzenberg 2008; Yoder and Bartelink 2010). Preservation of enamel apatite is calculated by the percent yield of apatite after pretreatment. Enamel, unlike bone, contains a much lower organic content and therefore has a higher percentage of apatite, around 95-97% (Katzenberg 2008; Crowley and Wheatley 2014). The apatite yields for the samples in this study indicate great preservation (see Table 9).

Table 9: Summary of Preservation Values for Enamel Apatite in Study Sample

Sample ID	Enamel Apatite Yield (%)
B26 I34	86.77
B27 I36	89.23
B28 I36	88.64
B29 I37	88.68
B30 I38	87.53
B31 I39	88.93
B32 I40	87.61
B33 I41	88.98
B40 I48	88.74
B42 I51	90.63
B43 I52	87.71
B46 I55	87.67
B47 I56	87.32
B51 I60	89.28
B87 I96	87.44
B93 I102	87.47

Precision and Accuracy

Stable carbon and nitrogen isotopes from bone and dental collagen were analyzed by CPSIL on a PDZ Europa ANCA-GSL elemental analyzer interfaced to a PDZ Europa 20-20 isotope ratio mass spectrometer at the Stable Isotope Facility at the University of California, Davis. Precision was calculated by analyzing multiple samples from a few individuals; however, collagen material to run multiple samples was only available from dental collagen (Table 10). Therefore, precision for bone collagen was not determined. Precision for values from dental collagen was $\pm 0.15\%$ for $\delta^{13}\text{C}$ and $\pm 0.41\%$ for $\delta^{15}\text{N}$. Stable carbon and oxygen isotopes from

enamel carbonate were analyzed on a Finnigan-MAT 252 isotope ratio mass spectrometer.

Precision could not be calculated for enamel carbonate since multiple samples from the same individual were not analyzed.

Table 10: Summary of Calculated Precision based on Duplicate Samples

<i>Sample (dental collagen)</i>	Difference in $\delta^{13}\text{C}$ values	<i>Sample (dental collagen)</i>	Difference in $\delta^{15}\text{N}$ values
B47 I56	0.2	B47 I56	0.67
B29 I37	0.1	B51 I60	0.14
<i>Precision</i>	± 0.15	<i>Precision</i>	± 0.41

Accuracy for carbon and nitrogen values from bone and dental collagen was assessed using a laboratory Nylon 5 standard, which provided an average $\delta^{13}\text{C}$ value of $-27.72 \pm 0.09\text{‰}$ and an average $\delta^{15}\text{N}$ value of $-10.31 \pm 0.15\text{‰}$ (Table 11). Accuracy for carbon and oxygen values from enamel apatite was assessed using the TC/EA-IRMS standard, which was $\pm 0.03\text{‰}$ for $\delta^{13}\text{C}$ and $\pm 0.09\text{‰}$ for $\delta^{18}\text{O}$ (Table 11).

Table 11: Summary of Lab Reported Accuracy

<i>Lab</i>	Accuracy for $\delta^{13}\text{C}$	Accuracy for $\delta^{15}\text{N}$	Accuracy for $\delta^{18}\text{O}$
<i>Stable Isotope Facility at the University of California, Davis</i>	$\pm 0.15\text{‰}$	$\pm 0.41\text{‰}$	N/A
<i>Light Stable Isotope Mass Spec at the University of Florida</i>	$\pm 0.03\text{‰}$	N/A	$\pm 0.09\text{‰}$

Distinguishing Resources

One research aim of this study is to investigate whether the combination of nitrogen and carbon values from bone and dental collagen could be used to determine the difference between C_4 plants and aquatic resources. First, it is important to distinguish between marine and freshwater resources. There appears to be a standard of differentiation between the two resources of about 3 to 4‰ $\delta^{15}\text{N}$. Schoeninger et al. (1983) conducted a similar study to investigate

differences in nitrogen values among varying diets. The results of this study are displayed in Table 12 and show cultural groups relying on large offshore marine animals as having the highest enrichment, 15 to 20‰, and with agriculturalists and groups relying on freshwater resources to all have similar values ranging from, 5 to 12‰. France (1994) also conducted a study supporting this difference by sampling from zooplankton and zoobenthos that were living in both marine and freshwater environments (Table 13). Estuarine animals that inhabited a gradient between marine and freshwater displayed intermediate nitrogen values. These two studies demonstrate that while a particular species has a standard enrichment based on aquatic environment (France 1994), these bodies of water display a vast number of resources that demonstrate a range in nitrogen values (Schoeinger et al. 1983). In addition, individuals subsisting on a diet of freshwater resources have values that overlap with those who are strictly agriculturalists.

Table 12: Range of Nitrogen and Carbon Values for Populations with Known Diet (adapted from Schoeinger et al. 1983)

Population/Known Diet	$\delta^{15}\text{N}$ Values	$\delta^{13}\text{C}$ Values
North American marine mammal hunters	17 to 20‰	-17 to -11‰
North American salmon fishers	15 to 20‰	-20.5 to -12‰
North American agriculturalists	5.5 to 12‰	-11 to -7‰
South American agriculturalists	6 to 12‰	-14 to -10.5‰
Populations reliant on freshwater resources	6.6 to 9.5‰	N/A

Table 13: Differences in Nitrogen Values for Invertebrate from Marine and Freshwater Environments (adapted from France 1994)

<i>Invertebrate</i>	<i>$\delta^{15}\text{N}$ Value Mode</i>	<i>Nitrogen Mean</i>
Marine zooplankton	+10‰	+9‰
Freshwater zooplankton	+6‰	+7‰
Marine zoobenthos	+10‰	+9‰
Freshwater zoobenthos	+6‰	+6‰

A Flora and Faunal Food Web for the Lower Río Verde Valley

Comparing the $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values from Río Viejo's population with $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values from flora and fauna has allowed for a more detailed analysis of diet. A food web for the lower Río Verde Valley was created by combining flora and fauna data from comparable sites and regions. The bulk of flora data used in this study was collected and analyzed by Warriner et al. (2013) and combines data from the modern Valley of Oaxaca and Villahermosa in Tabasco, Mexico, historic Oaxaca, and archaeological Atzompa in Oaxaca. Archaeological flora and faunal data from the sites of San Pedro and Marco Gonzalez in Belize was also used. This data was collected and analyzed by Williams (2000) for her thesis research on coastal Maya diet. Finally, modern and archaeological flora and faunal data was incorporated from the Bahamas, Turks and Caicos, Jamaica, Belize, and Cuba; this data was collected and analyzed by Keegan and DeNiro (1988). These studies were used because of their comparability to diet in the lower Río Verde Valley and similarities in climate and environment. Descriptive statistics were run on each flora and fauna group, and their means were then compared with the samples processed for this study from Río Viejo. The results for $\delta^{13}\text{C}$ from collagen are in Table 14 and the results for $\delta^{15}\text{N}$ from collagen are in Table 15. Bolded and italicized food values which could be possible food sources based on a 1.0‰ enrichment of $\delta^{13}\text{C}$ from resource to consumer and a 3 to 4‰

enrichment of $\delta^{15}\text{N}$ from resource to consumer. $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values from flora and fauna are plotted alongside bone and dental collagen values in Figures 6 and 7. It is clear that C_4 plants, such as maize and amaranth, and CAM plants, such as agave and cacti, were dominant staples within the Río Viejo population for both time periods. However, the graph also indicates that reptiles and aquatic resources were relied upon in some capacity.

Table 14: Comparison of Río Viejo Bone and Dental Collagen $\delta^{15}\text{C}$ Values with Known Food Web $\delta^{15}\text{C}$ Values

	N	Mean	Minimum	Maximum	Range	St. Error	St. Deviation	Variance
<i>Amaranth</i>	3	-11.90	-12.90	-10.10	2.80	0.90	1.56205	2.440
<i>Maize</i>	15	-11.01	-13.40	-9.40	4.00	0.22	.88549	.784
<i>Agave/Cacti</i>	8	-13.06	-13.80	-12.20	1.60	0.25	.71701	.514
Beans	17	-25.67	-28.10	-23.20	4.90	0.37	1.55755	2.426
Chiles	53	-27.92	-33.20	-24.80	8.40	0.25	1.88755	3.563
Squash	13	-26.31	-29.80	-23.50	6.30	0.50	1.82339	3.325
Tuber	5	-26.54	-27.60	-25.70	1.90	0.41	.92898	.863
Avocado	6	-28.53	-31.70	-25.90	5.80	0.91	2.24202	5.027
Chayote	6	-25.16	-26.90	-23.40	3.50	0.51	1.26596	1.603
Cacao	2	-32.70	-34.10	-31.30	2.80	1.40	1.97990	3.920
White-tailed Deer	4	-20.27	-21.50	-19.30	2.20	0.47	.95350	.909
<i>Offshore Fish</i>	6	-6.35	-8.10	-5.10	3.00	0.46	1.13798	1.295
<i>Reef Fish</i>	6	-6.01	-10.10	-4.40	5.70	0.85	2.09801	4.402
Estuarine Fish	3	-4.20	-6.40	-2.20	4.20	1.21	2.10713	4.440
Reptiles	5	-18.76	-21.80	-13.20	8.60	1.46	3.27460	10.723
RV Late Classic Bone	10	-9.76	-12.41	-8.31	4.10	0.34	1.09	1.19
RV Late Classic Dentin	5	-9.58	-10.16	-8.71	1.45	0.26	0.59	0.40
RV Early Postclassic Bone	2	-9.15	-9.37	-8.94	0.43	0.21	0.30	0.09
RV Early Postclassic Dentin	10	-9.46	-11.85	-8.40	3.45	0.32	1.04	1.08

Table 15: Comparison of Bone and Dental Collagen $\delta^{15}\text{N}$ Values with Known Food Web $\delta^{15}\text{N}$ Values

	N	Mean	Minimum	Maximum	Range	St. Error	Std. Deviation	Variance
<i>Amaranth</i>	3	3.93	1.80	6.90	5.10	1.53	2.65	7.02
<i>Maize</i>	10	3.90	.80	6.20	5.40	0.61	1.94	3.78
<i>Agave/Cacti</i>	8	5.73	-.10	11.30	11.40	1.43	4.06	16.54
Beans	17	4.11	-1.70	8.10	9.80	0.60	2.48	6.15
Chiles	53	3.11	-3.10	9.90	13.00	0.34	2.50	6.25
Squash	13	4.70	-.90	8.50	9.40	0.83	2.99	8.97
Tuber	4	9.82	2.20	16.80	14.60	3.39	6.78	46.06
Avacado	5	5.66	.10	10.40	10.30	1.68	3.75	14.12
Chayote	6	7.96	3.90	14.80	10.90	1.80	4.42	19.57
Cacao	2	3.80	3.30	4.30	1.00	0.50	0.70	0.50
White-tailed Deer	4	4.37	3.20	6.20	3.00	0.67	1.35	1.84
Offshore Fish	6	8.91	7.10	11.10	4.00	0.60	1.48	2.19
Reef Fish	6	9.70	4.60	16.60	12.00	1.79	4.40	19.40
Estuarine Fish	3	9.30	7.80	11.20	3.40	1.00	1.73	3.01
Reptiles	5	5.62	4.30	8.00	3.70	0.66	1.49	2.23
RV Late Classic Bone	10	7.69	6.65	8.43	1.78	0.18	0.59	0.35
RV Late Classic Dentin	5	8.35	7.79	8.64	0.85	0.16	0.36	0.13
RV Early Postclassic Bone	2	8.20	8.12	8.28	0.16	0.08	0.11	0.01
RV Early Postclassic Dentin	10	8.45	7.72	8.80	1.08	0.11	0.34	0.12

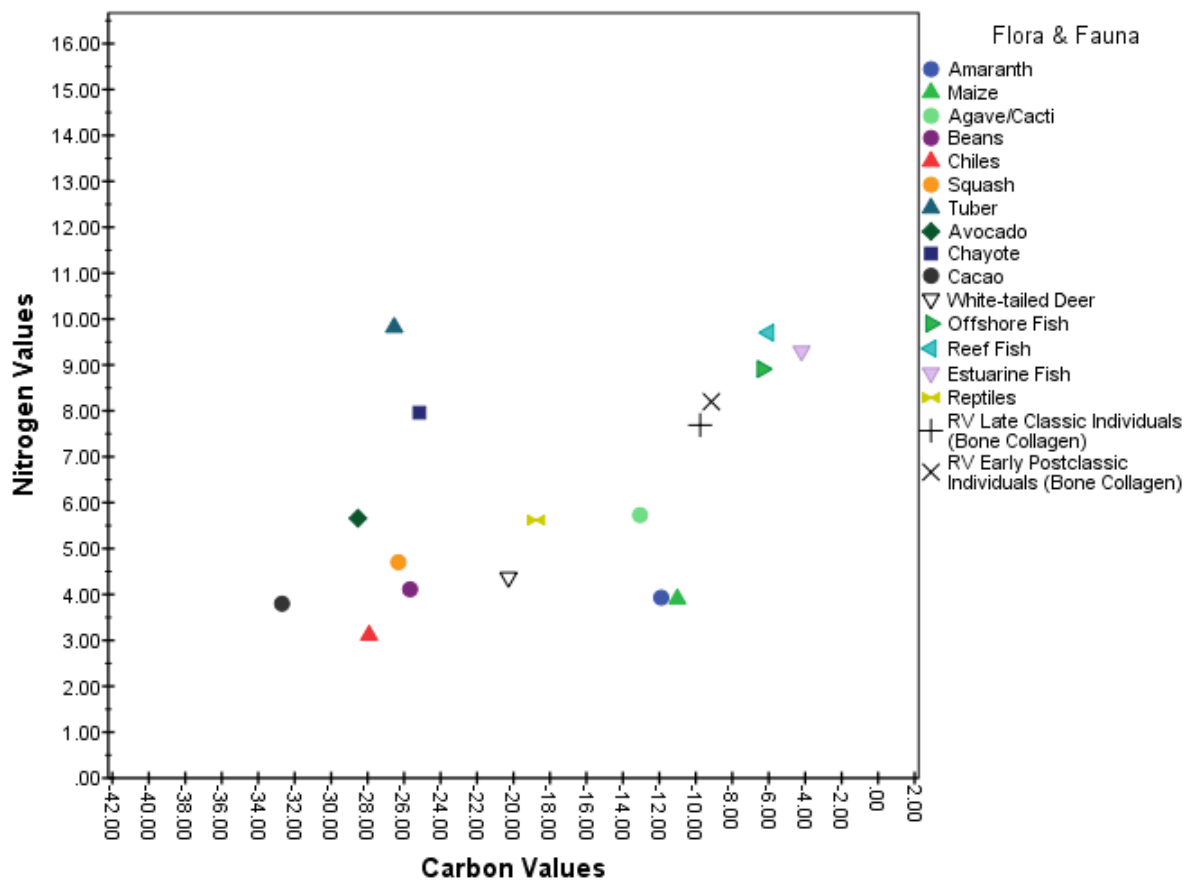


Figure 6: Comparison of Bone Collagen $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ Values with Known Food Web Values

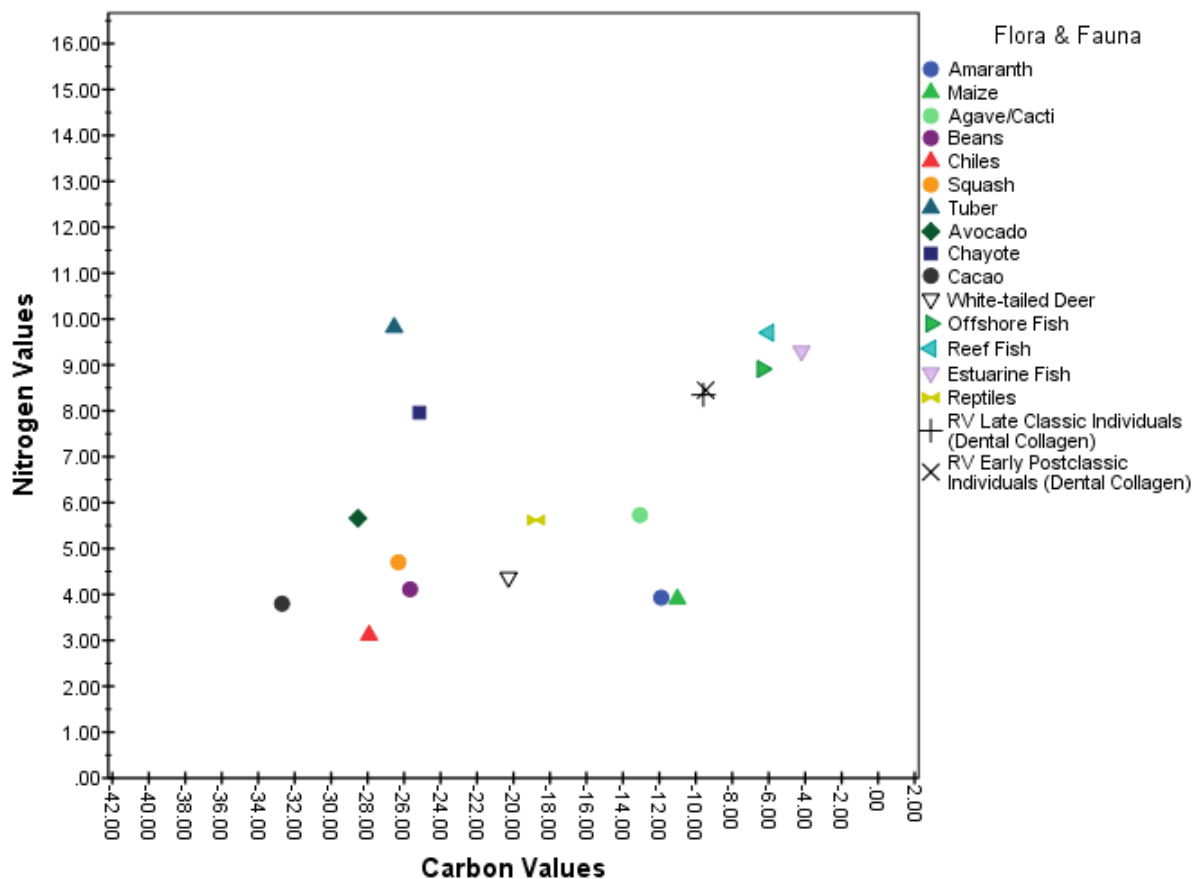


Figure 7: Comparison of Dental Collagen $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ Values with Known Food Web Values

Using Dentition to Reconstruct Diet and Human Mobility Patterns

Teeth develop under fairly strict genetic control during childhood and, unlike bone, once fully developed teeth do not remodel (Hillson 2008). Therefore, the chemical signatures extracted from the dentin and enamel of teeth display values from a specific period of development in an individual's life. Second and third molars were sampled for this study. The crown for the permanent second molars begins to form around age 3 and formation ends between 6 and 7 (Smith 1991; Scheuer and Black 2004:161). The root then begins to develop and formation ends between ages 11 and 15 (Smith 1993; Scheuer and Black 2004:161). The crown for the permanent third molar begins to develop around age 9 and formation ends at age 12 (Smith 1991; Scheuer and Black 2004:161). The root then begins to develop and formation ends

between ages 17 and 20 (Smith 1991; Scheuer and Black 2004:161). Therefore, stable isotope values from the enamel apatite of a second molar will represent an individual between the ages of 3 and 7; while, value from the enamel apatite of a third molar will represent an individual between the ages of 9 and 12. Stable isotope values from the dentin collagen of a second molar will represent an individual between the ages of 7 and 15; while, values from the dentin collagen of a third molar will represent an individual between the ages of 12 and 20.

As discussed previously, $\delta^{13}\text{C}$ values from apatite have a larger enrichment from producer to consumer; for this study the fractionation of 9.4‰ will be used due to a greater body of literature supporting this value. Furthermore, the determination of this value is based off the notion that digestive physiology plays a greater role in the fractionation process than body size (Kellner and Schoeninger 2007).

Bone Collagen, Dental Collagen, and Enamel Apatite Results

Eleven individuals were analyzed from the Late Classic; nine of the individuals produced carbon and nitrogen values from bone collagen (Table 16), five of the individuals produced carbon and nitrogen values from dental collagen (Table 17), and five of the individuals produced carbon and oxygen values from enamel apatite (Table 18). Nine individuals from the Late Classic are male, one is female, and one is undetermined; skeletal analysis was completed by Dr. Arion Mayes (Barber and Joyce et al. 2012). Eleven individuals were analyzed from the Early Postclassic; two of the individuals produced carbon and nitrogen values from bone collagen (Table 16), ten of the individuals produced carbon and nitrogen values from dental collagen (Table 17), and ten of the individuals produced carbon and oxygen values from enamel apatite (Table 18). Five individuals from the Early Postclassic are male, two are female, and four are

undetermined; skeletal analysis was completed by Pedro Antonio Juárez of Centro INAH Oaxaca (King 2003).

Table 16: $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ Values from Bone Collagen

Sample ID	Sex	Age	Pathology	Time Period	Op.	Bone	$\delta^{13}\text{C}$	$\delta^{15}\text{N}$
B42 I51	M	Adult	No	Late Classic	B	Femur	-9.06	7.89
B44 I53	N/A	Adult	Yes	Late Classic	B	Femur	-	7.37
B47 I56	F	Adult	Yes	Late Classic	B	Femur	-9.66	8.05
B51 I60	M	Adult	Yes	Late Classic	B	Femur	-8.31	8.15
B64 I73	M	Adult	Yes	Late Classic	A	Femur	-9.46	8.43
B64 I103	M	Adult	Yes	Late Classic	A	Femur	-9.30	7.63
B65 I74	M	Adult	Yes	Late Classic	D	Femur	-9.70	7.12
B76 I85	M	Adult	Yes	Late Classic	E	Femur	-10.34	7.11
B87 I96	M	Adult	Yes	Late Classic	C	Femur	-12.41	6.65
B93 I102	M	Adult		Late Classic		Femur	-10.16	7.48
B97 I107	M	Adult	Yes	Late Classic	A	Femur	-9.23	8.22
B29 I37	N/A	Subadult	No	Early Postclassic	B	Femur	-9.37	8.12
B35 I43	M	Adult	Yes	Early Postclassic	B	Femur	-8.94	8.28

Table 17: $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ Values from Dental Collagen

Sample ID	Sex	Age	Pathology	Time Period	Op.	Tooth	$\delta^{13}\text{C}$	$\delta^{15}\text{N}$
B42 I51	M	Adult	No	Late Classic	B	3 rd Molar	-8.71	8.52
B47 I56	F	Adult	Yes	Late Classic	B	3 rd Molar	-10.16	8.64
B87 I96	M	Adult	Yes	Late Classic	C	3 rd Molar	-10.05	8.17
B93 I102	M	Subadult	No	Late Classic	A	2 nd Molar	-9.70	7.79
B26 I34	N/A	Adult	No	Early Postclassic	B	3 rd Molar	-8.98	8.21
B27 I35	N/A	Adult	No	Early Postclassic	B	3 rd Molar	-11.85	7.72
B28 I36	M	Adult	No	Early Postclassic	B	3 rd Molar	-9.12	8.19
B29 I37	N/A	Subadult	No	Early Postclassic	B	2 nd Molar	-9.50	8.72
B31 I39	F	Adult	No	Early Postclassic	B	3 rd Molar	-9.06	8.42
B32 I40	M	Adult		Early Postclassic		3 rd Molar	-8.80	8.65
B33 I41	M	Adult		Early Postclassic		Premolar	-8.52	8.77
B43 I52	F	Adult	Yes	Early Postclassic	B	3 rd Molar	-10.15	8.80
B46 I55	M	Adult	Yes	Early Postclassic	B	3 rd Molar	-8.40	8.35

Table 18: $\delta^{18}\text{O}$ and $\delta^{13}\text{C}$ Values for Enamel Apatite

Sample ID	Sex	Age	Pathology	Time Period	Op.	Tooth	$\delta^{18}\text{O}$	$\delta^{13}\text{C}$
B40 I48	N/A	Juvenile	No	Late Classic	B	2 nd Molar	24.1	-3.57
B42 I51	M	Adult	No	Late Classic	B	3 rd Molar	24.07	-3.77
B47 I56	F	Adult	Yes	Late Classic	B	3 rd Molar	25.33	-3.8
B51 I60	M	Adult	Yes	Late Classic	B	2 nd Molar	24.3	-3.6
B87 I96	M	Adult	Yes	Late Classic	C	3 rd Molar	24.3	-2.74
B93 I102	M	Subadult	No	Late Classic	A	2 nd Molar	24.03	-3.13
B26 I34	N/A	Adult	No	Early Postclassic	B	3 rd Molar	24.47	-1.27
B27 I35	N/A	Adult	No	Early Postclassic	B	3 rd Molar	23.82	-4.62
B28 I36	M	Adult	No	Early Postclassic	B	3 rd Molar	23.65	-1.93
B29 I37	N/A	Subadult	No	Early Postclassic	B	2 nd Molar	23.89	-2.59
B30 I38	N/A	Adult	No	Early Postclassic	B	3 rd Molar	24.28	-3.74
B31 I39	F	Adult	No	Early Postclassic	B	3 rd Molar	24.9	-3.29
B32 I40	M	Adult	No	Early Postclassic	B	3 rd Molar	24.26	-2.46
B33 I41	M	Adult	No	Early Postclassic	B	Premolar	24.16	-2.21
B43 I52	F	Adult	Yes	Early Postclassic	B	3 rd Molar	23.61	-1.68
B46 I55	M	Adult	Yes	Early Postclassic	B	3 rd Molar	23.83	-1.93

Stable Carbon Isotope Results (Collagen)

A total of 12 bone samples were analyzed for stable carbon isotopes and the $\delta^{13}\text{C}$ values can be found in Table 19. The mean $\delta^{13}\text{C}$ value for all the individuals represented by bone collagen samples is $-9.66\text{‰} \pm 1.01\text{‰}$ with a standard error of 0.29‰ and a range from -12.41‰ to -8.31‰ . Overall, the $\delta^{13}\text{C}$ mean of -9.66‰ indicates that individuals during both the Late Classic and the Early Postclassic were primarily consuming C_4 plants, most likely maize, with secondary resources including aquatic resources, reptiles, agave, and cacti (see Figures 6 and 7). Out of all the individuals with $\delta^{13}\text{C}$ values from bone, only one individual was identified as female and had a $\delta^{13}\text{C}$ value of -9.66‰ . The mean $\delta^{13}\text{C}$ value for the ten males represented by bone collagen samples is $-9.69\text{‰} \pm 1.12\text{‰}$ with a standard error of 0.35‰ and a range from -12.41‰ to -8.31‰ . The mean $\delta^{13}\text{C}$ value for the ten individuals from the Late Classic represented by bone collagen samples is $-9.76\text{‰} \pm 1.09\text{‰}$ with a standard error of 0.34‰ and a range from -12.41‰ to -8.31‰ . The mean $\delta^{13}\text{C}$ values for the five individuals from the Early Postclassic represented by bone collagen $-9.15\text{‰} \pm 0.30\text{‰}$ with a standard error of 0.21‰ and a range from -9.37‰ to -8.94‰ .

A total of 15 dentin samples were analyzed for stable carbon isotopes and the $\delta^{13}\text{C}$ values can be found in Table 19. The mean $\delta^{13}\text{C}$ value for all the individuals represented by dental collagen samples is $-9.50\text{‰} \pm 0.89\text{‰}$ with a standard error of 0.23‰ and a range from -11.85‰ to -8.40‰ . Overall, the $\delta^{13}\text{C}$ mean of -9.50‰ indicates that individuals during both the Late Classic and the Early Postclassic were primarily consuming C_4 plants, most likely maize, with secondary resources including aquatic resources, reptiles, agave, and cacti (see Figure 8). The mean $\delta^{13}\text{C}$ value for the three females represented by dental collagen samples is $-9.79\text{‰} \pm 0.63\text{‰}$ with a standard error of 0.37‰ and a range from -10.16‰ to -9.06‰ . The mean $\delta^{13}\text{C}$ value for

the eight males represented by dental collagen samples is $-9.07\text{‰} \pm 0.58\text{‰}$ with a standard error of 0.20‰ and a range from -10.16‰ to -9.06‰ . The mean $\delta^{13}\text{C}$ value for the five individuals from the Late Classic represented by dental collagen samples is $-9.58\text{‰} \pm 0.59\text{‰}$ with a standard error of 0.26‰ and a range from -10.16‰ to -8.71‰ . The mean $\delta^{13}\text{C}$ values for the ten individuals from the Early Postclassic represented by dental collagen $-9.46\text{‰} \pm 1.04\text{‰}$ with a standard error of 0.32‰ and a range from -11.85‰ to -8.40‰ .

Table 19: Bone and Dental Collagen $\delta^{13}\text{C}$ values (‰) by demographic category

		Tissue	N	Mean	Min	Max	Range	Standard Deviation	Standard Error	Variance
Total		Bone	12	-9.66	-12.41	-8.31	4.10	1.01	0.29	1.03
		Dentin	15	-9.50	-11.85	-8.40	3.56	0.89	0.23	0.80
Sex	Female	Bone	1	-9.66	-9.66	-9.66	N/A	N/A	N/A	N/A
		Dentin	3	-9.79	-10.16	-9.06	1.1	0.63	0.37	0.4
	Male	Bone	10	-9.69	-12.41	-8.31	4.10	1.12	0.35	1.25
		Dentin	8	-9.07	-10.05	-8.40	1.65	0.58	0.20	0.33
Time Period	Late Classic	Bone	10	-9.76	-12.41	-8.31	4.10	1.09	0.34	1.19
		Dentin	5	-9.58	-10.16	-8.71	1.45	0.59	0.26	0.40
	Early Postclassic	Bone	2	-9.15	-9.37	-8.94	0.43	0.30	0.21	0.09
		Dentin	10	-9.46	-11.85	-8.40	3.45	1.04	0.32	1.08

The Mann-Whitney U non-parametric t-test was chosen to analyze the difference between male and female and Late Classic and Early Postclassic $\delta^{13}\text{C}$ values from bone and dental collagen samples because of small sample sizes and unequal variances; the results are displayed in Table 20. The Mann-Whitney U test for dental collagen revealed that there was no statistical difference between $\delta^{13}\text{C}$ values by time period (p-value 0.540). The Mann-Whitney U test for dental collagen demonstrated no statistical difference (p-value 0.102) in $\delta^{13}\text{C}$ values by sex. The Mann-Whitney U test for bone collagen revealed no statistical difference (p-value 0.283) in $\delta^{13}\text{C}$ values between the two time periods. The Mann-Whitney U test for bone collagen also revealed no statistical difference (p-value 0.752) in $\delta^{13}\text{C}$ values by sex.

Table 20: Results for Statistical Analyses of Bone and Dental Collagen Stable Carbon Isotopes

Grouping variable: Time Period

	Dentin		Bone
Mann-Whitney U	20.000	Mann-Whitney U	5.000
Wilcoxon W	35.000	Wilcoxon W	60.000
Z	-.612	Z	-1.074
Asymp. Sig. (2-tailed)	0.540	Asymp. Sig. (2-tailed)	0.283
Exact Sig. [2*(1-tailed Sig.)]	0.594	Exact Sig. [2*(1-tailed Sig.)]	0.364

Grouping Variable: Sex

	Dentin		Bone
Mann-Whitney U	4.000	Mann-Whitney U	4.000
Wilcoxon W	10.000	Wilcoxon W	5.000
Z	-1.633	Z	-0.316
Asymp. Sig. (2-Tailed)	0.102	Asymp. Sig. (2-tailed)	0.752
Exact Sig. [2*(1-tailed Sig.)]	0.133	Exact Sig. [2*(1-tailed Sig.)]	0.909

Stable Nitrogen Isotope Results

A total of 13 bone samples were analyzed for stable nitrogen isotopes and the $\delta^{15}\text{N}$ values can be found in Table 21. The mean $\delta^{15}\text{N}$ value for all the individuals represented by bone collagen samples is $7.73\text{‰} \pm 0.54\text{‰}$ with a standard error of 0.15‰ and a range from 6.65‰ to 8.43‰ . Overall, the $\delta^{15}\text{N}$ mean of 7.73‰ indicates that individuals during both the Late Classic and the Early Postclassic were likely consuming a combination of maize and aquatic resources. Out of all the individuals with $\delta^{15}\text{N}$ values from bone, only one individual was identified as female and had a $\delta^{15}\text{N}$ value of 8.05‰ . The mean $\delta^{15}\text{N}$ value for the ten males represented by bone collagen samples is $7.69\text{‰} \pm 0.59\text{‰}$ with a standard error of 0.18‰ and a range from 6.65‰ to 8.43‰ . The mean $\delta^{15}\text{N}$ value for the ten individuals from the Late Classic represented by bone collagen samples is $7.69\text{‰} \pm 0.59\text{‰}$ with a standard error of 0.18‰ and a range from 6.65‰ to 8.43‰ . The mean $\delta^{15}\text{N}$ values for the two individuals from the Early Postclassic

represented by bone collagen $8.20\text{‰} \pm 0.11\text{‰}$ with a standard error of 0.08‰ and a range from 8.12‰ to 8.28‰ .

A total of 15 dentin samples were analyzed for stable nitrogen isotopes and the $\delta^{15}\text{N}$ values can be found in Table 21. The mean $\delta^{15}\text{N}$ value for all the individuals represented by dental collagen samples is $8.42\text{‰} \pm 0.34\text{‰}$ with a standard error of 0.08‰ and a range from 7.72‰ to 8.43‰ . Overall, the $\delta^{13}\text{C}$ mean of 8.42‰ indicates that individuals during both the Late Classic and the Early Postclassic were likely consuming maize, marine fish, reef fish, or a combination of the three. The mean $\delta^{15}\text{N}$ value for the three females represented by dental collagen samples is $8.62\text{‰} \pm 0.19\text{‰}$ with a standard error of 0.11‰ and a range from 8.42‰ to 8.80‰ . The mean $\delta^{15}\text{N}$ value for the eight males represented by dental collagen samples is $8.38\text{‰} \pm 0.32\text{‰}$ with a standard error of 0.11‰ and a range from 7.79‰ to 8.77‰ . The mean $\delta^{15}\text{N}$ value for the five individuals from the Late Classic represented by dental collagen samples is $8.35\text{‰} \pm 0.36\text{‰}$ with a standard error of 0.16‰ and a range from 7.79‰ to 8.64‰ . The mean $\delta^{15}\text{N}$ values for the seven individuals from the Early Postclassic represented by dental collagen $8.45\text{‰} \pm 0.34\text{‰}$ with a standard error of 0.11‰ and a range from 7.72‰ to 8.80‰ .

Table 21: Bone and Dental Collagen $\delta^{15}\text{N}$ values (‰) by demographic category

		Tissue	N	Mean	Min	Max	Range	Standard Deviation	Standard Error	Variance
Total		Bone	13	7.73	6.65	8.43	1.78	0.54	0.15	0.30
		Dentin	15	8.42	7.72	8.80	1.08	0.34	0.08	0.12
Sex	Female	Bone	1	8.05	8.05	8.05	N/A	N/A	N/A	N/A
		Dentin	3	8.62	8.42	8.80	0.38	0.19	0.11	0.36
	Male	Bone	10	7.69	6.65	8.43	1.78	0.59	0.18	0.35
		Dentin	8	8.38	7.79	8.77	0.98	0.32	0.11	0.10
Time Period	Late Classic	Bone	10	7.69	6.65	8.43	1.78	0.59	0.18	0.35
		Dentin	5	8.35	7.79	8.64	0.85	0.36	0.16	0.13
	Early Postclassic	Bone	2	8.20	8.12	8.28	0.16	0.11	0.08	0.01
		Dentin	10	8.45	7.72	8.80	1.08	0.34	0.11	0.12

The Mann-Whitney U non-parametric t-test was chosen to determine if there was a statistical difference between male and female and Late Classic and Early Postclassic $\delta^{15}\text{N}$ values from bone and dental collagen samples because of small sample sizes and unequal variances; results are displayed in Table 22. The Mann-Whitney U test that evaluated $\delta^{15}\text{N}$ values of dental collagen by time period produced a p value of 0.327 showing no statistical difference between the two time periods. The Mann-Whitney U test that evaluated $\delta^{15}\text{N}$ values of dental collagen by sex produced a p value of 0.260 showing no statistical difference between males and females. The Mann-Whitney U test that evaluated $\delta^{15}\text{N}$ values of bone collagen by time period produced a p value of 0.167 showing a statistically significant difference between the two time periods. The Mann-Whitney U test that evaluated $\delta^{15}\text{N}$ values of bone collagen by sex produced a p value of 0.752 showing no statistical difference between males and females.

Table 22: Results for Statistical Analyses of Bone and Dental Collagen Stable Nitrogen Isotopes

Grouping variable: Time Period			
	Dentin		Bone
Mann-Whitney U	17.000	Mann-Whitney U	4.000
Wilcoxon W	32.000	Wilcoxon W	70.000
Z	-0.981	Z	-1.382
Asymp. Sig. (2-tailed)	0.327	Asymp. Sig. (2-tailed)	0.167
Exact Sig. [2*(1-tailed Sig.)]	0.371	Exact Sig. [2*(1-tailed Sig.)]	0.231
Grouping Variable: Sex			
	Dentin		Bone
Man-Whitney U	6.500	Mann-Whitney U	4.000
Wilcoxon W	42.000	Wilcoxon W	59.000
Z	-1.125	Z	-0.316
Asymp. Sig. (2-tailed)	0.260	Asymp. Sig. (2-tailed)	0.752
Exact Sig. [2*(1-tailed Sig.)]	0.279	Exact Sig. [2*(1-tailed Sig.)]	0.909

Stable Oxygen Isotope Results

A total of 16 enamel tooth samples were analyzed for stable oxygen isotopes and the $\delta^{18}\text{O}$ values can be found in Table 23. The mean $\delta^{18}\text{O}_{\text{VSMOW}}$ value for all the individuals represented by enamel apatite samples is $24.18\text{‰} \pm 0.44\text{‰}$ with a standard error of 0.11‰ and a range from 23.61‰ to 25.33‰ . The mean $\delta^{18}\text{O}_{\text{VSMOW}}$ value for the three females represented by enamel apatite samples is $24.61\text{‰} \pm 0.89\text{‰}$ with a standard error of 0.52‰ and a range from 23.61‰ to 25.33‰ . The mean $\delta^{18}\text{O}_{\text{VSMOW}}$ value for the eight males represented by enamel apatite samples is $24.07\text{‰} \pm 0.23\text{‰}$ with a standard error of 0.81‰ and a range from 23.65‰ to 24.30‰ . The mean $\delta^{18}\text{O}_{\text{VSMOW}}$ value for the six individuals from the Late Classic represented by enamel apatite samples is $24.35\text{‰} \pm 0.49\text{‰}$ with a standard error of 0.20‰ and a range from 24.03‰ to 25.33‰ . The mean $\delta^{18}\text{O}_{\text{VSMOW}}$ values for the 10 individuals from the Early Postclassic represented by enamel apatite is $24.08\text{‰} \pm 0.40\text{‰}$ with a standard error of 0.12‰ and a range from 23.61‰ to 24.90‰ .

Table 23: Enamel Apatite $\delta^{18}\text{O}\text{‰}$ values (‰) by demographic category

	Tissue	N	Mean	Min	Max	Range	Standard Deviation	Standard Error	Variance
Total	Enamel	16	24.18	23.61	25.33	1.72	0.44	0.11	0.19
Sex	Female	3	24.61	23.61	25.33	1.72	0.89	0.52	0.80
	Male	8	24.07	23.65	24.30	0.65	0.23	0.81	0.05
Time Period	Late Classic	6	24.35	24.03	25.33	1.30	0.49	0.20	0.24
	Early Postclassic	10	24.08	23.61	24.90	1.29	0.40	0.12	0.16

The Mann-Whitney U non-parametric t-test was used to determine if there is a statistically significant difference between males and females and Late Classic and Early Postclassic $\delta^{18}\text{O}_{\text{VSMOW}}$ values from enamel apatite samples because of small sample sizes and

unequal variances; results are displayed in Table 24. The Mann-Whitney U test for enamel apatite showed no statistically significant difference (p-value 0.278) in $\delta^{18}\text{O}$ values by time period. The Mann-Whitney U test for enamel apatite demonstrated no statistically significant difference (p-value 0.414) in $\delta^{18}\text{O}$ values by sex.

Table 24: Results for Statistical Analyses of Enamel Apatite Stable Oxygen Isotopes

Grouping variable: Time Period	
	Enamel
Mann-Whitney U	20.000
Wilcoxon W	75.000
Z	-1.085
<i>Asymp. Sig. (2-tailed)</i>	0.278
Exact Sig. [2*(1-tailed Sig.)]	0.313
Grouping variable: Sex	
	Enamel
Mann-Whitney U	8.000
Wilcoxon W	44.000
Z	-.816
<i>Asymp. Sig. (2-tailed)</i>	0.414
Exact Sig. [2*(1-tailed)]	0.497

Stable Carbon Isotope Results (Apatite)

A total of 16 enamel tooth samples were analyzed for stable carbon isotopes and the $\delta^{13}\text{C}$ values can be found in Table 25. The mean $\delta^{13}\text{C}$ value for all the individuals represented by enamel apatite samples is $-2.89\text{‰} \pm 0.95\text{‰}$ with a standard error of 0.23‰ and a range from -4.62‰ to -1.27‰ . The mean $\delta^{13}\text{C}$ value for the three females represented by enamel apatite samples is $-2.92\text{‰} \pm 1.11\text{‰}$ with a standard error of 0.64‰ and a range from -3.80‰ to -1.68‰ . The mean $\delta^{13}\text{C}$ value for the eight males represented by enamel apatite samples is $-2.72\text{‰} \pm 0.71\text{‰}$ with a standard error of 0.25‰ and a range from -3.77‰ to -1.93‰ . The mean $\delta^{13}\text{C}$ value for the six individuals from the Late Classic represented by enamel apatite samples is $-3.43\text{‰} \pm 0.42\text{‰}$ with a standard error of 0.17‰ and a range from -3.80‰ to -2.74‰ . The mean $\delta^{13}\text{C}$ values for the 10 individuals from the Early Postclassic represented by enamel apatite is $-2.57\text{‰} \pm 1.02\text{‰}$ with a standard error of 0.32‰ and a range from -4.62‰ to -1.27‰ .

Table 25: Enamel Apatite $\delta^{13}\text{C}$ values (‰) by demographic category

		Tissue	N	Mean	Min	Max	Range	Standard Deviation	Standard Error	Variance
Total		Enamel	16	-2.89	-4.62	-1.27	3.35	0.95	0.23	0.88
Sex	Female	Enamel	3	-2.92	-3.80	-1.68	2.12	1.11	0.64	1.22
	Male	Enamel	8	-2.72	-3.77	-1.93	1.84	0.71	0.25	0.52
Time Period	Late Classic	Enamel	6	-3.43	-3.80	-2.74	1.06	0.42	0.17	0.17
	Early Postclassic	Enamel	10	-2.57	-4.62	-1.27	3.35	1.02	0.32	1.05

The Mann-Whitney U non-parametric t-test was used to determine if there are significantly statistic differences between males and females and Late Classic and Early Postclassic $\delta^{13}\text{C}$ values from enamel apatite samples because of small sample sizes and unequal variances; results are displayed in Table 26. The Mann-Whitney U test for enamel apatite

demonstrated a statistically significant difference (p-value 0.051) in $\delta^{13}\text{C}$ values between the two time periods, indicating a change in diet from the Late Classic to the Early Postclassic. The Mann-Whitney U test for enamel apatite demonstrated no statistical significant difference (p-value 0.682) in $\delta^{13}\text{C}$ values by sex.

Table 26: Test Statistics for $\delta^{13}\text{C}\%$ Apatite

Grouping variable: Time Period	
	Enamel
Mann-Whitney U	12.000
Wilcoxon W	33.000
Z	-1.945
<i>Asymp. Sig. (2-tailed)</i>	0.051
Exact Sig. [2*(1-tailed Sig.)]	0.056
Grouping variable: Sex	
	Enamel
Mann-Whitney U	10.000
Wilcoxon W	16.000
Z	-0.409
<i>Asymp. Sig. (2-tailed)</i>	0.682
Exact Sig. [2*(1-tailed)]	0.776

Dental Collagen $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ Values: Dietary Differences between Males and Females

The boxplot (Figure 8) comparing $\delta^{13}\text{C}$ values from dental collagen of male and female individuals displays that while diet clearly has overlap, males generally have a slightly more enriched diet. The boxplot (Figure 9) comparing $\delta^{15}\text{N}$ values from dental collagen of male and female individuals displays that there is dietary overlap between the sexes, but females tend to have a slightly more nitrogen-enriched diet. $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values are plotted together in Figure 10.

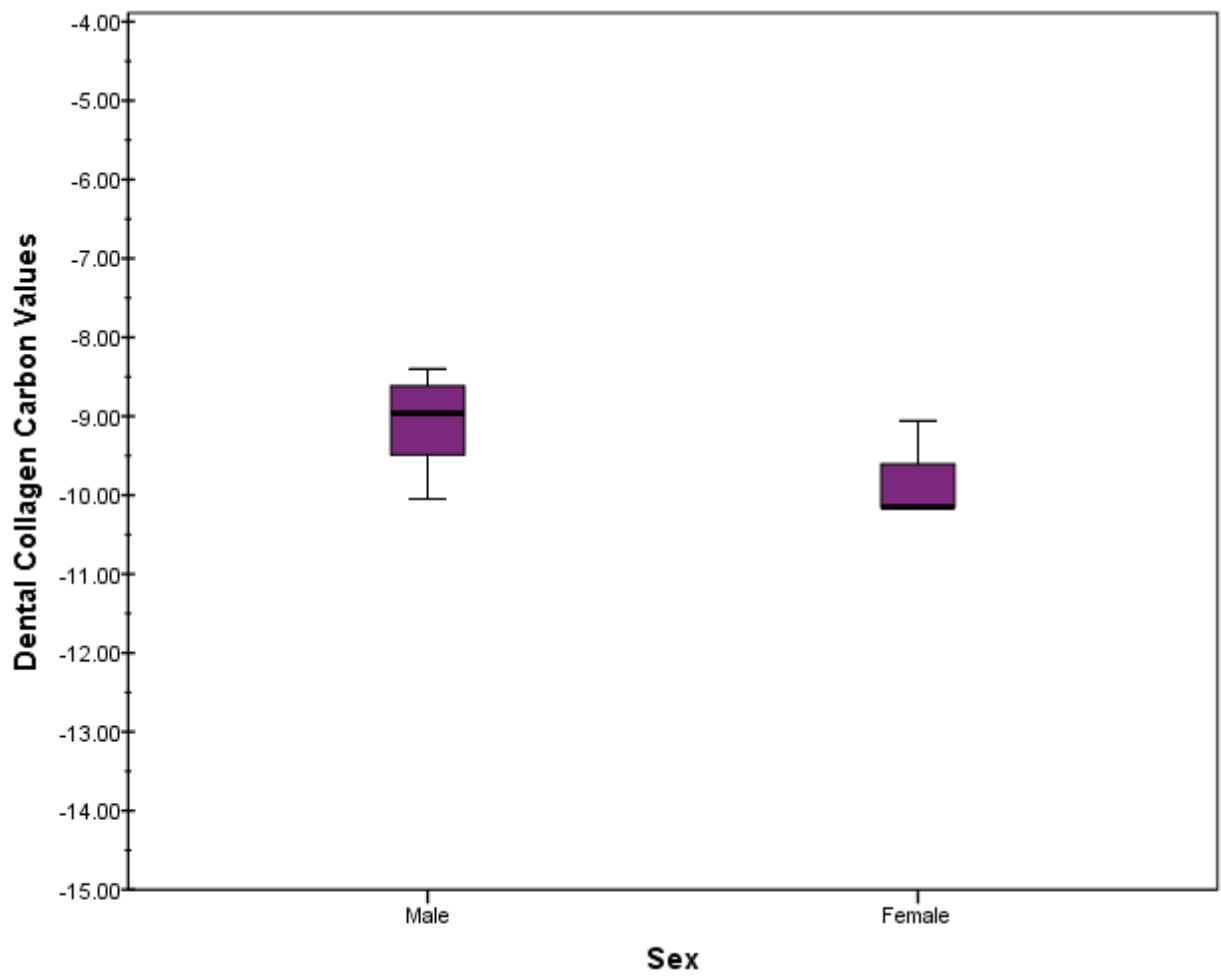


Figure 8: $\delta^{13}\text{C}$ Values of Dental Collagen compared by Sex

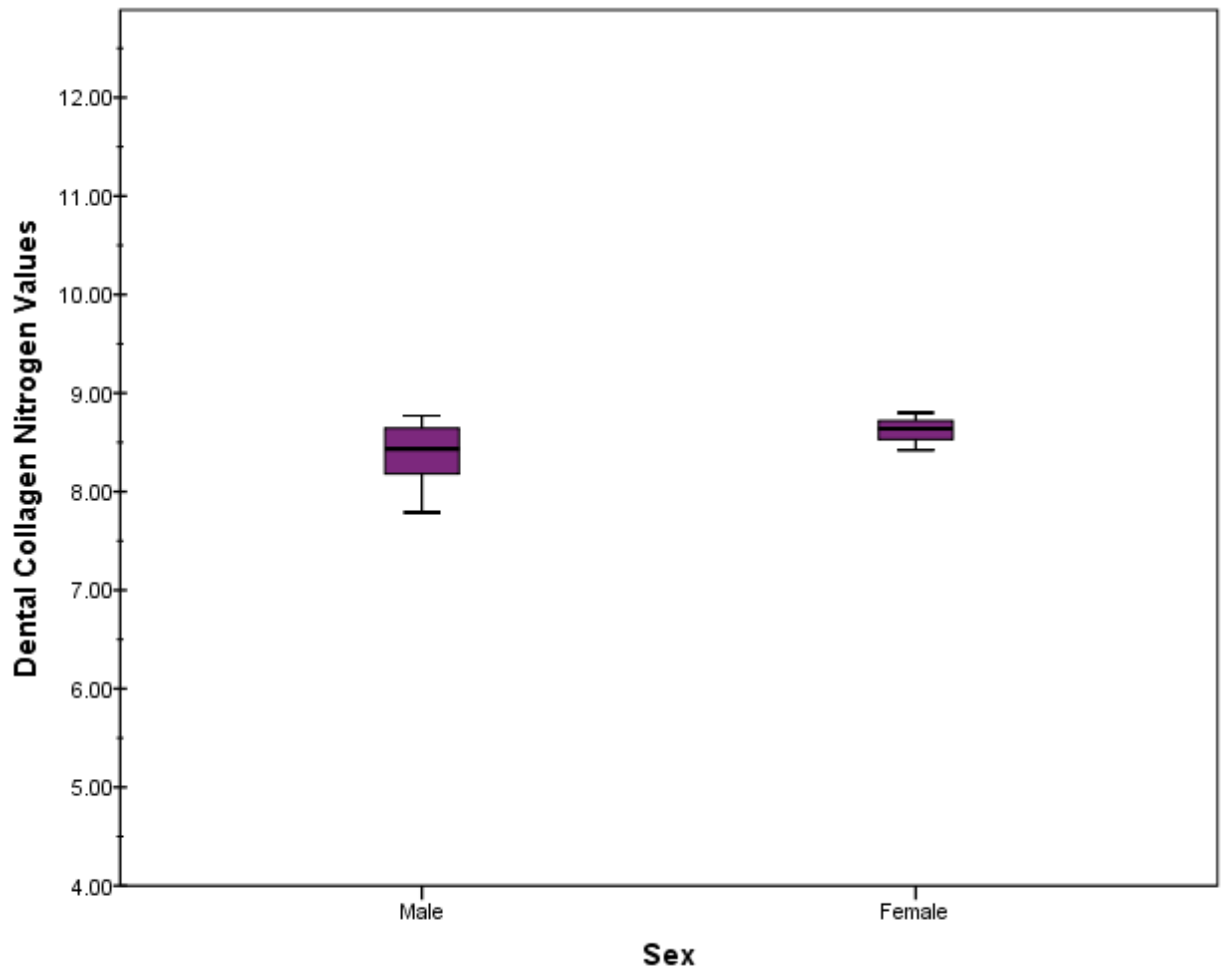


Figure 9: $\delta^{15}\text{N}$ Values from Dental Collagen compared by Sex

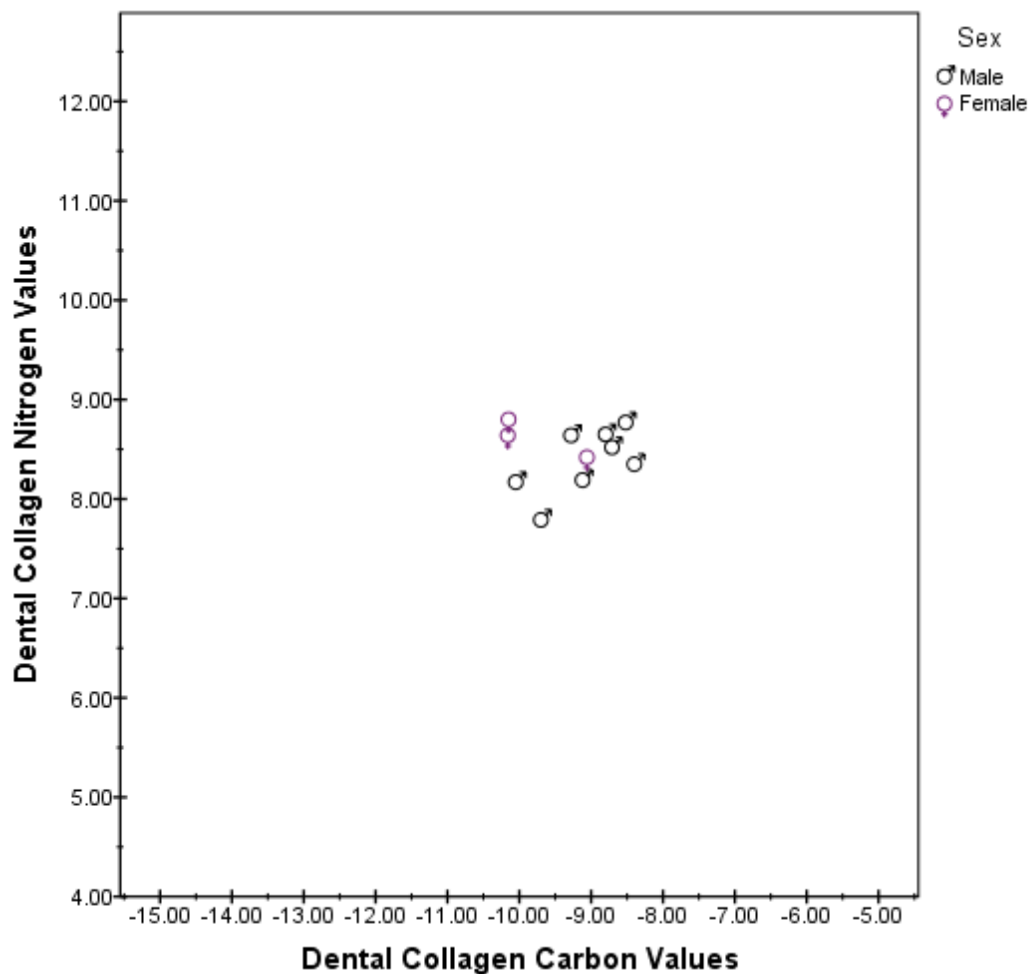


Figure 10: Comparison based on sex of Carbon and Nitrogen values from Dental Collagen

Dental Collagen $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ Values: Dietary Differences between Time Period

The boxplot (Figure 11) comparing $\delta^{13}\text{C}$ values from dental collagen from Late Classic and Early Postclassic individuals suggests that the individuals living during the Early Postclassic had a slightly more carbon-enriched diet as well as a larger range in values overall. The boxplot (Figure 12) comparing Late Classic and Early Postclassic $\delta^{15}\text{N}$ values from dental collagen suggests that individuals living during the Early Postclassic had a slightly greater nitrogen-enriched diet. $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ are plotted together in Figure 13 and suggest that Río Viejo’s population ate a diet centered on C_4 but also included CAM plants, aquatic resources, and

reptiles; furthermore, the graph demonstrates that Early Postclassic individuals may have incorporated these foods to a larger degree.

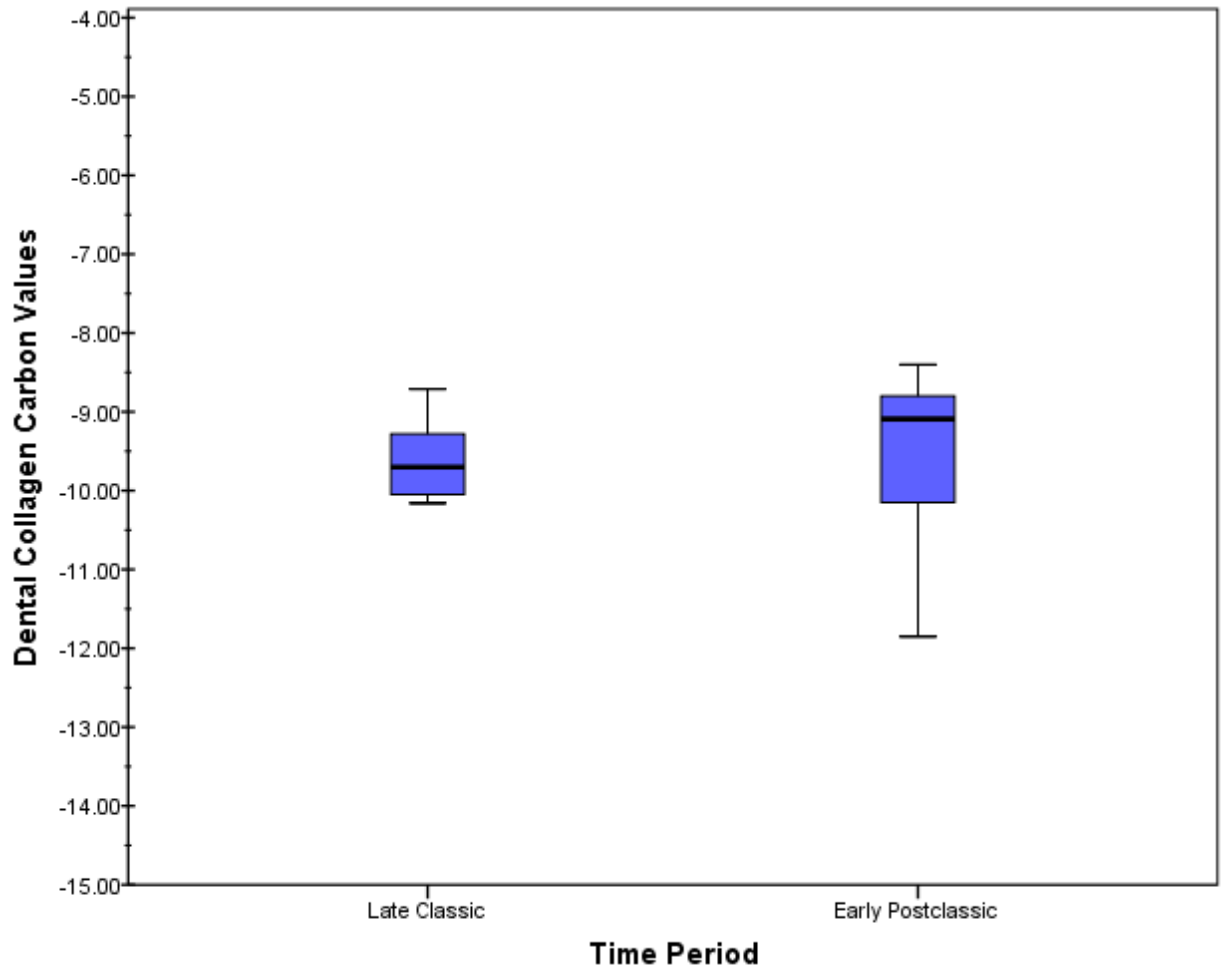


Figure 11: δ¹³C Values from Dental Collagen compared by Time Period

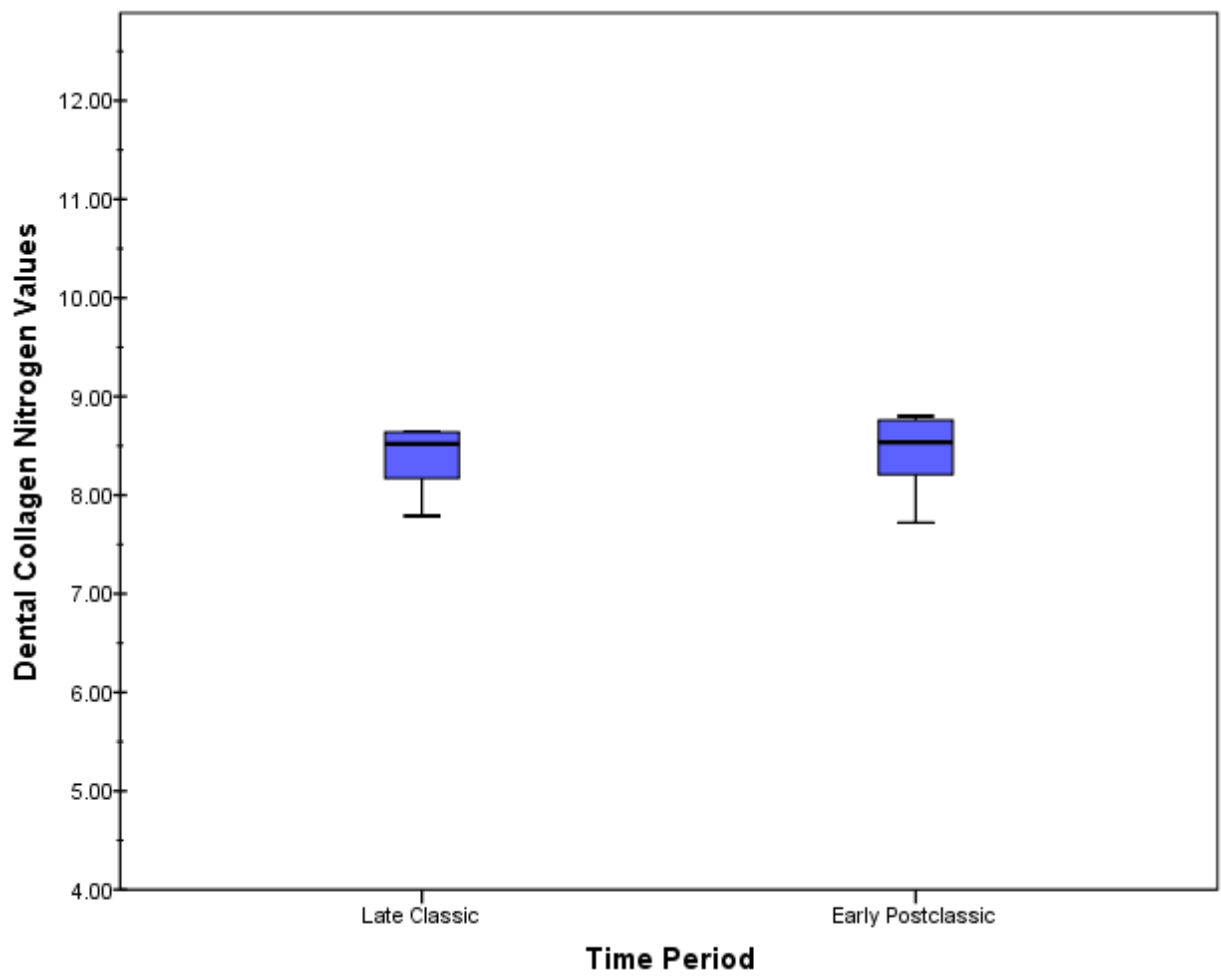


Figure 12: δ¹⁵N Values from Dental Collagen compared by Time Period

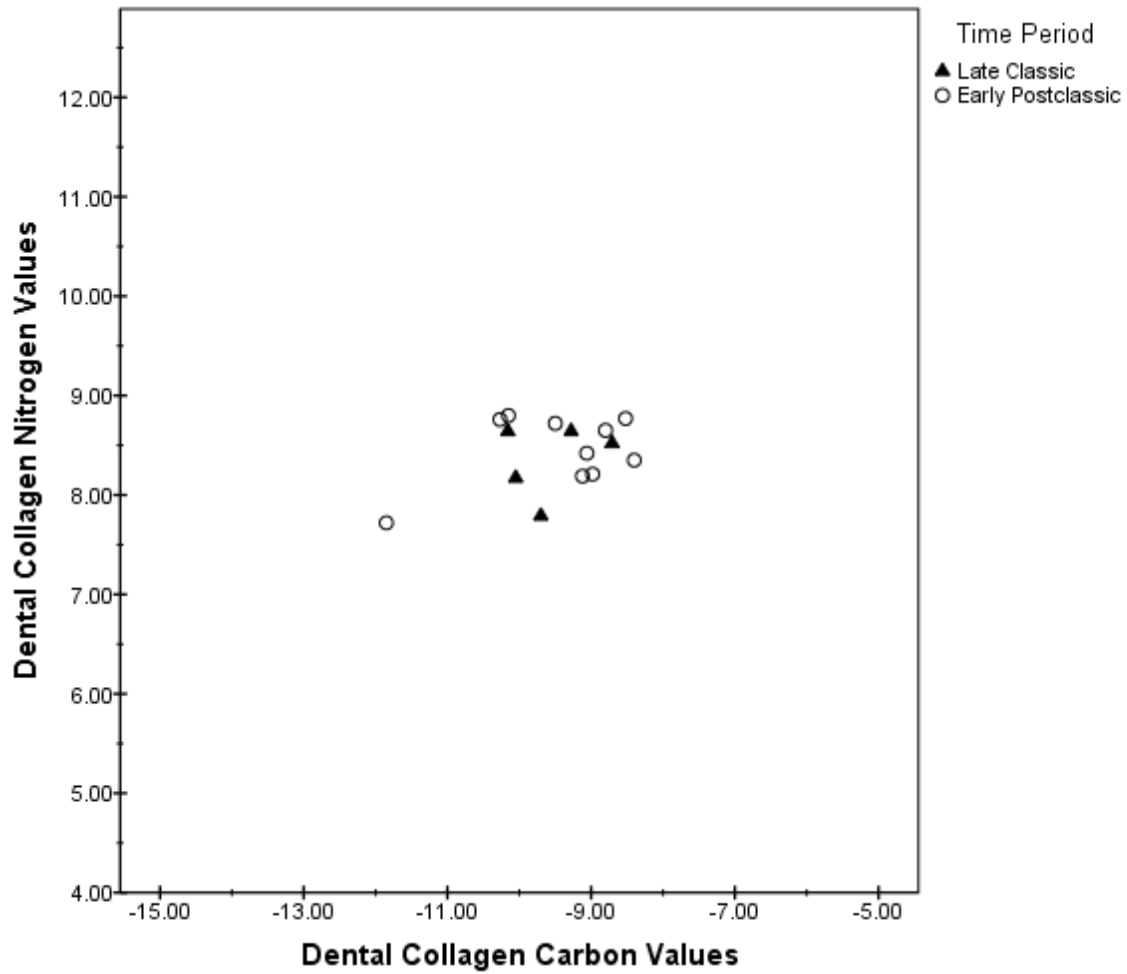


Figure 13: Comparison based on Time Period of Carbon and Nitrogen Values from Dental Collagen

Bone Collagen $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ Values: Dietary Differences between Males and Females

Since there is only one female in the bone collagen sample, it is difficult to discuss differences between the sexes based on $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values from bone collagen. However, it is clear that the female sample does fall within the range of the average male sample, as exemplified by Figure 14, indicating that male and female diets relied upon many of the same foods— C_4 plants, CAM plants, and aquatic resources.

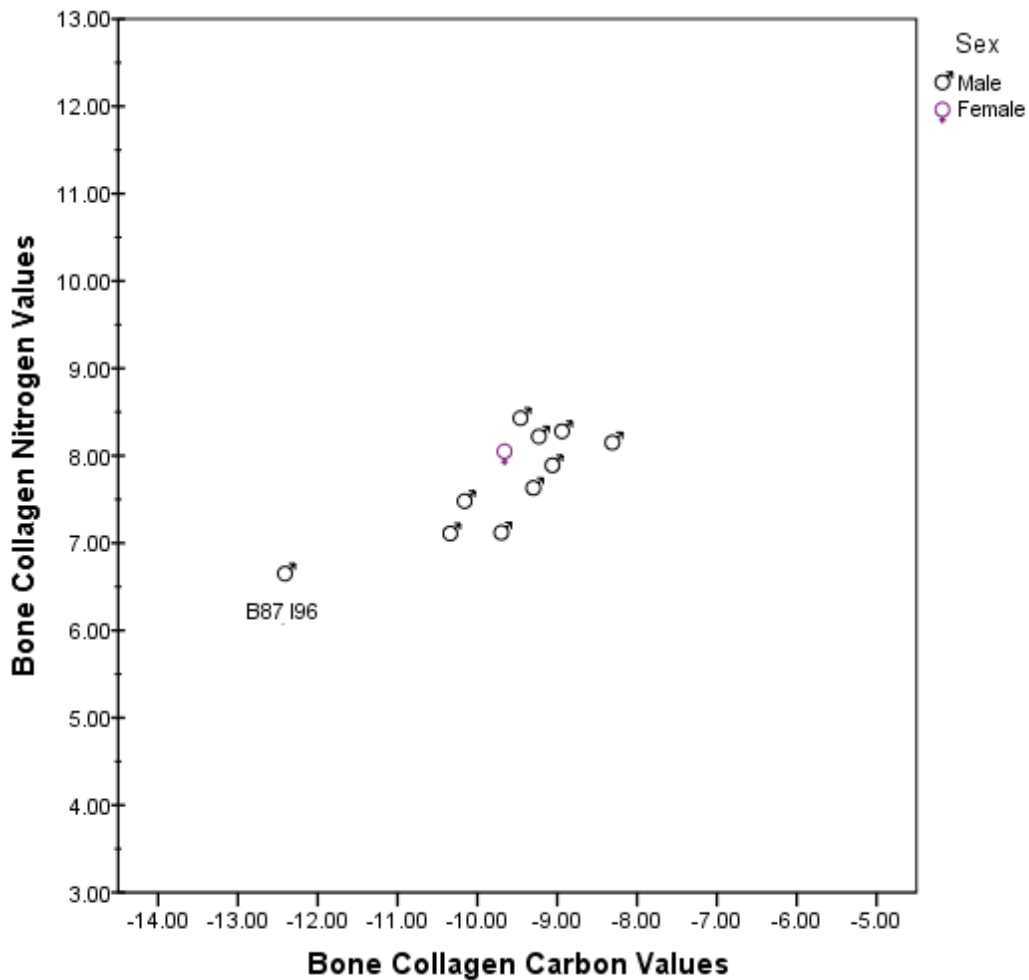


Figure 14: Comparison based on Sex of $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ Values from Bone Collagen

Bone Collagen $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ Values: Dietary Differences between Time Periods

The boxplot (Figure 15) comparing $\delta^{13}\text{C}$ values from bone collagen from Late Classic and Early Postclassic individuals suggests that the individuals living during the Early Postclassic had on average a greater carbon enrichment. The boxplot (Figure 16) comparing $\delta^{15}\text{N}$ values from bone collagen from Late Classic and Early Postclassic individuals suggests that individuals living during the Early Postclassic had on average a greater nitrogen enrichment. $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ are plotted together in Figure 17 and suggest that Early Postclassic individuals while consuming the same diet as Late Classic individuals on average fell toward both higher carbon and nitrogen enrichments.

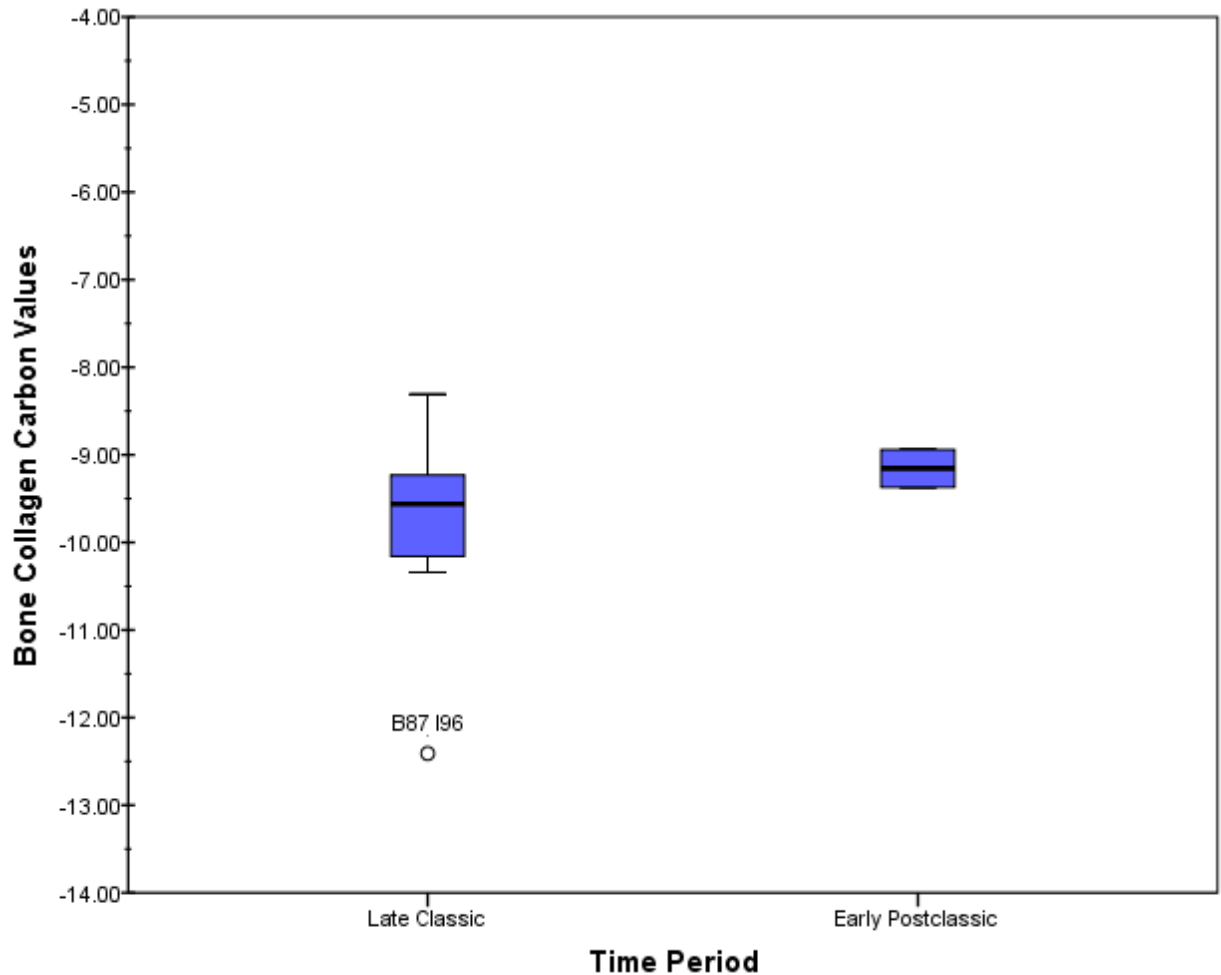


Figure 15: $\delta^{13}\text{C}$ Values from Bone Collagen compared by Time Period

Outlier B87 I96

Burial 87 Individual 96 represents an outlier for bone collagen with a $\delta^{13}\text{C}$ value of -12.41‰ in the entire bone collagen sample (mean= -9.66‰). B87 I96 also is the least nitrogen enriched sample (6.65‰) compared with the rest of the bone collagen sample (mean= 7.73‰). B87 I96 also has a higher than average $\delta^{13}\text{C}$ value (-10.05‰) from dental collagen compared with the sample mean (-9.50‰) and fairly average $\delta^{15}\text{N}$ value (8.17‰) from dental collagen compared with the sample mean (8.42‰). Furthermore, B87 I96's $\delta^{18}\text{O}$ (24.3‰) and $\delta^{13}\text{C}$ (-2.74‰) values from enamel apatite fall closely with the sample average for $\delta^{18}\text{O}$

(mean=24.18‰) and $\delta^{13}\text{C}$ (mean= -2.89‰). These dental values from both dentin and apatite indicate that B87 I96 is a local resident who ate a diet similar to others within the population during his young life. During his adult life, his diet diverged significantly from the rest of the population and ate primarily C_4 and CAM plants.

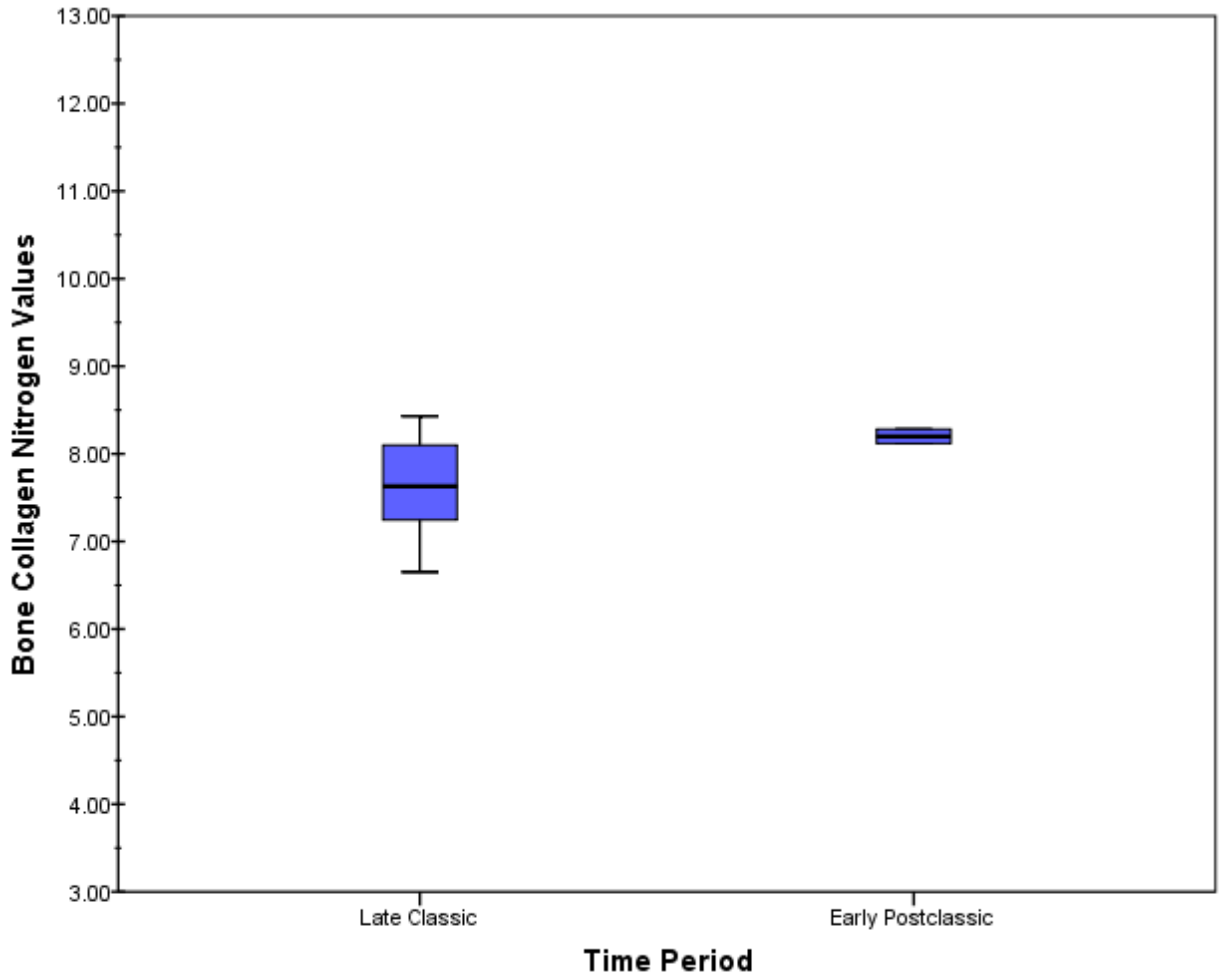


Figure 16: $\delta^{15}\text{N}$ Values from Bone Collagen compared by Time Period

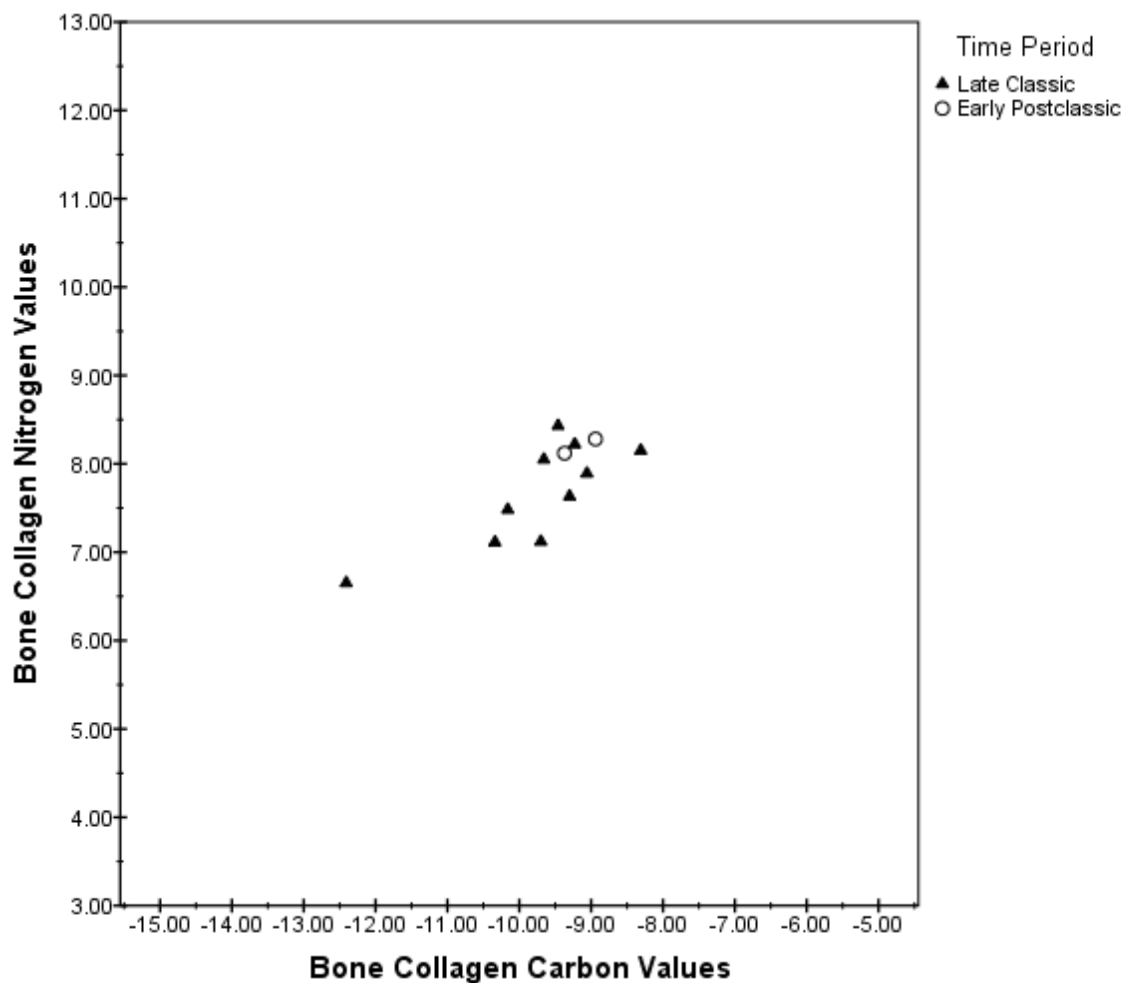


Figure 17: Comparison based on Time Period of $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ Values from Bone Collagen

Enamel Apatite $\delta^{18}\text{O}$ Values: Reconstruction of Human Mobility

The boxplot (Figure 18) comparing male and female $\delta^{18}\text{O}$ values from enamel apatite shows that females display a larger range in values compared to males; furthermore, females appear to display the highest oxygen values. When comparing the Late Classic and Early Postclassic, the boxplot (Figure 19) demonstrates that Early Postclassic oxygen values displayed a larger range than the Late Classic. This indicates that greater human mobility occurred following collapse.

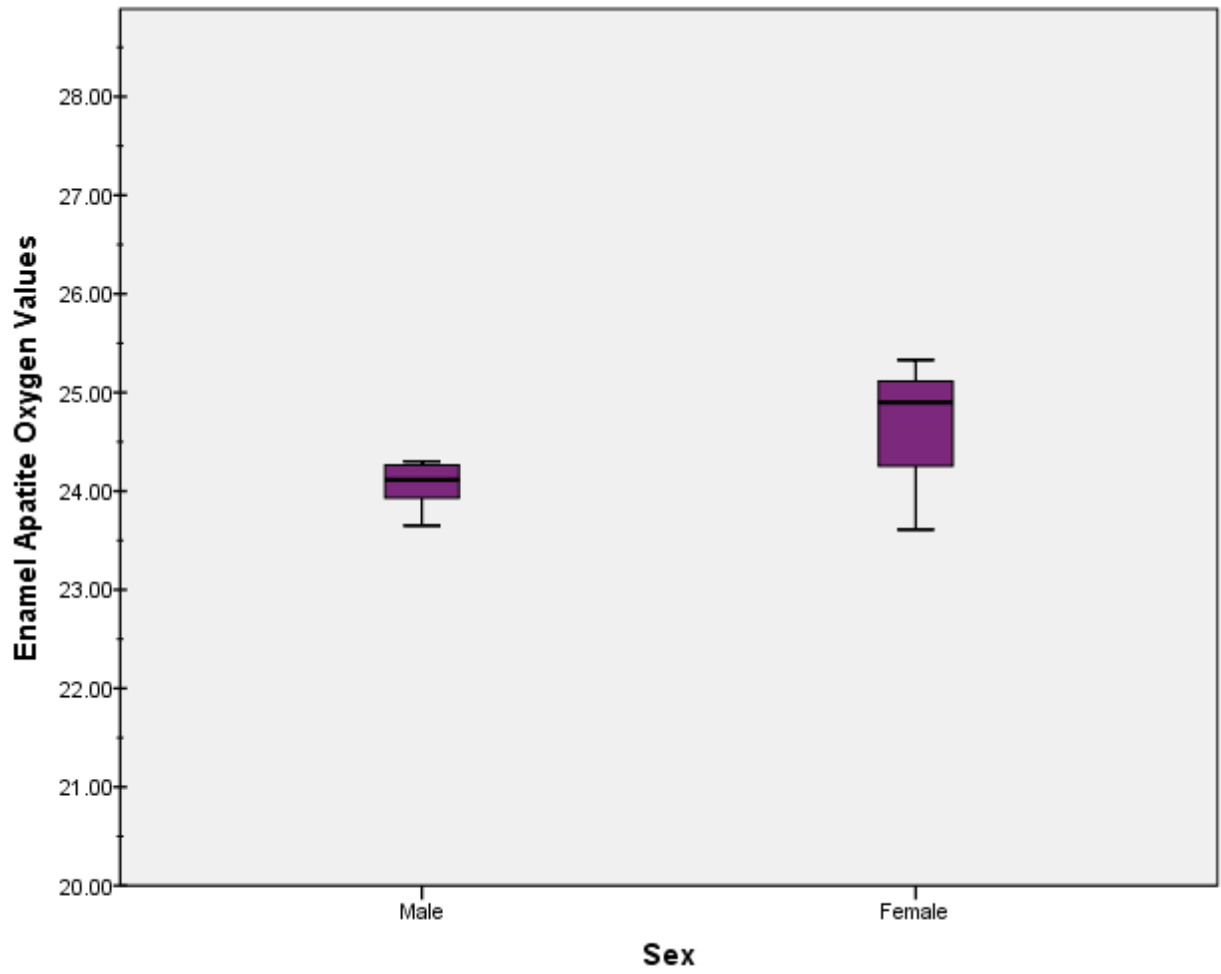


Figure 18: $\delta^{18}\text{O}$ Values from Enamel Apatite compared by Sex

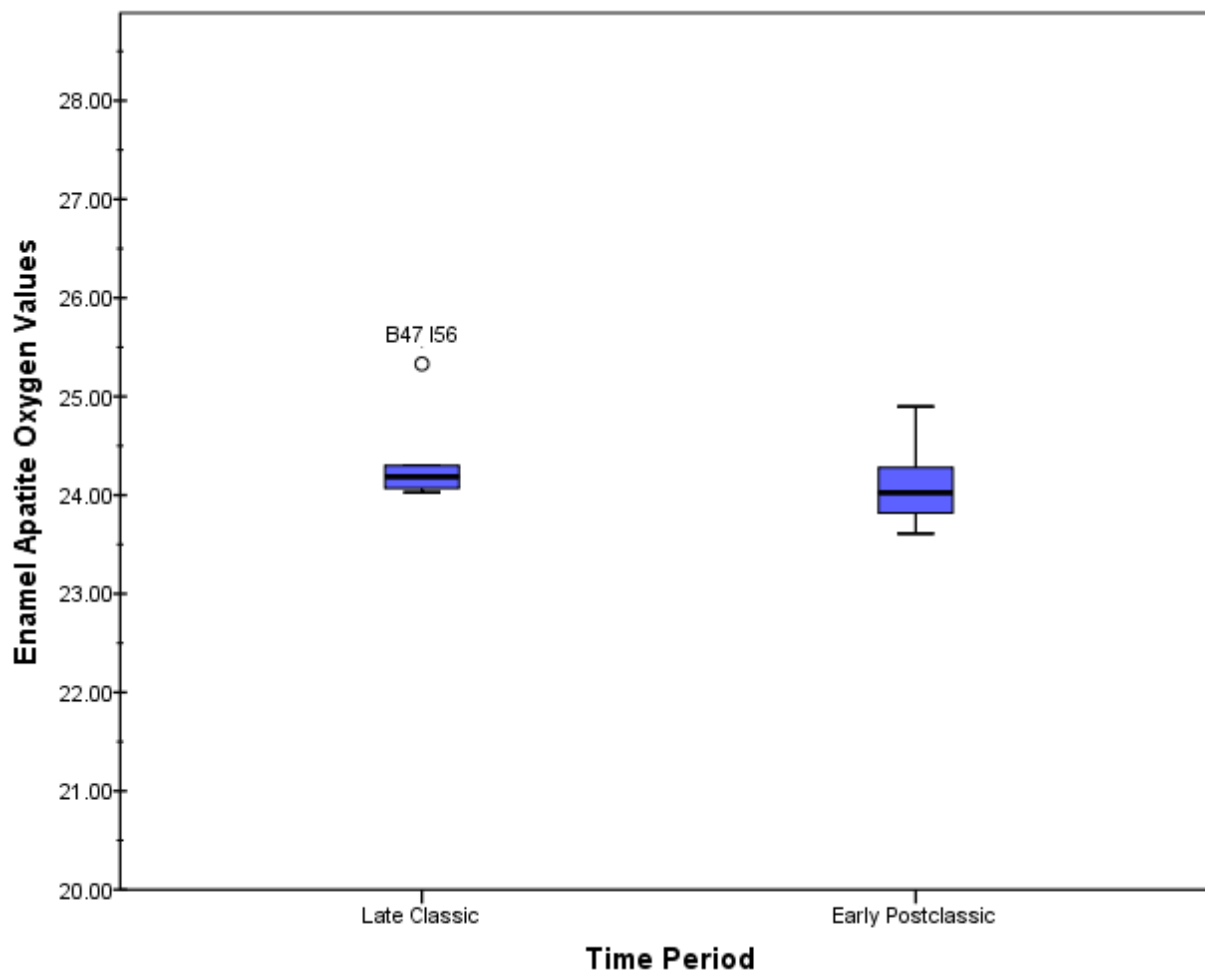


Figure 19: $\delta^{18}\text{O}$ Values from Enamel Apatite compared by Time Period

Outlier B47 I56

B47 I56 is a female outlier with a $\delta^{18}\text{O}$ value of 25.33‰ in the Late Classic sample (Figure 19) (mean= 24.35‰) and has the highest value within the entire sample (mean= 24.18‰). She has an enamel apatite $\delta^{13}\text{C}$ value of -3.8‰, a dentin collagen $\delta^{13}\text{C}$ value of -10.16‰, a dentin collagen $\delta^{15}\text{N}$ value of 8.64‰, a bone collagen $\delta^{13}\text{C}$ value of -9.66‰, and a bone collagen $\delta^{15}\text{N}$ value of 8.05‰. These values demonstrate this individual was eating a diet heavily reliant on C_4 and CAM plants. This paired with a higher $\delta^{18}\text{O}$ value suggest B47 I56 was possibly living somewhere without easy access to aquatic resources and moved to Río Viejo during adulthood.

Enamel Apatite $\delta^{13}\text{C}$ Values: Dietary Differences between Males and Females and Time Periods

$\delta^{13}\text{C}$ values from enamel apatite (Figure 20) indicate that males and females had an overlapping diet with no noticeable differences. The range suggests male and females were both subsisting on a diet rich in C_4 plants along with a variety of other secondary resources such as aquatic resources, CAM plants, and reptiles.

Figure 21 displays Late Classic and Early Postclassic $\delta^{13}\text{C}$ values from enamel apatite and suggests that Early Postclassic individuals while eating a diet high in C_4 plants incorporated CAM plants such as agave and cacti, aquatic resources, and reptiles more frequently.

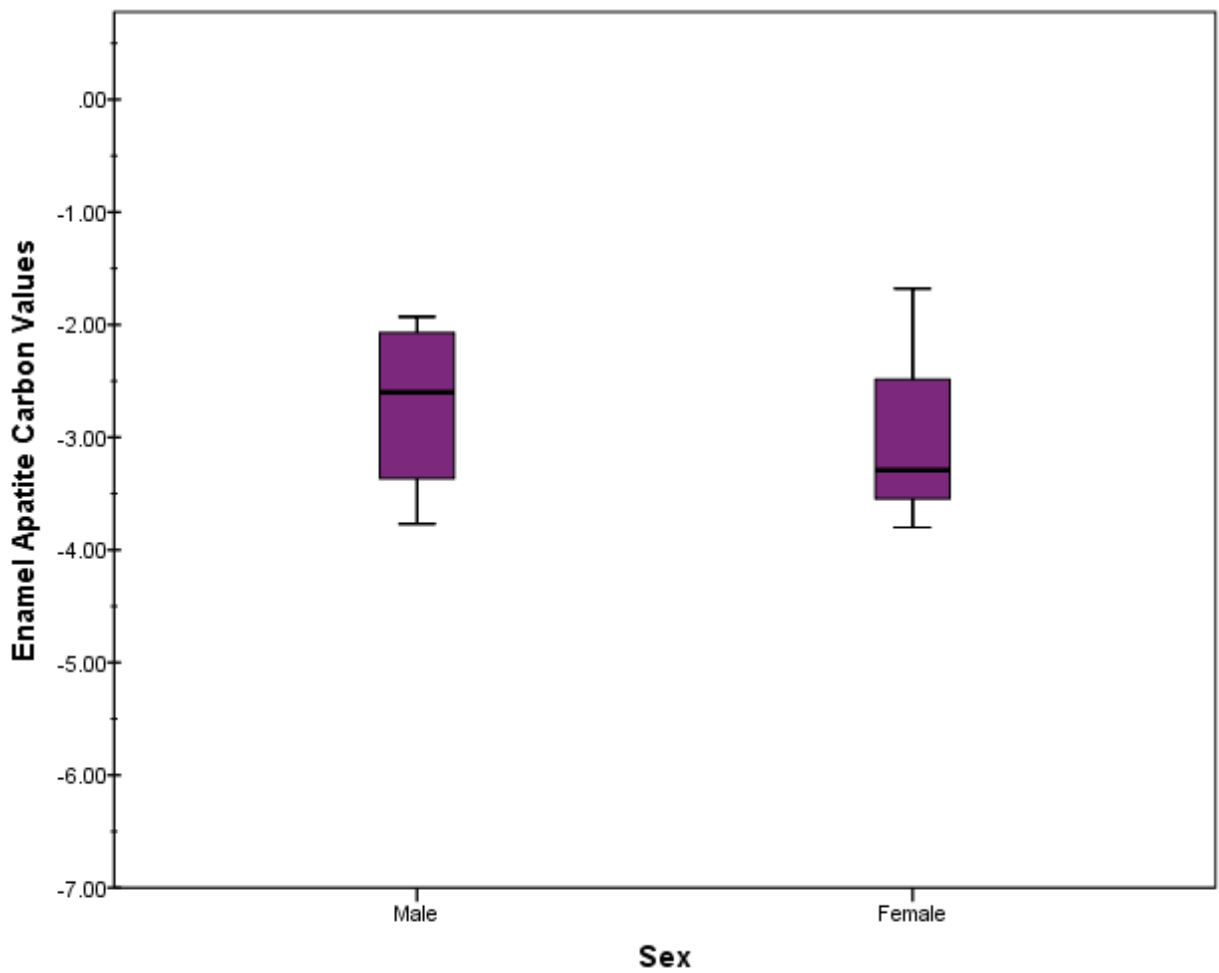


Figure 20: $\delta^{13}\text{C}$ Values from Enamel Apatite compared by Sex

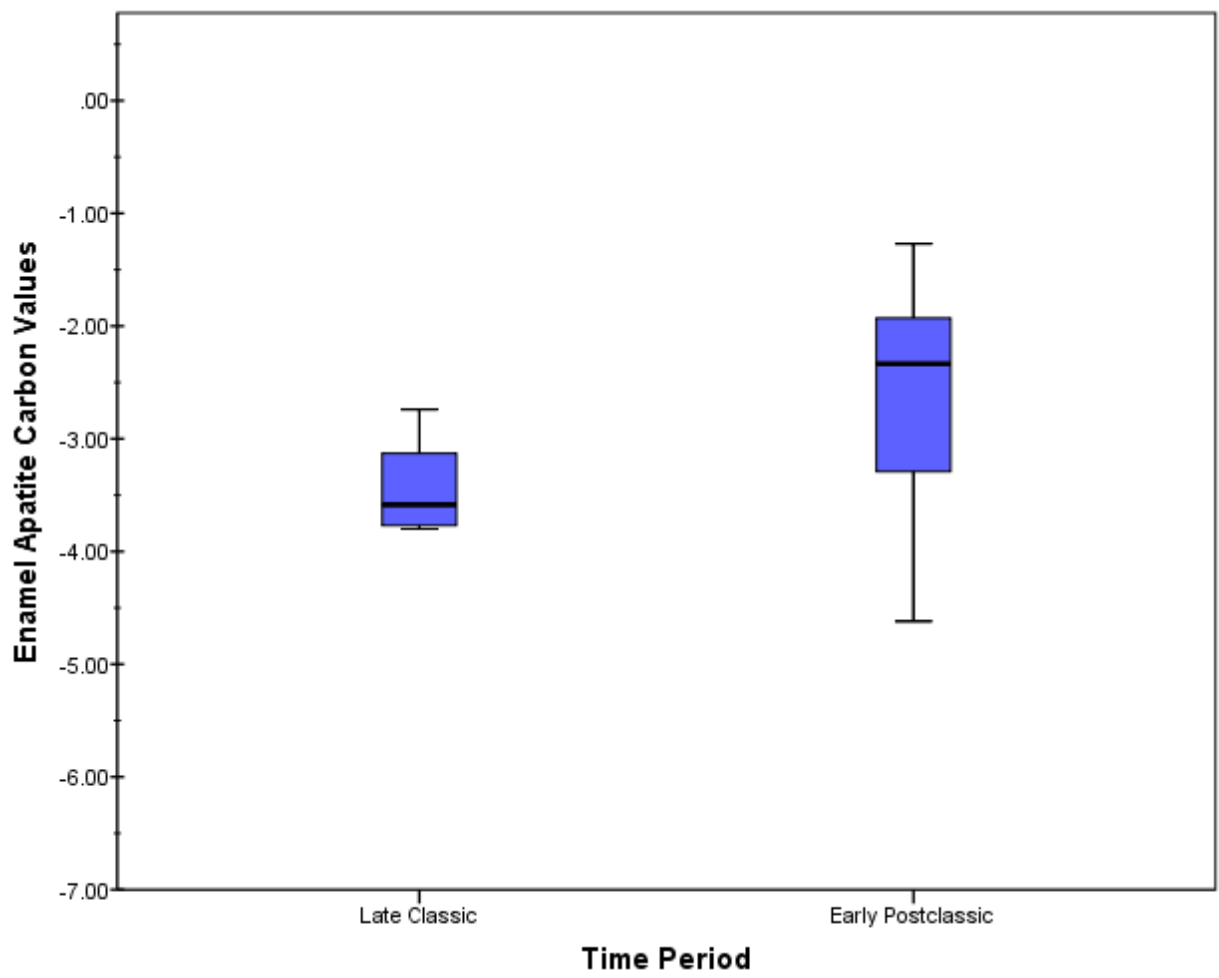


Figure 21: δ¹³C Values from Enamel Apatite compared by Time Period

CHAPTER 5: DISCUSSION

Analysis of stable oxygen isotopes were useful in identifying foreign individuals with in the ancient population at Río Viejo and lend some support the hypothesis that an increase in human mobility occurred following the Classic period collapse at the site. The $\delta^{18}\text{O}$ values from the individuals interred at Río Viejo fall between 23 to 26‰ which is different from the $\delta^{18}\text{O}$ values from individuals interred at Monte Albán, located inland in the Valley of Oaxaca, that range from 12 to 14‰ (White et al. 1998; White et al. 2004). In fact, the $\delta^{18}\text{O}$ values from the coastal sample vary greatly from the majority of values found throughout Mesoamerica (Wright 2012). However, similar values that range from 24 to 25‰ have been recorded at the coastal sites in Belize (Wright 2012). It is unlikely that individuals from the Belize coast were migrating and settling on the Oaxacan coast and therefore, the similarity in $\delta^{18}\text{O}$ isotope values is most likely due to a coastal climate. Assuming other inland $\delta^{18}\text{O}$ values for Oaxaca are more similar to values from Monte Albán rather than Río Viejo, it is unlikely any of the sampled individuals had migrated from the Valley of Oaxaca or the Mixtec Alta. However, some individuals in the sample appear to be “outliers”, having values slightly higher or lower than the mean. I suggest that these individuals were probably local to the Oaxacan coast or the lower Río Verde Valley, traveled throughout the region during their lifetime or migrated to Río Viejo during their lifetime. These individuals may have moved because of marriage or were traveling to participate in trade or carry out political activities. The Early Postclassic displays a wider range of $\delta^{18}\text{O}$ values compared with the Late Classic. This further supports the idea that political and social collapse may have led to a disbursement of people throughout the lower Verde and that individuals may have migrated from different places within the lower Río Verde Valley to settle at Río Viejo during the Early Postclassic.

Overall, the stable carbon and nitrogen isotopes suggest that major dietary components remained consistent from the Late Classic to the Early Postclassic. Dietary reconstruction for individuals living at Río Viejo was possible by comparing these data to food web data from the state of Oaxaca, coastal Belize, and the Caribbean. Through this comparison it was determined that individuals living at Río Viejo ate a diet rich in C₄ and CAM plants, which could have consisted of maize, amaranth, agave, and cacti. Literature notes amaranth as being a staple among the Aztec culture in central Mexico (Early 1990; Myers 1996;); while, maize is seen as a staple in most other parts of Mesoamerica suggesting this was most likely more relied upon in Oaxaca. Agave and cacti, such as the prickly pear and nopalea, were and are some of the most prevalent foods within Oaxaca (Feinman et al. 2007). Agave, in particular, was probably consumed as a fermented beverage that was refined upon Spanish arrival into the modern day alcohol known as mezcal (Zizumbo-Villarreal et al. 2009). Along with C₄ and CAM plants, individuals from Río Viejo had access to a wide range of aquatic resources and isotopic values indicate that offshore, reef, and estuary fish were all exploited, reef fish being the most common. Isotopic values also indicate that smaller reptiles like turtles, turtle eggs, and iguanas were also being exploited.

Individuals representing the Late Classic period (bone collagen: $\delta^{13}\text{C} = -9.76\text{‰}$, PC4 = 69%; dental collagen: $\delta^{13}\text{C} = -9.58\text{‰}$, PC4 = 72%) and the Early Postclassic period (bone collagen: $\delta^{13}\text{C} = -9.15\text{‰}$, PC4 = 70%; dental collagen: $\delta^{13}\text{C} = -9.46\text{‰}$, PC4 = 70%) demonstrate a heavy dependence on C₄ foods. Values from bone collagen show an increase (4%) in C₄ consumption from the Late Classic to the Early Postclassic; whereas, values from dental collagen show no change in C₄ consumption from the Late Classic to the Early Postclassic. However, when observing the widespread range of values from the Early Postclassic and that changes in

carbon values could reflect aquatic resources, the values suggest that following collapse individuals ate a more varied diet particularly including a larger amount of aquatic resources. These values are best compared to those of the coastal populations from the islands of Marco Gonzalez and San Pedro, Belize, whose diet consisted primarily of aquatic resources (Table 27) (Williams et al. 2009). A statistical significance in carbon values from enamel apatite between the Late Classic and Early Postclassic as demonstrated by the results of a Mann-Whitney U test also support the hypothesis that a dietary shift occurred following collapse (see Table 22).

Table 27: Comparison of bone collagen $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ Values from Río Viejo to other coastal Mesoamerican sites

Site	N	Mean $\delta^{13}\text{C}\%$	Mean $\delta^{15}\text{N}\%$
Marco Gonzalez	37	-7.5 ± 1.2	10.5 ± 1.1
San Pedro	29	-6.5 ± 1.1	9.9 ± 1.0
Río Viejo (Late Classic)	8	-9.76 ± 0.58	7.69 ± 0.48
Río Viejo (Early Postclassic)	5	-9.15 ± 0.68	8.20 ± 0.31

These results shed light on the previous carbon isotopic analysis conducted in the region by Taylor et al. (2009). Taylor et al. (2009) argue that maize agriculture increased steadily over time, with the exception of the Early Classic that appears to have abnormal values attributed to a small sample size. I suggest that this disruption may be due to the collapse occurring at Río Viejo during the Early Classic, leading individuals to widen their food resources because of political and social disruption, which may have either adversely affected food production or led to greater access of resources previously controlled by elites. Furthermore, the expansion of isotopic analysis for the Early Postclassic indicates that these values do not represent the continual trend towards an increase in maize production and consumption but rather a more varied diet in response to political and social collapse.

This observed dietary shift was most likely culturally influenced by the changing political and social dynamics following the Classic period collapse. Elite control over resources may have played a larger factor in dietary changes following a collapse of ruling institutions. For instance Mesoamerican elites are often defined by their ability to control, produce, or mobilize large quantities of resources within their society (Hirth 1996). These ideas about elite control are founded on notions of resource ownership and access to labor (Hirth 1996). Many argue therefore that the use of large-scale intensive agricultural systems such as terracing, raised fields, irrigation, and wetland fields indicates that food production and distribution was part of an elite directed and controlled political economy. The creation and maintenance of intensive agricultural systems would require a large, organized labor force, similar to that used for the creation of monumental architecture displayed in site cores. There is little to no evidence, however, for the mass storage of food resources, suggesting that staple commodities such as maize and beans were stored at the household level and distributed through markets depending on surpluses and demands (Brumfield and Earle 1987). Therefore a political collapse could have led to ramifications for the production of food resources and result in a decrease of maize consumption. On the other hand, ruling institutions may have exerted control of food resources in other capacities such as holding and maintain rights to fishing and hunting areas. Ethnohistoric documents discuss a lord of Tututepec, a major Postclassic center within the valley, holding ancestral rights to the Lagoons of Chacahua and Miniyua as well as the Lagoons of la Canada, Totalapa, and Alotengo (Levine 2007:98-99). If this practice persisted from earlier periods, this would have excluded commoners from participating in these activities and limited their ability to procure aquatic resources. During periods of political instability and collapse, elites may have

failed to maintain control of territorial rights leading to greater access for non-elite members of society.

Somerville et al. (2013) present data that argues against the idea that maize consumption would drop following a collapse due to elite control over resources. ANOVA results demonstrate that elite diet changed from the Classic to Terminal Classic while non-elite diet did not. This was attributed to the idea that non-elites utilized several forms of food procurement, such as kitchen gardens and forest foraging. On the other hand, elite diet changed because they were dependent on intensive agriculture and continually changing trade routes (Somerville et al. 2013:1551). While the Maya populations previously analyzed differ from the Río Viejo population in many ways it is not unlikely that non-elites residing at Río Viejo also used alternatives to intensive agriculture to buffer themselves against political and economic change. This suggests elite control over intensive agricultural systems such as terracing would not lead to a complete disruption in food production and a decrease in maize consumption. While it is unclear the status of many of the individuals used in this study, none appear to be elite and therefore the relatively staple consumption of maize may be due to the fact that the Río Viejo population utilized alternative forms of food procurement.

Of particular interest is that isotope values from both time periods do not indicate significant consumption of terrestrial resources despite faunal remains from terrestrial animals being present in the middens at Río Viejo (Cunningham-Smith and Barber 2016). Middens at Río Viejo do display a larger number of terrestrial resources compared with middens at other sites within the valley (Sarah Barber, personal communication). However, Río Viejo middens are seen as products of feasting events whereas domestic middens are found at other sites within the

valley. It is therefore possible that terrestrial animals were consumed during feasting events and likely did not play a large role in every day diet.

CHAPTER 6: CONCLUSION

The focus of this research was to investigate human mobility and diet in response to the political and social collapse of the Classic period at the site Río Viejo in the lower Río Verde Valley of coastal Oaxaca, Mexico. The study demonstrated the usefulness of using isotopic analysis in conjunction with archaeological data, faunal analysis, and ethnohistoric records. Human mobility was analyzed through the analysis of stable oxygen isotope values from enamel apatite, representing childhood and young adulthood. Diet was reconstructed through the analysis of stable carbon and nitrogen isotope values from dental and bone collagen and enamel apatite, representing childhood and adulthood.

The social status of the individuals used in this analysis is difficult to ascertain. The burials discussed as part of the Late Classic sample displayed a range of offerings and public space deposits; this makes it difficult to ascertain these individual's positions within society as it is unclear why they were chosen for special burial. On the other hand, the burials discussed as part of the Early Postclassic sample from Río Viejo represent two household groups that shared similar traditions based on mortuary practice. This indicates the burials present here are domestic in nature and are likely of individuals who resided in these households; however, their social status is unclear due to lack of comparative burials but appear to be non-elite based on grave goods. The people living in the lower Río Verde Valley likely subsisted on C₄ plants such as maize, CAM plants, and aquatic resources. A comparison of values from males and females demonstrate there was no difference in diet or mobility between the two groups; this was further confirmed with the results of a Mann-Whitney U test. Comparison based on time period however did show subtle differences in both human mobility and diet following the Classic period collapse. A statistically significant difference in nitrogen values between the Late Classic and

Early Postclassic periods further supports a dietary shift in diet, specifically to include a greater amount of aquatic resources.

Despite the success of this study, there are some limitations. Some samples originally collected were unable to be used in this analysis due to poor preservation of collagen, specifically within bone samples. Field methodologies, discussed fully in Chapter 4, allow for detailed osteological analysis providing invaluable information about sex, age, and skeletal pathology; however, these may also lead to further deterioration of collagen. Future research should focus on developing new methodologies that allow for complete osteological analysis while also preserving the integrity of the bone for biochemical analyzes. Another problem is the lack of food web data from coastal Oaxaca and specifically isotopic data (carbon and nitrogen values) for mollusks and barnacles, which make up the largest portion of faunal material present in middens in the region. The absence of this material may be a contributing factor in values indicating a consumption of reef resources over estuary and freshwater resources, specifically when Río Viejo is in greater proximity to estuaries and lagoons. Future research should include the creation of an isotopic food web for coastal Oaxaca with an aim to include resources found in middens throughout the region.

While this study determined dietary shifts occurred due to social and political collapse; a great majority of the literature surrounding the Classic period collapse in Mesoamerica supports the hypothesis of climate change. To further test the climate change hypothesis in the lower Verde, completing isotopic analysis of faunal remains dating to Classic and Postclassic periods will be useful. As discussed previously in Chapter 2, environmental stressors can impact nitrogen values, specifically causing increases due to water stress. If climate change were the contributing

factor to dietary changes it would be seen in both human and animal populations in the lower Verde.

APPENDIX: MORTUARY AND SKELETAL INFORMATION

Individual and burial information as well as photographs and illustrations are courtesy of Sarah Barber and Arthur Joyce for Late Classic interments and Stacie King for some Late Classic and all Early Postclassic interments (King 2003; King, personal communication; Barber and Joyce et al. 2012).

RV: Burial 64 Individual 73

Location: Op. A, MU-2

Burial Type: primary

Time Period: Late Classic

Sex: male

Age: adult (35-50)

Position: flexed, possibly sitting

Orientation: undetermined

Conservation: very poor condition

Skeletal Pathology: osteoarthritis and osteophytosis

Dental Pathology: none observed

Offerings: within a layer of burnt human and animal bones

Notes: only 50% complete skeleton, no skull

RV: Burial 64 Individual 103

Location: Op. A, MU-2

Burial Type: secondary

Time Period: Late Classic

Sex: male

Age: adult (27-31)

Position: flexed, possibly sitting

Orientation: undetermined

Conservation: very poor condition

Skeletal Pathology: osteoarthritis and osteophytosis

Dental Pathology: none observed

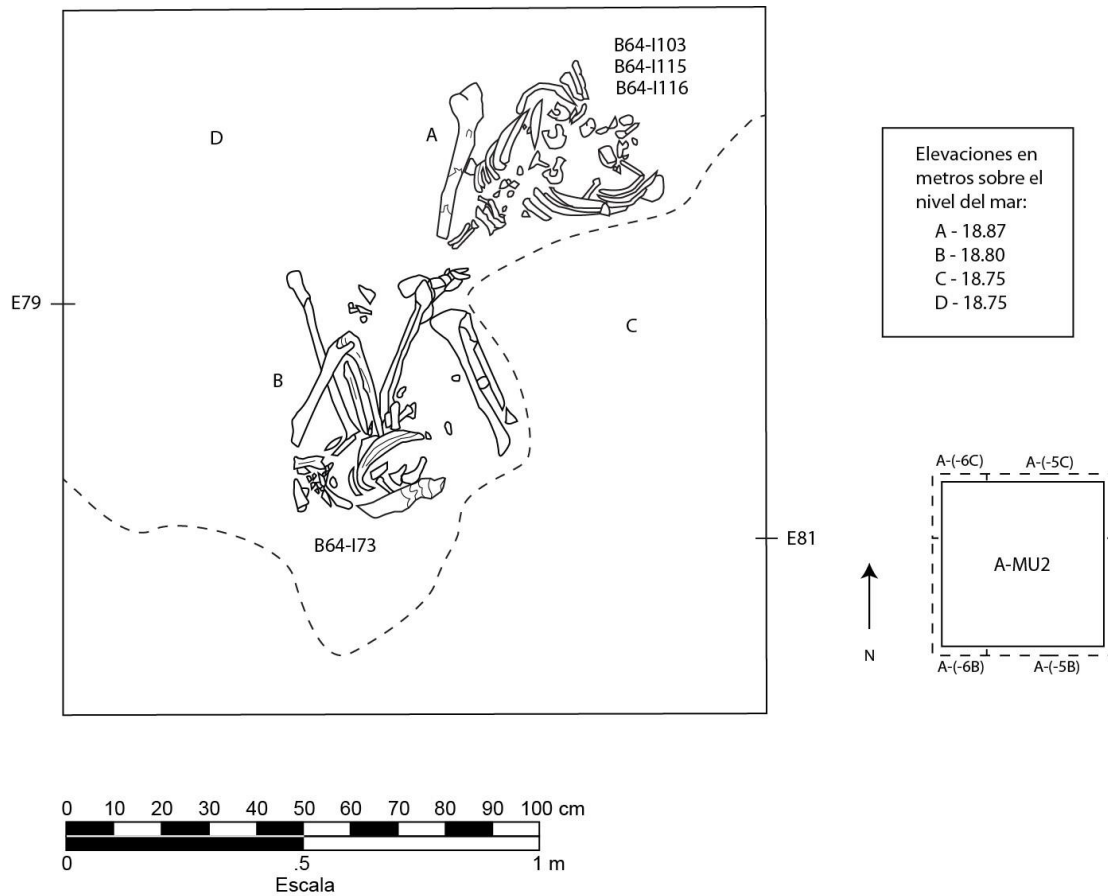


Figure 22: Illustration of B64 I103 in situ

RV: Burial 65 Individual 74

Location: Op. D, units 6Y, 6Z

Burial Type: primary

Time Period: Late Classic

Sex: male

Age: adult (30-39)

Position: extended, lying back down

Orientation: 18-198° (head to toe)

Conservation: very poor condition

Skeletal Pathology: osteoarthritis and osteophytosis; active and healing periostitis in lower limbs

Dental Pathology: linear enamel hypoplasia

Notes: skeleton less than 80% complete

RV: Burial 76 Individual 85

Location: Op. E, unidad 20A, 20B, 20ZZ

Burial Type: primary

Time Period: Late Classic

Sex: male

Age: adult (21-34)

Position: extended, lying prone

Orientation: 0-180° (head to toe)

Conservation: very poor condition

Skeletal Pathology: osteoarthritis and osteophytosis

Dental Pathology: antemortem tooth loss, periodontal disease

Notes: skeleton approximately 45% complete

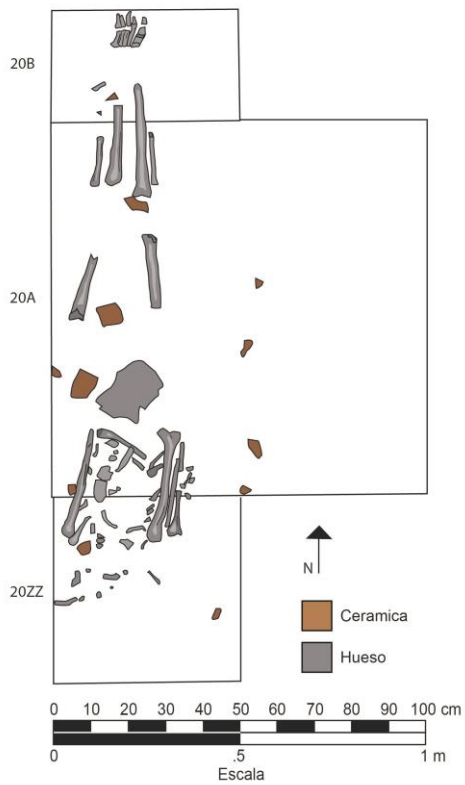


Figure 23: Illustration of B76 I85 in situ

RV: Burial 87 Individual 96

Location: Op. C, unit 000

Burial Type: primary

Time Period: Late Classic

Sex: male

Age: adult (20-35)

Position: extending, lying on ventral side

Orientation: 20-200° (head to toe)

Conservation: poor condition

Skeletal Pathology: osteoarthritis

Dental Pathology: hypoplastic defects in M1 resulting in a reduction in the size of the crown until the individual recovered from biological stress (linear enamel hypoplasia)

Offering: placed with three pots along the body (a bowl over the head, a cylindrical bowl on the chest, and a bowl over the pelvis), a partial metate was placed to the east of the legs

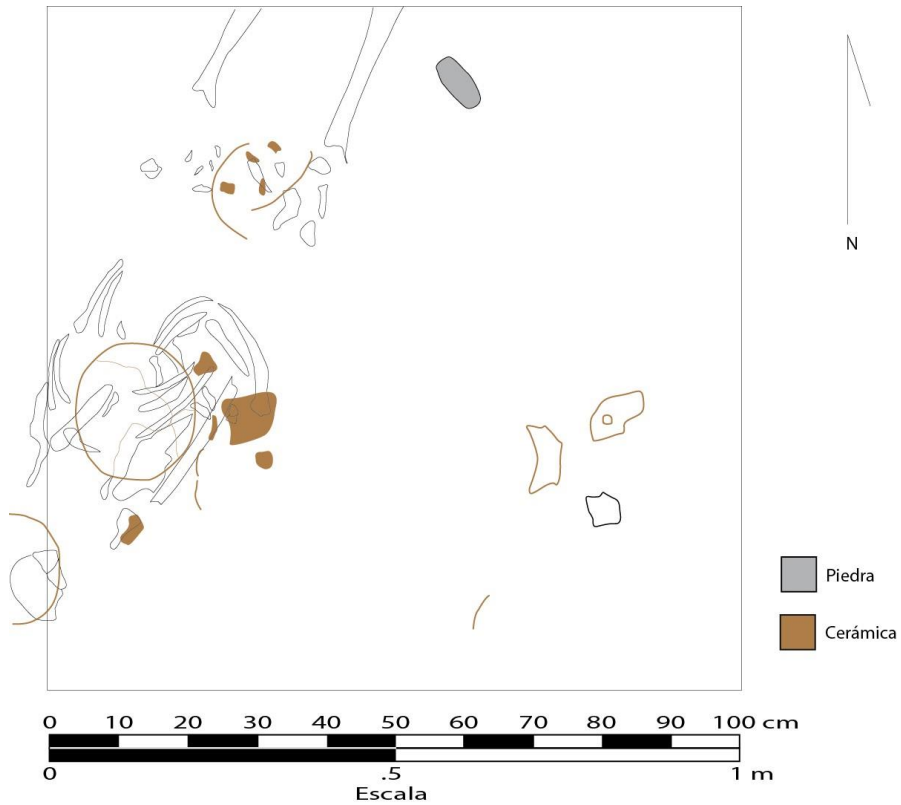


Figure 24: Illustration of B87 I96 in situ



Figure 25: Photograph of B87 I96 in situ

RV: Burial 93 Individual 102

Location: Op. A, MU-8 (units 0XX and 1XX)

Burial Type: primary

Time Period: Late Classic

Sex: male

Age: adolescent (16-18)

Position: extended, lying on ventral side

Orientation: 297-117° (head to toe)

Conservation: poor condition

Skeletal Pathology: none observed

Dental Pathology: dental modification, linear enamel hypoplasia

Offering: an orange ware jar from the Yuta Tiyoo phase (Late Classic)

Notes: skeleton 25% complete, cranium was inside orange ware vessel

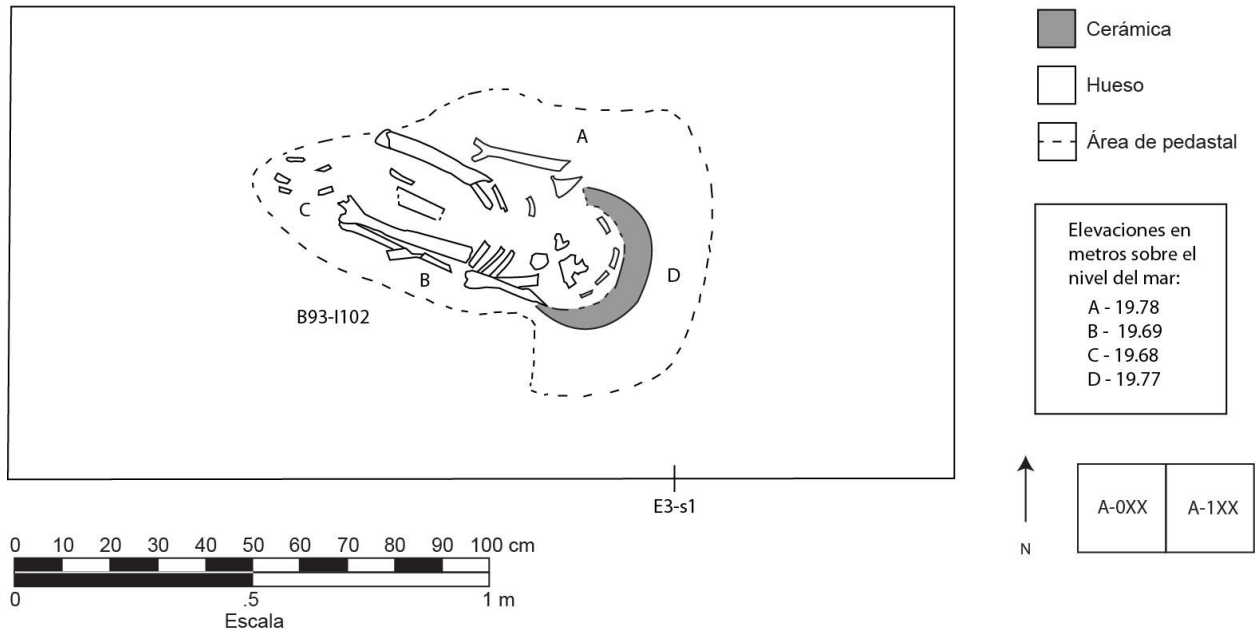


Figure 26: Illustration of B93 I102 in situ

RV: Burial 97 Individual 107

Location: Op. A, MU-7

Burial Type: primary

Time Period: Late Classic

Sex: male

Age: adult (24-35)

Position: flexed

Orientation: N/A

Conservation: very poor condition

Skeletal Pathology: osteophytosis

Dental Pathology: dental inlays and modifications, linear enamel hypoplasia

Offerings: Yuta Tiyoo phase orange cylindrical vessel, curved-convergent orange ware bowl with outer flange

Notes: skeleton 75% complete

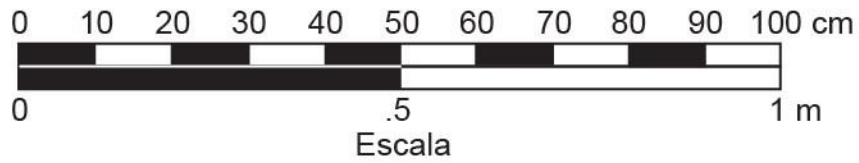
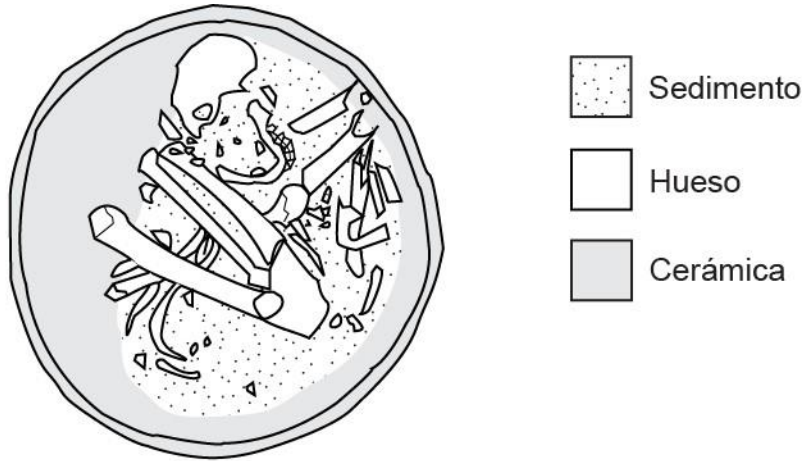


Figure 27: Illustration of B97 I107 in situ



Figure 28: Photography of the large pot containing the burial of B97 I107

RV: Burial 26 Individual 34

Location: Op. RV00 B, 5B60/6B60/7B60, Stratum 9

Burial Type: primary

Time Period: Early Postclassic

Sex: undetermined

Age: adult

Position: extended supine

Orientation: 8° west of north with head to the south

Conservation: incomplete and fragmentary, poor condition

Skeletal pathology: none observed

Dental pathology: none observed

Offerings: 2 ceramic vessels

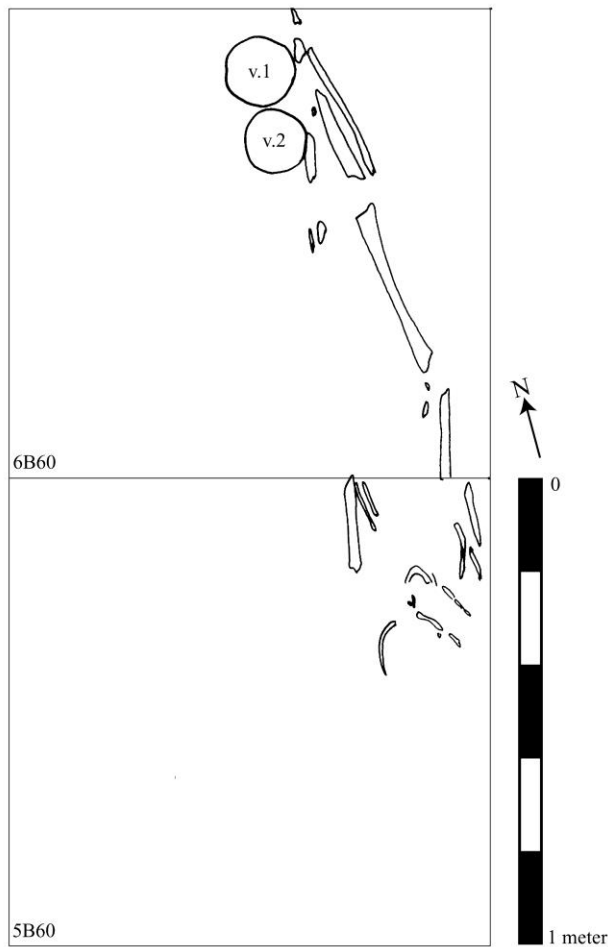


Figure 29: Illustration of B26 I34 in situ

RV: Burial 27 Individual 35

Location: Op. RV00 B, 7B59 Stratum 9/Stratum19

Burial Type: primary

Time Period: Early Postclassic

Sex: undetermined

Age: adult

Position: extended supine or possibly on right side

Orientation: 4° east of north with head to the south

Conservation: incomplete and fragmentary, poor condition

Skeletal pathology: none observed

Dental pathology: none observed

Offerings: 3 obsidian blades placed in the mouth and 1 well-smoothed quartz burnisher beneath the cranium

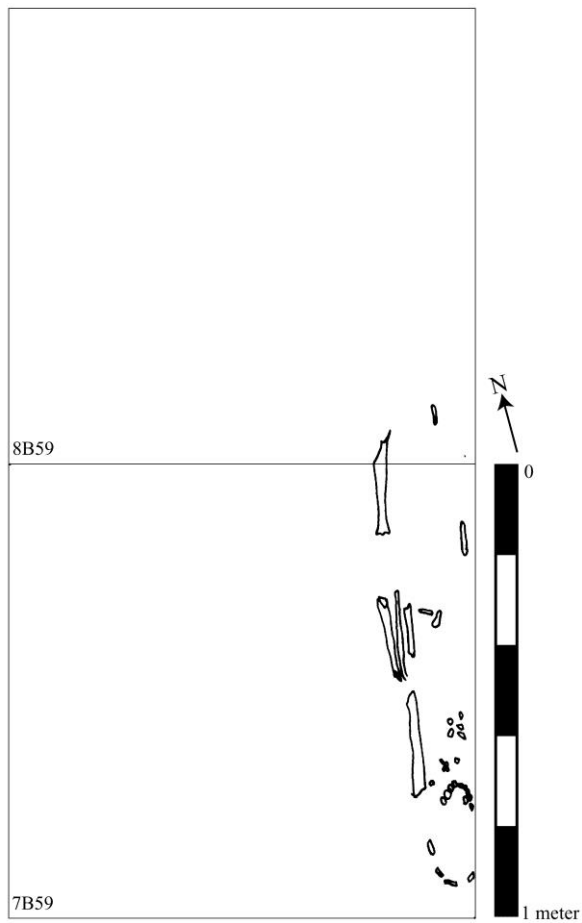


Figure 30: Illustration of B27 I35 in situ

RV: Burial 28 Individual 36

Location: Op. RV00 B, 5B59/6B59/7B59, Stratum 9/Stratum 19

Burial Type: primary

Time Period: Early Postclassic

Sex: male

Age: adult (30-35)

Position: extended supine

Orientation: 4° west of north with head to south

Conservation: incomplete and fragmentary with fragment of pelvis

Skeletal pathology: none observed

Dental pathology: none observed

Offerings: 3 ceramic vessels

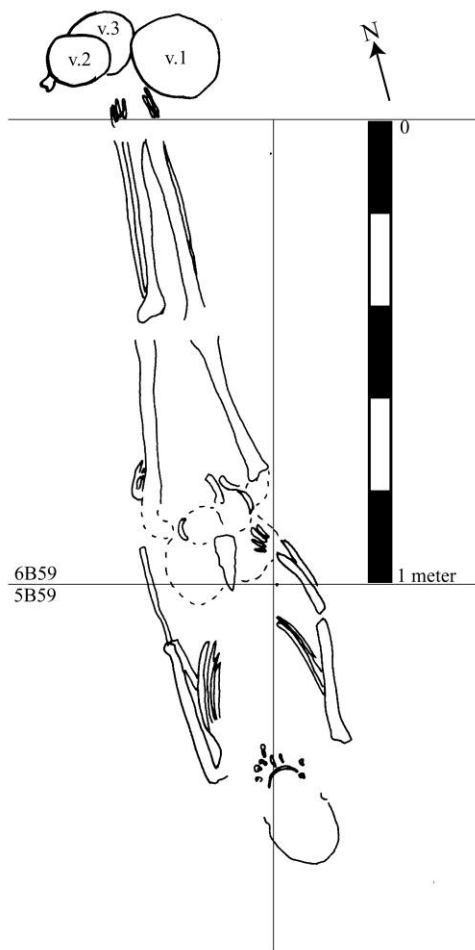


Figure 31: Illustration of B28 I36 in situ

RV: Burial 29 Individual 37

Location: Op. RV00 B, 4B62/5B62/6B62, Stratum 9

Burial Type: primary

Time Period: Early Postclassic

Sex: undetermined

Age: adolescent (15-18)

Position: extended supine, head to south

Orientation: 7° east of north

Conservation: incomplete and fragmentary

Skeletal pathology: none observed

Dental pathology: dental calculus in lower incisors, severe wear on lower right M1, antemortem loss of lower left M1, severe abscess left side

Offerings: 2 ceramic vessels

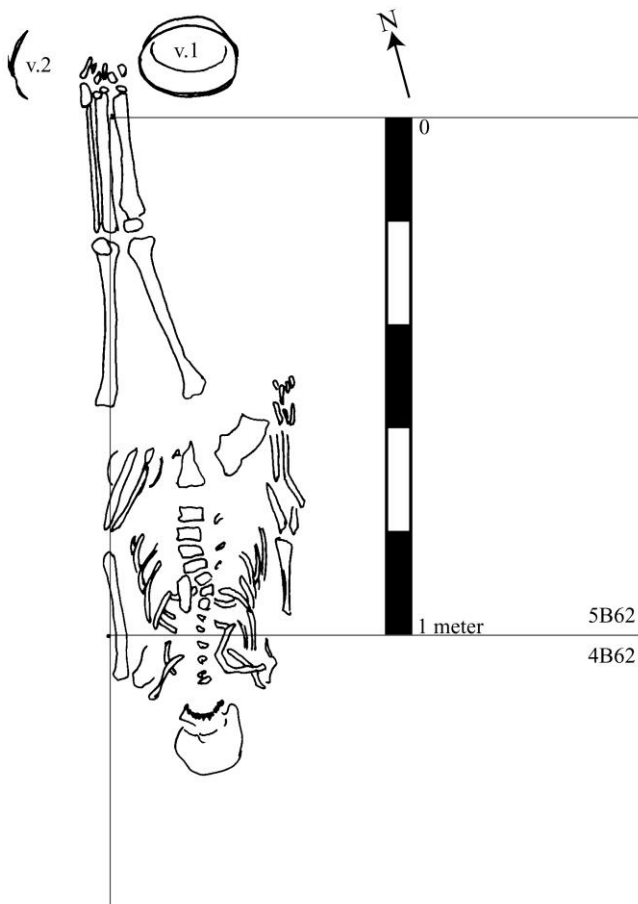


Figure 32: Illustration of B29 I37 in situ

RV: Burial 30 Individual 38

Location: Op. RV00 B, 5B61/6B61/7B61, Stratum 9

Burial Type: primary

Time Period: Early Postclassic

Sex: undetermined

Age: adult

Position: extended supine

Orientation: 4° east of north with head to the south

Conservation: incomplete and fragmentary, poor condition

Skeletal pathology: none observed

Dental pathology: none observed

Offerings: 2 ceramic vessels, 1 well-polished quartz burnisher underneath the cranium

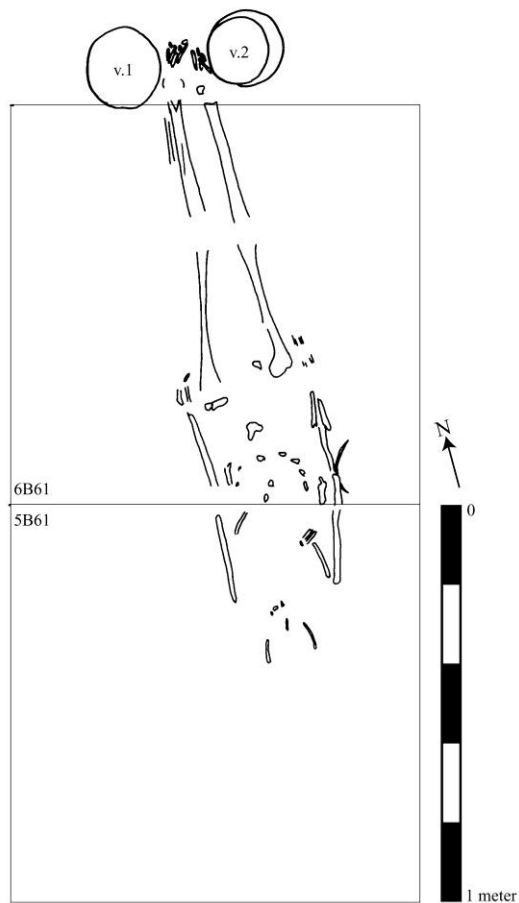


Figure 33: Illustration of B30 I38 in situ

RV: Burial 31 Individual 39

Location: Op. RV00 B, 5B59/6B59/7B59, Stratum 9/Stratum 19

Burial Type: primary

Time Period: Early Postclassic

Sex: female

Age: adult (30-35)

Position: extended supine

Orientation: 4° east of north with head to the south

Conservation: incomplete and fragmentary, poor condition

Skeletal pathology: none observed

Dental pathology: severe wear on first molars

Offerings: 2 ceramic vessels

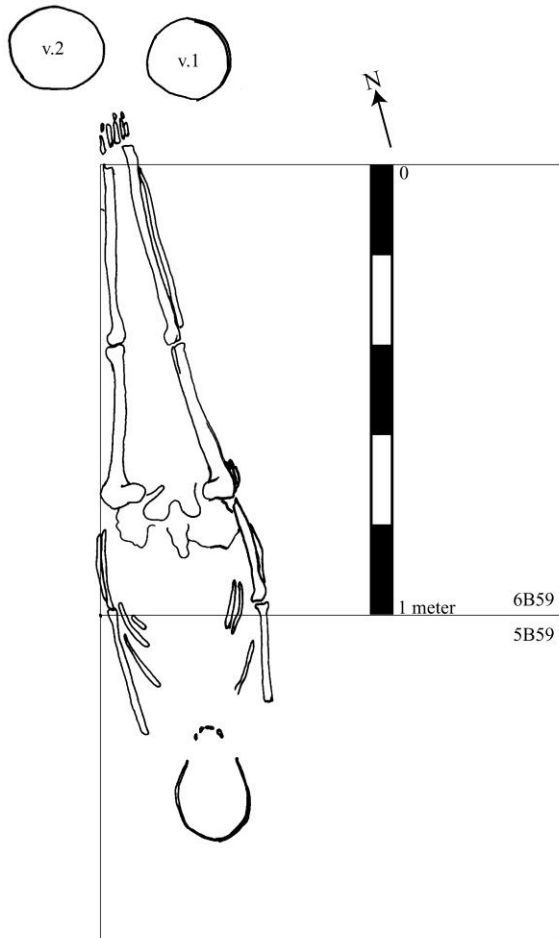


Figure 34: Illustration of B31 I39 in situ

RV: Burial 32 Individual 40

Location: Op. RV00 B, 6B62/7B62, Stratum 9

Burial Type: primary

Time Period: Early Postclassic

Sex: male

Age: adult

Position: extended supine

Orientation: 6° east of north, head to the south

Conservation: incomplete and fragmentary, poor condition

Skeletal pathology: none observed

Dental pathology: severe wear and some antemortem loss

Offerings: 2 ceramic vessels

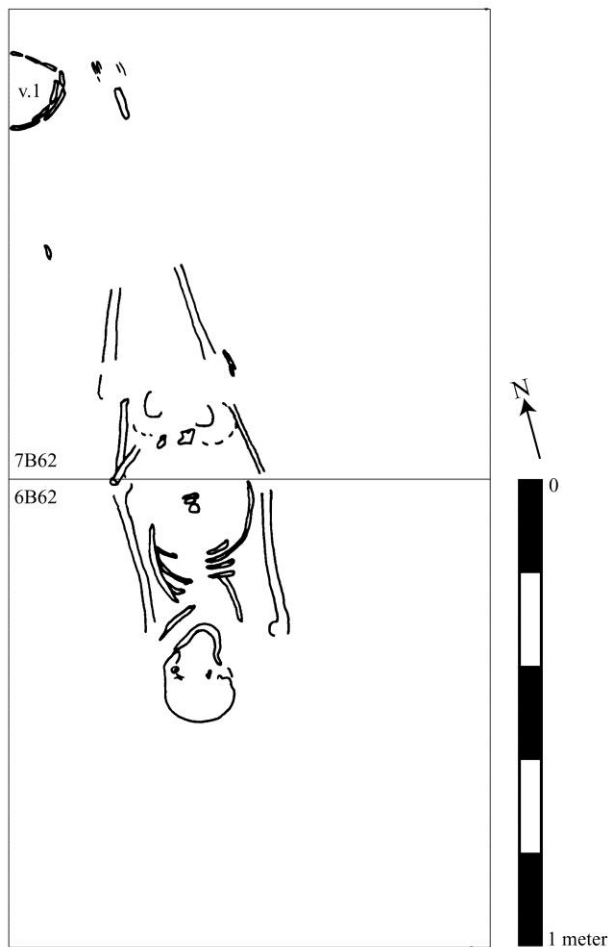


Figure 35: Illustration of B32 I40 in situ

RV: Burial 33 Individual 41

Location: Op. RV00 B, 5B58/6B58/7B58, Stratum 9

Burial Type: primary

Time Period: Early Postclassic

Sex: male

Age: adult

Position: extended supine, head to south

Orientation: 7° east of north, head to south

Conservation: incomplete and fragmentary, fair condition

Skeletal pathology: none observed

Dental pathology: wear, some teeth with calculus, caries on lower right canine

Offerings: 2 ceramic vessels

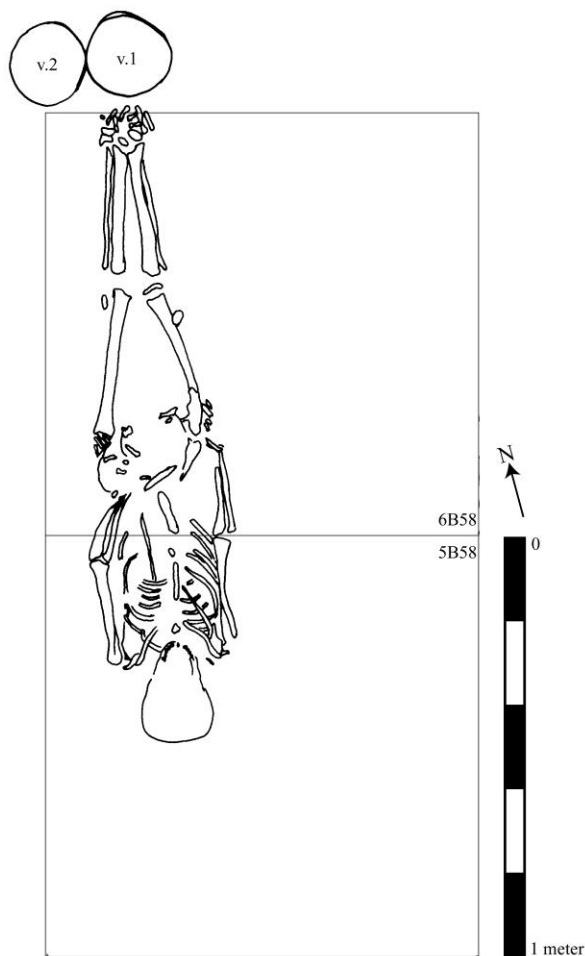


Figure 36: Illustration of B33 I41 in situ

RV: Burial 35 Individual 43

Location: Op. RV00 B, 5B64/6B64/7B64, Stratum 9

Burial Type: primary simple

Time Period: Early Postclassic

Sex: male

Age: adult

Position: extended supine

Orientation: 2° east of north with head to the south

Conservation: incomplete and fragmentary, fair condition

Skeletal pathology: osteoarthritis on vertebrae, T2-3

Dental pathology: none observed

Offerings: none observed

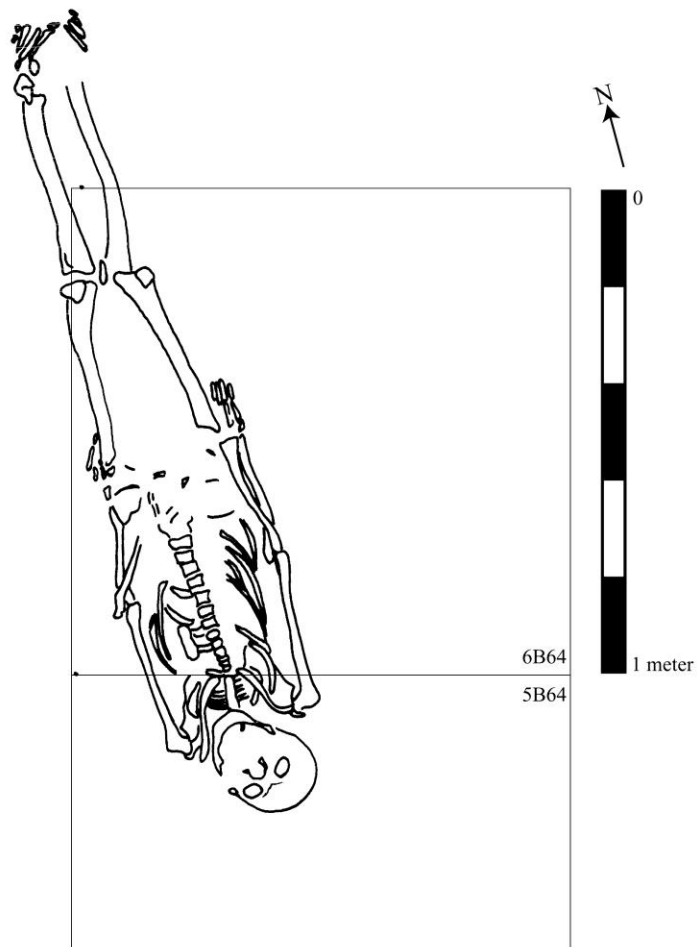


Figure 37: Illustration of B35 I43 in situ

RV: Burial 40 Individual 48

Location: Op. RV00 B, 8B59/9B59, Stratum 2

Burial Type: primary

Time Period: Late Classic

Sex: undetermined

Age: juvenile (8)

Position: flexed on the left side

Orientation: 4° west of north with head to the south

Conservation: incomplete and fragmentary

Skeletal pathology: none observed

Dental pathology: lower right I1 and I2 fused

Offerings: 4 ceramic vessels and earflare with a carved monkey insert

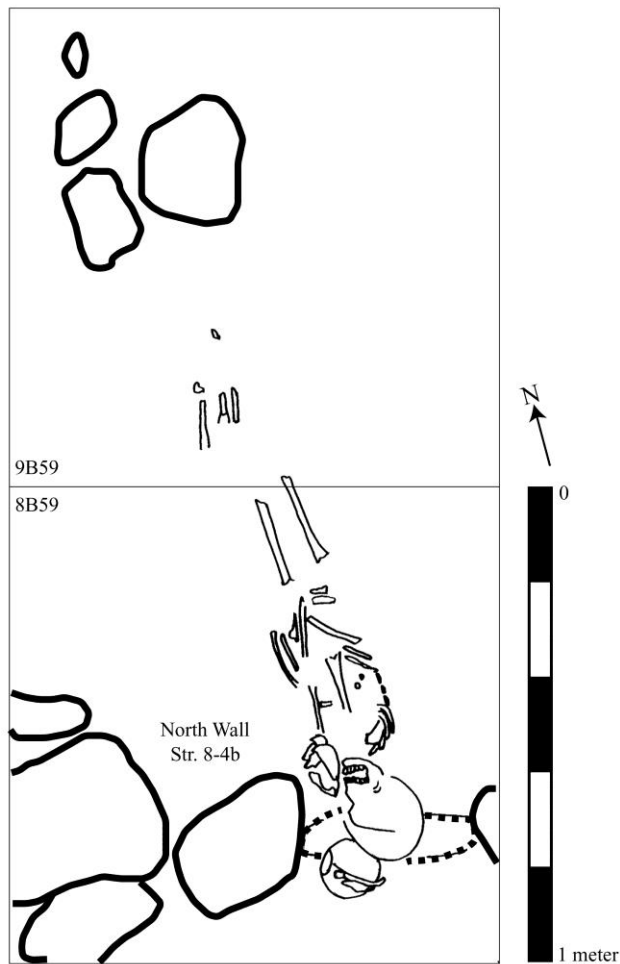


Figure 38: Illustration of B40 I48 in situ

RV: Burial 42 Individual 51

Location: Op. RV00 B, 0D51/0D52, Stratum 28/31/33

Burial Type: primary

Time Period: Late Classic

Sex: male

Age: adult (30-35)

Position: flexed on left side

Orientation: 113° east of north with head to the west

Conservation: incomplete and fragmentary, fair condition, cranium well preserved

Skeletal pathology: none observed

Dental pathology: dental calculus, wear on the central and lateral incisors, dental modification

Offerings: none observed

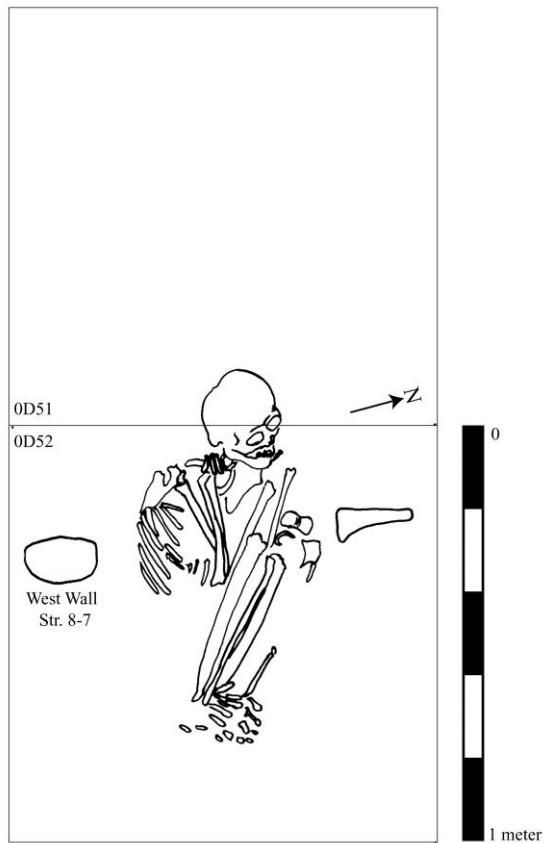


Figure 39: Illustration of B42 I51 in situ

RV: Burial 43 Individual 52

Location: Op. RV00 B, 8C53/9C53/0D53, Stratum 28/31/33

Burial Type: primary

Time Period: Early Postclassic

Sex: female

Age: adult

Position: extended supine, legs crossed at ankles (left over right)

Orientation: 17° east of north with head to the south

Conservation: incomplete and fragmentary

Skeletal pathology: arthritis of the hand

Dental pathology: 6 mandibular molars with severe wear, 2 maxillary molars with light wear

Offerings: 3 ceramic vessels

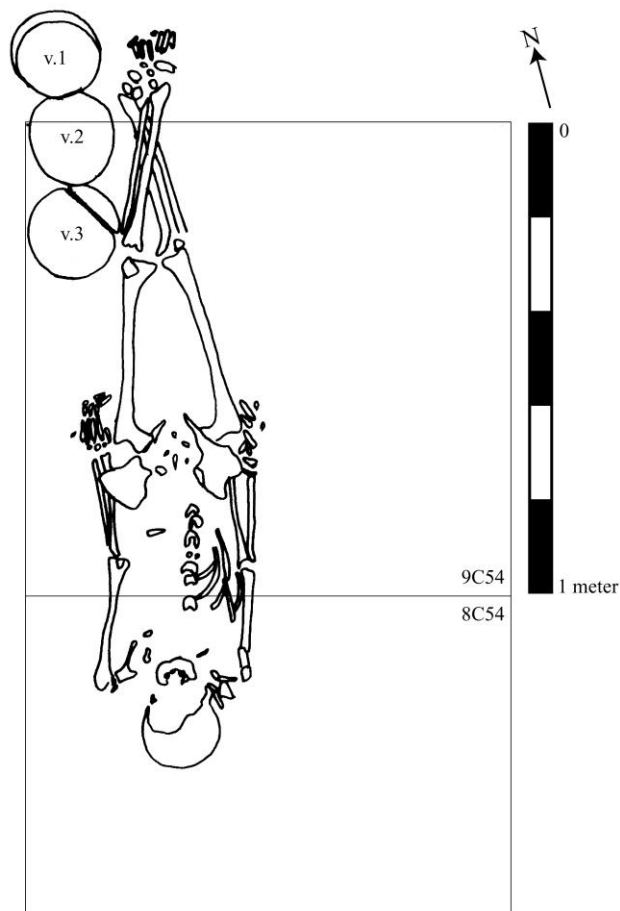


Figure 40: Illustration of B42 I52 in situ

RV: Burial 44 Individual 53

Location: Op. RV00 B, 0D53/0D54, Stratum 28/31/33

Burial Type: primary

Time Period: Late Classic

Sex: undetermined

Age: adult

Position: flexed on the left side, arms crossed

Orientation: 100° east of north with head to the west

Conservation: incomplete and fragmentary, poor condition

Skeletal pathology: possible arthritic fusion of vertebrae

Dental pathology: none observed

Offerings: none observed

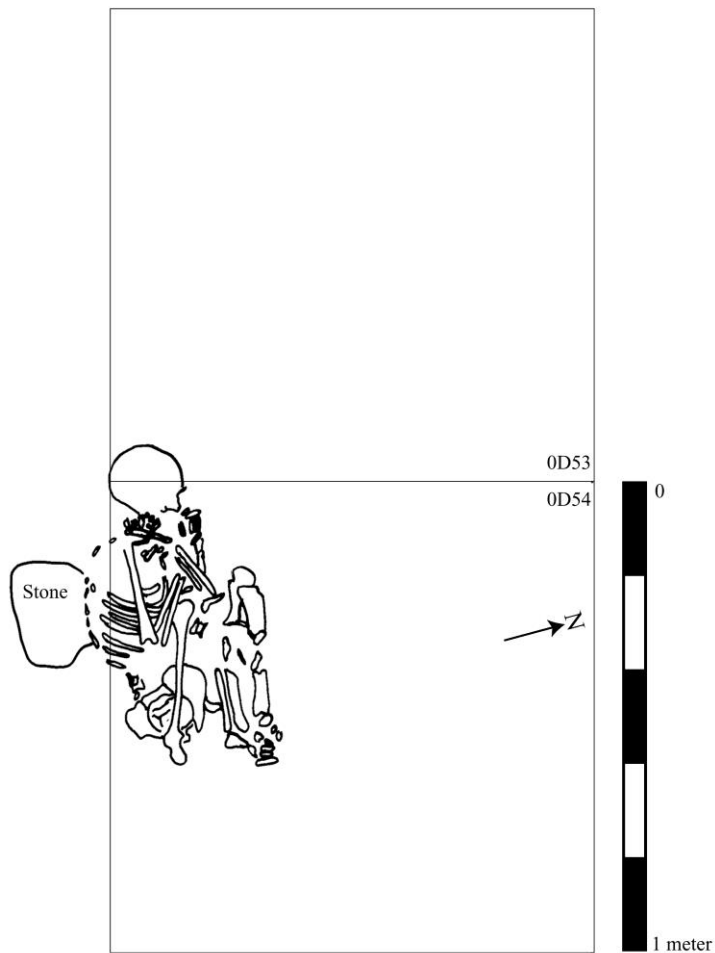


Figure 41: Illustration of B44 I53 in situ

RV: Burial 46 Individual 55

Location: Op. RV00 B, 8C54/9C54/0D54, Stratum 27/30/32 and Stratum 28/31/33

Burial Type: primary

Time Period: Early Postclassic

Sex: male

Age: adult (25-30)

Position: extended supine

Orientation: 9° east of north with head to the south

Conservation: incomplete and fragmentary

Skeletal pathology: light osteophytes (arthritis) in the vertebrae

Dental pathology: none observed

Offerings: 2 ceramic vessels, shell pendants

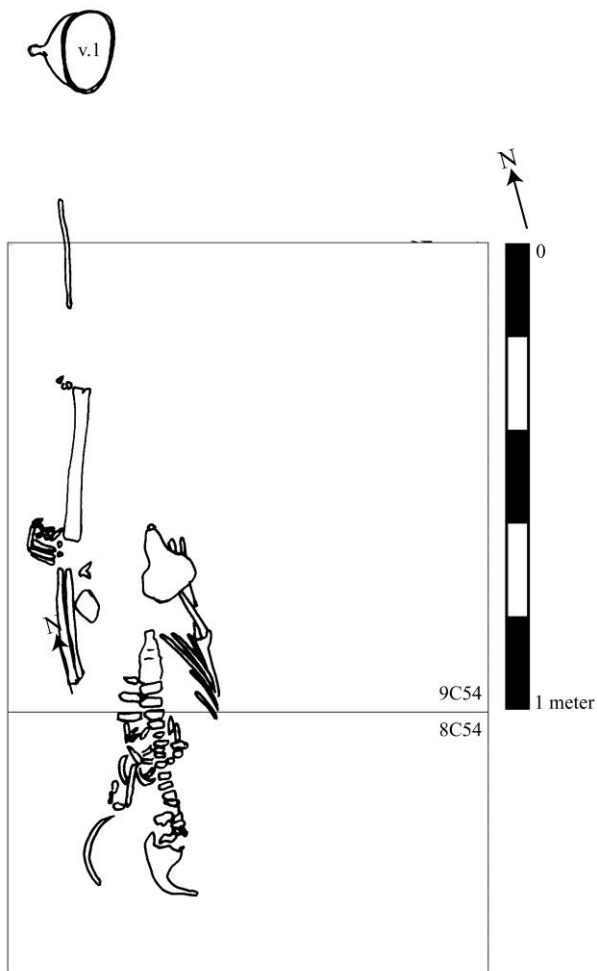


Figure 42: Illustration of B46 I55 in situ

RV: Burial 47 Individual 56

Location: Op. RV00 B, 0D57/0D58, Stratum 28/31/33 and Stratum 34

Burial Type: primary

Time Period: Late Classic

Sex: female

Age: adult (35)

Position: rolled over and extended on the right side or semi-prone, looking east

Orientation: 23° east of north

Conservation: incomplete, good condition

Skeletal pathology: deflated vertebrae indicative of osteoporosis

Dental pathology: severe wear on canines, molars, and down to the roots on the incisors, antemortem loss of lower left molar and M3, P3 and P4 of lower right side

Offerings: 6 ceramic vessels of gray paste, earflare fragments, and the face resting on a well-worn *mano*

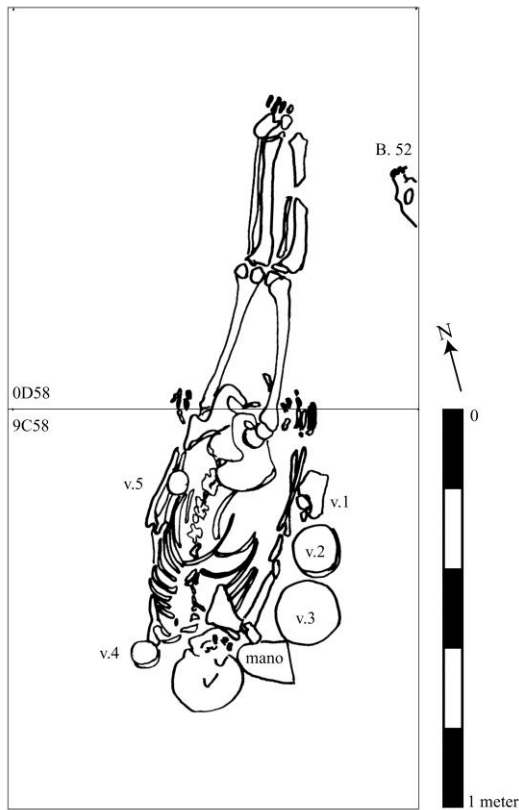


Figure 43: Illustration of B47 I56 in situ

RV: Burial 51 Individual 60

Location: Op. RV00 B, 8C53/8C54/9C53/9C54, Stratum 27/30/32 and Stratum 28/31/33

Burial Type: primary

Time Period: Late Classic

Sex: male

Age: adult

Position: seated with body bent over and positioned downward, looking east

Orientation: 199° east of north

Conservation: incomplete and fragmentary

Skeletal pathology: severe osteophytes on vertebrae

Dental pathology: none observed

Offerings: none observed

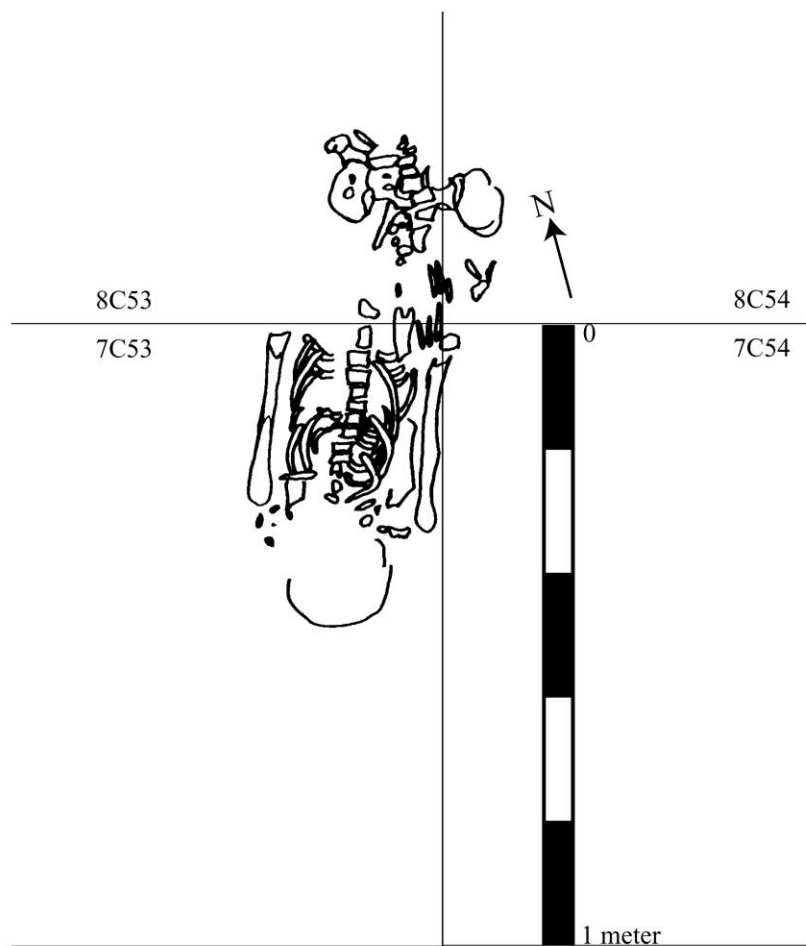


Figure 44: Illustration of B51 I60 in situ

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