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THE USE OF STABLE ISOTOPE ANALYSIS ON BURIALS AT CAHAL PECH, BELIZE IN ORDER TO IDENTIFY TRENDS IN MORTUARY PRACTICES OVER TIME AND SPACE.

By

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ABSTRACT

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The Late (AD 500-700) to Terminal (AD 700-900) Classic transition in the Maya Southern Lowlands has been defined as a period of decline and large scale migrations out of ceremonial centers. The reduced access to food due to multi-decadal droughts severely affected the social and political environments during this period. Previous research focused on large scale geographic migration and diet in this area. What is less understood is the degree and direction of migration at a site-specific level, as well as the community's specific response through time. This research uses the human remains along with their associated mortuary artifacts from the site of Cahal Pech, Cayo District, Belize in order to understand one community's response to environmental stress during the Late to Terminal Classic period. Several multivariate statistical analyses were run on a comprehensive stable isotope plan ($\delta^{13}C$, $\delta^{15}N$, $\delta^{34}S$, $^{86}Sr/^{87}Sr$, and $\delta^{18}O$) and mortuary database for 27 individuals from the site core. These result were then compared to models created by the author in order to find a best fit. This research found that migration into and out of Cahal Pech was occurring at a similar rate over time and that almost all individuals that showed non-local isotope signatures came from the Macal River region south of the site. The mortuary patterns do not trend on time period, age and sex, origin of the individual, or location of the burial at the site. Rather, the mortuary patterns initially cluster based on grave type and presence or absence of certain grave goods. The findings show no effect during the transition from the Late to Terminal Classic based on the mortuary and bioarchaeological data. This unexpected result may be due to sampling only the Cahal Pech core, possibly representing elite individuals buffered from the worst effects of deteriorating environmental conditions. In order to understand if this is a unique occurrence or regionally expressed, future research will need to be undertaken with broader parameters.

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CHAPTER 1 - INTRODUCTION

Humans have a unique connection to their environment, which provides food and water to keep us alive, but it also challenges us by constantly changing and creating instability in our lives. There is a deeper human-environment connection that goes beyond the practical, it is a trust and bond with the land that is sacred and part of the human psyche. The Maya believed their leaders were in communion with the gods that oversaw the environment and that these leaders would provide fruitful land and water sources for the people (Gill et al., 2007; Lucero, 2002). When the elite Maya leaders were unable to ward off significant environmental shifts, specifically droughts, the trust waivered and profound shifts occurred after the Late Classic Maya (AD 500-700) period, particularly in the Southern lowlands.

The question of how the Maya responded to the socio-political and environmental instability that began towards the end of the Late Classic (AD 500-700) and became exacerbated during the Terminal Classic (AD 700-900) has been a topic of research since the late 1800s. The Classic Maya collapse and abandonment of the Terminal Classic has been romanticized as a sudden mass exodus of Maya people from sites across the Southern Lowlands (Demarest et al., 2005a; Gill et al., 2007; Haug et al., 2003; Medina-Elizalde and Rohling, 2013; Webster, 2002). On the flip side, there are also those that dismiss the socio-political shift as nothing more than a slight migration of people during a time of drought (Aimers, 2007; Rice et al., 2005), and of course there are those that fall somewhere in between (Kennett et al., 2012). It is the goal of this research to identify how the medium sized ceremonial site of Cahal Pech was affected by the environmental stress and the disintegration of their social and political structures using evidence from burials. Specifically, the response at the Cahal Pech epicenter will be examined by testing for indications of migration, changes in status and diet, and changes in mortuary patterns.

The response across the Maya Southern Lowlands during the Terminal Classic period is clearly complex (Aimers, 2007; Demarest et al., 2005a; Webster, 2002) and the patterns at one site may not be the same pattern for all sites. Nevertheless, the importance of understanding how one particular site might have responded to major changes in the environment allows for comparison with other sites of similar size, as well as creating a model of how to approach this problem using bioarchaeological data in future research. It must also be considered that Cahal Pech, because of its unique history and placement among the competing polities in the Belize Valley, experienced these changes in a way dissimilar to other sites. Until future research identifies how other sites were affected, this research regarding Cahal Pech should be used as a starting point to interpreting other sites.

Specifically, this research uses several lines of evidence to identify migration of individuals, diet and status, trends based on time periods and/or geography that illuminate the effects of the environmental and socio-political shifts during the transition from the Late to the Terminal Classic period. The bioarchaeological techniques include stable isotope analysis and the statistical interpretation of mortuary data. Within each method there are several lines of evidence explored. The stable isotope analysis includes a comprehensive stable isotope plan using multiple biological materials, several complimentary isotope values to interpret migration and diet, and previous research on stable isotopes from the epicenter of Cahal Pech. This research is also groundbreaking in that it is the first to report sulfur stable isotope results for human remains in Belize. This dissertation has created a preliminary database that consists of mortuary, biological, and archaeological data and includes evidence of status and origin from the stable isotope analysis. The findings in this research create a baseline model that will allow for other sites to be compared to in order to better understand the regional response to the socio-political disintegration of the Late Classic Maya.

This research is built upon previous investigations (Awe, 1992b; Chase and Chase, 2004; Freiwald, 2011; Hoggarth, 2012; Rice et al., 2005), but is also meant to be a model for future research regarding the transition from the Late to Terminal Classic. The use of multiple lines of evidence and methods allows us to understand the complex society of the Classic Maya and their relationship between the environment and socio-political systems. Along with the creation of models, this research has created a database that will continue to grow and become more comprehensive with future research. The database will help archaeologists and bioarchaeologists record burials and mortuary data more thoroughly in order for it to be used to answer complex research questions about similarities and differences within and between sites. The answers discovered and the foundation created by this research will strengthen our understanding of the Late and Terminal Classic Maya, their response to socio-political shifts, and their relationship with their environment.

CHAPTER 2 – BACKGROUND

Maya chronology

The Maya have occupied parts of Mexico, Guatemala, Belize, Honduras, and El Salvador since at least the Early Preclassic period (2000-1000 BC). Belize, located in the Southern Maya Lowlands, was first occupied by the Maya culture by the end of the Early Preclassic period (1200-900 BC) as seen by ceramics, maize agriculture, emerging trade networks, and permanent settlements (Awe, 1992a; Ebert et al., 2016; Garber and Awe, 2008). During the subsequent Middle Preclassic period (900 – 300 BC), these precocious Maya communities rapidly increased in size and community leaders began to construct monumental architecture that served both ritual and residential purposes. E-groups are permanent architectural assemblages that consist of raised platforms topped with pyramids that are likely arranged for astronomical purposes. Coe and Houston (2015b) state that the spread of Maya-speaking peoples coincides with the introduction of pottery, specifically the Cunil phase, which can be found at sites such as Cahal Pech, Blackman Eddy, and Xunantunich. This ceramic phase preceded the Jenny Creek phase culture (600-400 BC) that included Jenny Creek architecture and pottery, and likely consisted of simple villages with larger sites in the surrounding area. Mamon architecture includes unadorned structures and platforms and the pottery is simple monochrome red and orange red (Coe and Houston, 2015b). As for mortuary practices during this period, Houston and Inomata (2009) state that a basic form of ancestor veneration and burials located under house floors probably arose during the Middle Preclassic. In summarizing a discussion of the Middle Preclassic and some of the more ephemeral aspects of Maya life during this time, Coe and Houston state that "it was during this period when the Maya became truly "Maya"' (Coe and Houston, 2015b).

The Late Preclassic period (300 BC-AD 300) is characterized by the Barton Creek pottery style in northern Belize, increased population, large-scale maize agriculture, monumental architecture, elaborate rituals, display vessels (specifically, mammiform bowls and polychrome decoration), and a various incantations of hierarchical social structures (Garber and Awe, 2008; Hammond et al., 1992; Lee and Awe, 1995). This period marks the beginnings of an institutionalized heredity rulership system that bound increasing populations over every expanding geographical areas into a cohesive political entity (Houston and Inomata, 2009). The increase in social and political complexity was validated by the creation of new ritual practices, which in turn lead to more complex religious and mortuary practices. The architecture of this period sees an end to E-groups (Aimers and Rice, 2006) and the beginnings of triadic structures at places such as Uaxactun, Lamanai, and Cerros. The shift from E-group architecture to large centrally located structures mirrors the shift in political and social complexity, from ceremonial and astronomical to public ceremony, political ritual, and ancestor veneration. Although Houston and Inomata (2009) point out that their meaning may differ from the triadic structures in the Classic period. A final contribution from the Late Preclassic is the establishment of institutionalized hereditary inequality or rulership that would forever change the social and political landscape of the Maya (Freidel and Schele, 1988; Houston and Inomata, 2009).

The Early Classic period (AD 300-500) was marked by continued population increase and intensification of food production on the landscape, as well as by the increase in erection of stelae recording ruling families and public events, public architecture (triadic structures), perfection of the Maya Calendar, and a complex social structure (Coe and Houston, 2015a; Culbert, 1991; Houston and Stuart, 1996). A major difference separating the Early Classic from the Late Classic is the cessation of relationships with the central Mexican city of Teotihuacan on

(Coe and Houston, 2015c; Houston and Inomata, 2009). This influence is seen in monuments and facades of Tlaloc and the Feathered Serpent, both of which are rooted in Teotihuacan cosmology. The architecture of the Early Classic includes renovation of previous pyramidal structures to increase size and height, and the introduction of ballcourts at many centers used for public ritual and elite ceremonies (Houston and Inomata, 2009). The Early Classic is also known for its written language and recording of events on stelae, staircases, walls, and pottery. The recording process involved using and perfecting the Maya Long Count calendar. The oldest recorded date comes from Stela 29 at Tikal with a date of AD 292 (Coe and Houston, 2015c).

Along with direct Teotihuacan influence, several other hybrid Teo-Maya cultures rose to power in different regions, such as the Esperanza culture in the southern highlands, and the Tzakol culture in the central lowlands (Coe and Houston, 2015c). These hybrid cultures combined Teotihuacan influences with Maya hieroglyphs and locally made goods and likely included marriage and political alliances (McAnany et al., 1999; Wright, 2005a). Wright (2005) found that people were moving into and out of Tikal during the Early Classic and more generally that migration started early at some larger Maya sites, which probably led to their expansion of power and influence.

The Late Classic period (AD 500-700) is defined, in part, by having reached the maximum population for the resources available, of which water was the most important. Harrison (1999) estimated that Tikal reached 100,000 people during the Late Classic. Small cities and rural areas, particularly those in the Maya Lowlands, reached maximum density during this time putting strain on the food and water resources which in turn lead to distrust and dissention with the political and social systems (Ball and Taschek, 1991; Lucero, 1999; Masson and Freidel, 2002). To add to the Late Classic Maya resource stress was the constant vying for political power that resulted in large-scale alliances and movement of power from one center to another. There was also an increase in warfare and turmoil, no doubt related to the dwindling resources and access to food (Demarest, 1997). The problems that plagued the Late Classic Maya were set in motion years before during the establishment of the socio-political and hierarchical system of governance which all came to a head at the end of the Late Classic period.

This period is also known for its environmental instability. Kennett et.al (2012) found a multi-decade drought that occurred during the end of the Late Classic period. This drought had a significant effect on the sites in the Maya Lowlands, particularly loss of food and water resources which in turn lead to population decrease, warfare, and disintegration of the political system (see also: Demarest et al., 2005a; Gill et al., 2007).

There are a number of large sites that were central to political power during the Early Classic and Late Classic periods including Tikal, Calakmul, Copan, and Palenque. With the collapse and abandonment of Teotihuacan in highland Mexico, there is a florescence of purely Maya culture (Coe and Houston, 2015a; LeCount, 1999). The architecture of the period consisted of large temples and stepped pyramidal structures that surrounded plazas and courtyards for both public and private events. There is also an increase in ballcourt construction and sweat baths during this period (Coe and Houston, 2015a). Late Classic ceramics became more ornate with a variety of polychrome vessels, figurines, and other ornaments made from clay. The explosion of craftsmanship can also be seen in the variety of stone tools, jade ornaments and eccentrics, obsidian eccentrics, musical instruments, and other artifacts (Houston and Inomata, 2009; LeCount, 1999; West, 2002). In summary, the Late Classic period reaches the height of splendor for the Classic Maya while hinting at the demise that would soon follow.

The Terminal Classic (AD 700-900) has been separated from the Late Classic because of its unique characteristics and significant changes to the Classic Maya social and political structures. Studies indicate large migrations of people into and out of the lowland Maya region (Freiwald, 2011; Hodell et al., 2004; Meiggs and Freiwald, 2014) as well as dwindling populations based on housemound construction (Hoggarth, 2012; Hoggarth and Alexander, 2009; Powis and Hohmann, 1995) and burial practices (Hoggarth et al., 2014). Specifically, the architecture associated with this transition period includes low-lying, quickly constructed plazas, with materials robbed from Classic buildings (Awe and Helmke, 2007; Douglas and Brown, 2014; Santasilia, 2012). The reuse of materials may be evidence of changes in the use of sites and varying degrees of migration to and from different regions. Previous dating research (Hoggarth et al., 2014) of sites within the Maya Lowlands shows that not all sites were occupied at the same time or at the same capacity. The Terminal Classic also sees an accumulation of the environmental instability that effected the Classic period (Kennett et al., 2012) and lead to the depopulation of sites as well as disintegration of the socio-political structure of the Classic Maya (Budd et al., 2004; Freiwald, 2011; Price et al., 2000). Literacy, in particular the writing of Maya hieroglyphs, is also another aspect of the Classic Maya that appears to be lost during this transition in the southern lowlands. Pseudo-glyphs are unreadable glyphs that are copies of readable glyphs (Calvin, 2006; Longyear, 1952) and are most commonly found on Terminal Classic pottery indicating a loss of literacy sometime during the transition from Late to Terminal Classic. Since the elite were the educated class and the ones commissioning and making the pottery, it is likely that when the social structure disintegrated this left only lower class individuals to emulate writing.

One of the hallmarks of the Terminal Classic period is depopulation of many sites. It is hypothesized that some the communities left smaller ceremonial sites for larger sites to condense power, while some sites were completely abandoned (Demarest et al., 2005a; Hoggarth et al., 2014; Hughes, 1999; Suck, 2011). The term abandoned may still be under debate (Aimers, 2007), but there is little doubt that people were moving into and out of different areas throughout this period, and regional populations plummeted (Awe and Helmke, 2007; Freiwald, 2011; Hodell et al., 2004; Rice et al., 2005), and the maintenance and the continued construction of public and elite buildings was halted. The population decline, migration, and the unraveling of divine kingship as a hallmark social institution are the main characteristics of the Terminal Classic.

The Postclassic period (AD 900-1550) is characterized by shifts in power toward sites in the Yucatan that were influenced by the resurgence of the Mexican central highlands, particularly the Toltec culture, typified by the famous blood heart cult and the presence of Chacmool (reclining figure) sculptures (Coe and Houston, 2015a; Webster, 2002). The Postclassic saw the rise and fall of several major Maya centers in the north, such as Uxmal, Chichen Itza, and Mayapan. Lamanai in northern Belize, a center first occupied in the Preclassic, survived the Terminal Classic reorganization and flourished during the Postclassic, but it is noted that there is a decline of recorded events and erection of stelae during this period (Demarest et al., 2005a; Kowalski, 2003).

As stated above, each Maya period has unique characteristics that separate it from the others; one of those characteristics is thought to be a specific mortuary pattern. While this research found no specific mortuary practice associated with a particular time period, there are expected mortuary characteristics that combine with regional and site specific variants. Mortuary practices tend to reflect the position of the deceased, the connection between the living and the dead, and can be proxies for changes in social, religious, and/or political systems. Mortuary patterns, therefore provide an essential understanding of the Maya archaeological record.

Below is an abbreviated timeline of some of the major Maya events, including significant recordings, environmental shifts, marriages, and battles. This timeline is a visual tool to illuminate political alliances throughout the region as well as to concisely illustrate the ebb and flow of Maya social and political systems during the Early, Late, and Terminal Classic periods. Also included are common pseudonyms useful in studies of the Maya.

Timeline:
AD 292 – First Maya Long Count Date on a Maya Stela at Tikal (Stela 29)
AD 378 – Death of Chak Tok Ich'aak I and arrival of Suhyaj K'ahk at Tikal, start of Teotihuacan influence
AD 379 – Ascension of Yax Nuun Ahiin I to ruler of Tikal, son of Spearthrower Owl
AD 379-562 Tikal asserts influence over the Paison region and Guatemala Highlands, Teotihuacan influence diminishes
AD 411 – Ascension of Siyaj Chan K'awiil II as ruler of Tikal
AD 426/427 – Arrival of K'inich Yax K'uk Mo', dynastic founder of Copan
AD 546 - Calakmul installs a new king at Naranjo
AD 553 – Caracol installs new king Yajaw Te' K'inich II sponsored or supported by Tikal's ruler Wak Chan K'awiil, probable failed attempt at control without warfare (Caracol Altar 21 and Stela 6)
AD 556 – Tikal enacts "axe war" against Caracol. Axe wars are minor military undertakings.
AD 557 – Beginning of Tikal's hiatus, last recorded event on Stela 17 at Tikal
AD 562 – Caracol defeats Tikal (Caracol Altar 21), Caracol supported by Calakmul and the Kan dynasty, first "star war" ever recorded. Star wars are considered the most involved military undertakings (Chase and Chase, 1998).
AD 572 – Reference of ahau from Calakmul found on Stela 3 at Caracol, confirms complete shift in alliance of Caracol from Tikal to Calakmul
AD 588 – Caracol and Naranjo are in alliance
AD 599 – Palenque defeated by Calakmul
AD 611 – Palenque defeated by Calakmul… again
AD 625 – Dos Pilas is founded by Bahlaj Chan K'awiil, likely royal Tikal prince, splinter the hegemony of Tikal with the rulers considering themselves the "New Tikal"
AD 640-660 – Major drought (Kennett et al., 2012)
AD 659 - Nu Bak Chak I lead Tikal in battle against Yaxchilan, Yaxchilan was under control of Piedras Negras which was allied with Calakmul

- Nu Bak Chak I arrive at Palenque as an ally, companion-at-arms

AD 672 – Tikal defeats Dos Pilas in a "star war", war lead by Nu Bak Chak I

AD 677 – Dos Pilas defeats Tikal with help from Calakmul
AD 679 - Dos Pilas defeats Tikal with help from Calakmul… again. Nu Bak Chak I die's or is taken captive during this battle
AD 682 – Hasaw Chan K'awiil, son of Nu Bak Chak I and Lady Jaguar Throne, succeeds the throne and revitalizes Tikal, starts recording events
  - Lady Six Sky, daughter of Bahlaj Chan K'awiil, is sent to Naranjo to reestablish dynasty/marriage alliance

AD 683 – Death of Hanab Pakal at Palenque
AD 686 – Accession of Fire Jaguar Claw at Calakmul
AD 692 – First monuments erected at Tikal since hiatus, Stela 30 and Altar 14
AD 695 – Tikal defeats Calakmul (Tikal Lintel 3 Temple 1)
AD 711 – End of 14th katun, erection of N Group at Tikal by Hasaw Chan K'awiil
AD 726 – Death of Ruler 2 at Dos Pilas
AD 731 – Construction of Complex O at Tikal
AD 734 – Accession of Yik'in Chan K'awiil, Hasaw's son, to Ruler of Tikal (Tikal Stela 21 & 5)
AD 735 – Dos Pilas defeats Ceibal
  - Dos Pilas finds secondary capital of Aguateca

AD 738 – Waxaklajuun Ubaah K'awiil, ruler of Copan, is killed by Quirigua's ruler K'ahk Tiliw Chan Yopaat
AD 743 – Tikal's Yik'in Chan K'awiil defeats El Peru Waka
AD 744 - Tikal's Yik'in Chan K'awiil defeats Naranjo
  - Decline of Caracol elite activities
  - Decline of Calakmul, no erection of new stelae, no snake glyphs

AD 761 – Death of K'awiil Chan K'inich, last ruler of Dos Pilas
AD 800 – Death of Nuun Ujol K'inich ruler of Tikal, Hasaw Chan K'awiil's grandson
AD 808 – K'inich Tatbu Skull IV, last recorded ruler of Naranjo
AD 820-870 – Major drought (Kennett et al., 2012)
AD 822 – Ukit Tok', last recorded ruler of Copan
AD 859 – Caracol Ruler XIII (13), last recorded ruler
AD 869 – Jasaw Chan K'awiil II, last recorded ruler of Tikal
AD 900 – Chichen Itza rises to power
AD 909 – Aj Took', last recorded ruler of Calakmul
AD 1200 – Mayapan empire emerges
AD 1300 – Chichen Itza empire declines
AD 1519 – Arrival of Hernan Cortes and the Spanish conquest

References for this time line include Andrews et al. (2003), Coe and Houston (2015a), Fitzsimmons (2010), Houston and Inomata (2009), and McKillop (2004). For a complete list of rulers see Coe and Houston (2015: 306-307).

Common pseudonyms for some Maya rulers:

- Nu Bak Chak I = Nuun Ujol Chahk = Shield Skull I = Oracle Bone Chak, 25th ruler of Tikal

- Hasaw Chan K’awiil = Jasaw Chan K’awiil = Ruler A = Heavenly Standard Bearer, 26th ruler of Tikal
- Yich’ak K’ak = Yich’aak K’ahk = Fire Jaguar Claw, ruler of Calakmul ~ AD 695
- Yik’in Chan K’awiil = Ruler B = Darkness of the Night Sky = 27th ruler of Tikal, son of Hasaw
- K’inich Janahb Pakal = Hanab Pakal = Pakal the Great
- K’inich Yax K’uk Mo’ = Yax Kuk Mo
- Yajaw Te’ K’inich II = Double Bird

Classic Maya Socio-political Structure

The Classic Maya social and political systems were one and the same with interwoven social and political identities for all participants. The Classic Maya have been characterized as an oligarchy, with elite rulers living in medium to large ceremonial sites (Ball and Taschek, 1991; Culbert, 1991; Chase and Chase, 1996a). These rulers were theocrats who ruled the government and the religious institution as well. The social aspect of this socio-political structure was built upon a class system with kings (*ajaw*) and elite families topping the pyramid, individuals such as scribes and merchants, and nobles creating the center of the pyramid, commoners creating the foundation of the pyramid, and finally the servants and slaves at the bottom.

Kings and ruling elites derived from kin groups or families that were either founders of a city or revered for other reasons. An elite rulers power was legitimized by their ability to communicate with the gods, their knowledge of cosmology and astronomy, their ability to command large labor forces, their leadership in rituals, and the architecture they used to permanently mark their territory and social standing (Grove and Gillespie, 1992; Rice, 2004; Webster, 1976, 2002). This can also be seen in the names given to the individual upon ascension to the throne that name would liken them to a god without claiming divinity. There were also thought to be sub-hierarchies within each class, for example kings that ruled over several sites were more powerful than a king who ruled only one site and its hinterland (Houston and Stuart, 1996). The majority of kings were male, but on rare occasions females did ascend to leadership. Ladies, or queens, were typically daughters of elite families that found themselves in power during dynastic turmoil or rejuvenation of a royal lineage (Houston and Inomata, 2009). Rulers not only oversaw the political and practical facets of Maya society, but they also governed the moral aspect of Maya life. Elites would dole out judgement on aesthetics (i.e. pottery styles, artistic depictions, costume design), as well as an individual's importance to the society and in the process put themselves and the ruling class more generally above everyone else (Weber, 1978).

Marriage played a significant role in maintaining or increasing the power of a lineage. It was common for elites to marry off their daughters to gain power, land, and strategic alliances (Houston and Stuart, 1996). Education, in particular literacy, was also a major force separating the elite and upper middle class from the lower class and slaves. Though reading rudimentary texts was likely possible for the public, writing and having access to written texts was saved for the elite class and was used as a form of dominance over the public at large (McAnany, 2014). Finally, the importance of resource control in maintaining power cannot be underestimated in Maya society. Resources, in particular water, were significant to food production, community health, production of goods, and general morale of the masses (Lucero, 2002, 2009).

Nobles were members of the elite class but with limited power. Houston and Inomata (2009) note that the only reason nobles are mentioned in texts is probably due to their access to record making tools. They also state that nobles would have grandiose houses and have elaborate grave goods in their tombs. Nobles would also have control over land and water resources therefore wielding power by granting access to them. Nobles would have participated in public ritual, business, and special access to supernatural beings (Houston and Inomata, 2009). They included elite extended families, scribes, successful warriors, and religious figures.

Farmers were the cornerstones of Maya society for the sole reason that they produced the staple crop, maize, that fed the large communities. It is believed that farmers, which included agricultural workers, their families, along with fishermen and hunter/gathers, consisted of 90% of the Maya population. Because they constituted such a significant amount of the population, it is probable that they participated in a variety of activities, held differing social statuses, and likely held limited political influence (Houston and Inomata, 2009). Along with corn, farmers, or food producers, cultivated cacao, cotton, legumes, and fruit trees. Small groups of farmers lived in continuous settlements that stretched out in every direction from the epicenter of major city-states and would consist of at least one family, but likely multiple families, that would tend the land around their patio group (Coe and Houston, 2015a; Houston and Inomata, 2009).

Although it appears that status of individuals would be defined in complex ways within the Maya world, for the purposes of this research, Maya social structure is considered a two-tier system of elites and non-elites. Part of this is due to the limitations of the analysis imposed by the available sample size and by the subclasses that are not identifiable in the archaeological record. If at all possible, sub-hierarchies will be taken into account, particularly for the elite finding as it pertains to the mortuary data analyses completed in this research.

Maya Mortuary Practices

Mortuary practices are those protocols dictated by a culture to deal with the disposal of the deceased within the community (Buikstra and Beck, 2006; Rakita et al., 2005). Mortuary practices consist of where, when, and how a community chooses to dispose of their dead. This also includes items or characteristics that reflect the deceased individual as well as their living relatives, such as grave goods, location of burials, and body orientation. Mortuary practices are followed in order to convey messages about the deceased individual, as well as their surviving relatives, but in the process, they give insight into the religious, social and political structure of the community, and possibly the population at large.

Comparing differences between mortuary practice characteristics or traits within and between communities, time periods, or geographic regions can tell us about the differing political systems, social stresses, population movement, kinship relationships, and even ecological changes that may have affected change to a religious or power structure. Mortuary practices often reflect the complexity of the sociopolitical structure and distribution of the population, allowing for bioarchaeologists and mortuary archaeologists to infer social structure, religious beliefs, population demographics, and political or ecological shifts (Bartel, 1982; Binford, 1971, 1985; Gillespie, 2001a; Rakita et al., 2005; Tainter, 1978). These general principles are employed in this research to examine the mortuary practices of the Maya, paying particular attention to the Maya of the Belize River Valley.

Classic Maya religion and cosmology, social structure, political structure, and architecture were all interrelated within the broader Maya culture. Maya mortuary practices should be viewed within the broader Maya cultural sphere and understood that they reflect multiple aspects of Maya life. This is because specific religious as well as social, political, and environmental influences were felt either directly or indirectly in ways that are unknowable to archaeologists. However, general religious beliefs are often evident in Maya burials. To summarize briefly, the Maya religion was centered on the world tree with nine gods in the underworld and thirteen in the heavens (Brady and Prufer, 2005; León-Portilla, 1990; Rice, 2004). The day began with the rising of the sun in the east and continued through each of the thirteen benign day gods, then the sun would set in the west and go into night where it would pass through the underworld and the nine malevolent night gods. The Maya also believed that there were several creations before the present one of their time. Their creation myth focused on the Hero Twins and their journey to bring their father back from the dead (Tedlock, 1996). Their father, the Maize God, was eventually resurrected by the Twins, after which he ascends to the three heart place of creation and creates the first four human ancestors from corn. Maize was thus extremely important in rituals, as well as a principal food source, and is literally the defining material for the creation of humans. The Maya world was also separated into four quadrants, usually corresponding to the four cardinal directions and reflected in the layout of their ceremonial centers and city-states (Ashmore, 1989; Brady, 1997; Coggins, 1980; Gossen and Leventhal, 1993; Rice, 2004).

The Maya upper class consisted of elite kin groups or families that would legitimize their claim to an area through architecture that they used to permanently mark their territory (Grove and Gillespie, 1992; Rice, 2004; Webster, 1976, 2002). This architecture includes graves within structures used as ancestor shrines and places for ancestor veneration. Ancestor veneration for the elite Maya included invoking ancestors by name and events such as feasting or public displays (McAnany, 2014). Ancestor veneration for the lower-class Maya was more private and consisted of communing with ancestors in a general and domestic setting. Blanton et al. (1996) note that elites would publicly promote or venerate former rulers in order to legitimize their claim to kingship (*ahaw*) as well as land rights. This likely includes public burial rituals and subsequent ceremonies venerating ancestors that were buried within public structures.

Trying to understand the Maya social, political, and religious structures has been a focus of previous research. The influence of each aspect of Maya life on each other and how that is reflected in mortuary patterns is one goal of this research.

Previous Studies

Mortuary archaeology and bioarchaeology in the Southern Maya Lowlands are fraught with obstacles; the tropical climate, which causes poor preservation of biological material, especially human remains; the complex socio-political structure of the Maya that lead to complex mortuary programs; and the landscape with its thick vegetation and varying geography making it difficult to locate sites, with burials or otherwise (Wrobel, 2014). That being said, burials have been excavated for well over a century and numerous efforts to interpret mortuary practices have been published. Below is a brief discussion of some of the major mortuary archaeological reports that have made significant impacts on Maya archaeology and mortuary analysis in Central America.

In 1925, Oliver Ricketson wrote *Burials in the Maya Area*, which gives a brief description of burials found from the Yucatan to southern Belize. The author notes that the first accounts of burials and mortuary practices are from Bishop Landa (1937 [1566]), a Spanish Franciscan priest that headed the Catholic Church's efforts in the Yucatan in the 1500s. The Bishop wrote that the Maya feared death and that the ritual of the mortuary practice was meant to ask their gods to grant them health and a good life. Bishop Landa also talks about a few specifics of the mortuary practice such as: graves were dug beneath the floor of the house, the dead had corn and stones placed in their mouths, grave objects reflected their owners occupation and rank, and that the elite were cremated and placed in urns (Ricketson, 1925). Ricketson then moved on to systematically report all previous burials by site. Several of the previous burial reports (Blackiston, 1910; Gann, 1918; Holmes, 1895; Mercer, 1896; Price, 1899; Saville, 1899;

Thompson, 1897, 1904) have simple descriptions, but Ricketson notes that most excavations were exploratory and not meant for locating burials. Therefore, the previous field work did not give the proper time or effort toward recording burials and mortuary practices (Ricketson, 1925).

Saville (1899), who worked with Zapotecan burial mounds in the Oaxaca region, while not directly working with the Maya, did inform subsequent Maya researchers who appropriated his characteristics of mortuary practices and applied them to Maya sites. Ricketson (1925) was one of those researchers who adopted Saville's eight general characteristics for Maya mortuary practices which are as follows: 1. Graves have stone doors, face east, and are sealed with large stones, 2. Funeral urns are found at the front of tombs, on the roof, or attached to the façade, 3. Vaults are ossuaries because there is an absence of grave furniture, 4. Bones are painted red, tombs have food and incense offerings, but are absent of decorated vessels, 5. There are filed and inlayed teeth, which tend to be inlayed with hematite, 6. Sometimes an isolated cranium is buried with an individual, 7. Tombs have elaborate murals and hieroglyphs, and 8. There is little to no use of mosaics for decoration (Ricketson, 1925). One major point to take from Ricketson's report, as well as the previous work he uses, is that while there may be a typical burial custom or a mortuary practice, these are not absolute and variation can be seen within and between sites. One variation that Ricketson does not consider is temporal variation and how it relates to changes in the mortuary patterns.

More recently, Ruz (1965, 1991) published an extensive volume on burial practices from all ancient societies in Mesoamerica, including the Maya. This work, while thorough, does not provide enough detail to allow researchers to ask specific questions and test complex models. As with Ruz's work and other publications (Rathje, 1970), a shortcoming that affects mortuary analysis was the limited amount of data and burials to work with (Ruz, 1965). WBM Welsh's seminal work, *An Analysis of Classic Lowland Maya Burials* (Welsh, 1988) was the first comprehensive report on Classic Lowland Maya burial data and mortuary practices that includes a large sample of burials from sixteen sites. Welsh's study focused largely on creating a typology for different aspects of mortuary practices in order to standardize recording. Welsh created a thorough list of characteristics for mortuary practices and provides excavation information such as date, excavator, and provenance imparting the full context of his sample. Due to the extensiveness of Welsh's burial data (building on Ruz's previous work) he was able to identify patterns in mortuary practices that he calls "pan lowland Maya burial customs" (Welsh, 1988). Below are brief descriptions of the twenty pan-Maya customs as described by Welsh (Welsh, 1988):

1. Little evidence for cremation in Preclassic, and Classic periods. Cremation is popularized in the Postclassic.
2. Inhumation was most common in the Classic Period; the Classic Maya did not use cemeteries.
3. Interments tend to be placed on the eastern sides of plazas in buildings (household shrines) constructed for the purpose of housing burials, and these burials tend to be elite or wealthier members of society.
4. Elites were buried in temples with a lot of grave goods.
5. Most graves with significant grave furnishings had special structures built over them (i.e. altars, benches, stair blocks, temples, etc.). These structures acted as memorials and probably had rituals that took place on or in them.
6. Complex graves tended to have more grave goods and are located in temples, household shrines, or platforms.

7. Primary, individual interment is most common.
8. Sacrifice type #1: multiple, primary burials consisting of either a mother and child, a child and an adult, or children and adults.
9. Sacrifice type #2: secondary interment, usually accompanies a primary interment and is placed at one extreme of the grave or outside the grave, they also tend to show signs of mutilation.
10. Sacrifice type #3: dedicatory cache, tend to be infants or adult skulls placed in or between bowls and deposited below or in front of a temple, altar, or stelae.
11. Sacrifice type #4: purposeful mutilation, this consists of skeletons without cranium or femurs, craniums without bodies, mandibles, deliberately disarticulated and scattered skeletal elements. They are most likely found in plazas or in ceremonial platforms.
12. Removal of skull or facial bones for the purposes of ancestor worship.
13. Burials with a bowl under or on top of the cranium are common.
14. Urn burials.
15. Burials with a shell placed over the cranium.
16. Skeletal position is correlated with grave type and dimension at seven sites; extended in the larger tombs and crypts while flexed in smaller cists.
17. Heads tend to be oriented in one direction (the exception is at Altun Ha).
18. Common grave furniture for rulers and elites included stingray spines, jade mosaic masks, remains of codices, and jade or shell figurines.
19. Child burials commonly had clay figurine whistles, jade beads placed in mouths, and bodies covered in ochre.

20. Male and female burials had similar grave furnishings; adult and child burials had a marginal difference in grave furnishings.

Two mortuary practices that Welsh does not consider in his report are cave and rockshelter burials because of the lack of samples and excavation data available at that time. What Welsh's report did was collate all the important data and characteristics of burials in the lowland Maya area and then used those data to make justified statements on methods of disposal, common mortuary practices, ancestor worship, regional differences, and social implications of burial data (Welsh, 1988). Despite the systematic approach to his research, there are shortcomings of Welsh's (1988) study. Specifically, the interpretation of the regional differences are flawed because we now know that some of these differences are not regional, but site specific (Cucina and Tiesler, 2014; Gillespie, 2001a; Glassman and Villarejo, 2005; McAnany et al., 1999).

Since Welsh's publication, the amount of mortuary archaeology in Mesoamerica, and specifically that of the Maya, has grown significantly. This interest in mortuary archaeology has produced some amazing collections of artifacts, grave goods, skeletal remains, and architecture associated with mortuary practices. Mortuary archaeology and analysis has also shifted focus from large-scale exploratory excavations and recordings to studies of site and intersite mortuary patterns and studies focusing on one particular type of mortuary practice (e.g. sacrifice) (Fitzsimmons, 1998; Glassman and Villarejo, 2005; Olsen et al., 2014; Serafin et al., 2014; Tiesler et al., 2010).

The majority of mortuary archaeology and burial collections are of elite individuals because of excavation biases that tend to focus on temples, caves, and plazas and because of poor preservation of remains in housemounds and smaller settlement sites. According to previous research (Ashmore, 1989; Ball and Taschek, 1991; Chase and Chase, 1996a; Demarest et al., 2005b; Grove and Gillespie, 1992; McAnany et al., 1999; Rathje, 1970; Webster, 2002) interment within temples and palaces is typical of elite burials, which make collections biased toward only one or two classes of people within the Maya social structure. We know that the Maya social structure consisted of many classes and subgroups that are not represented in mortuary archaeology or burial collections because of excavation methodology biases of previous and current research.

This research will illuminate differences in social status based on diet and mortuary characteristics in the hope to identify subtle variations between social classes that can then be used in future research. It is also the goal of this dissertation to identify changes in mortuary practices at Cahal Pech that trend based on time and/or space. In order to accomplish these goals a fluent understanding of Maya religion, politics, social structure, mortuary practices, and previous studies must be acquired.

Mortuary Characteristics

The mortuary database created for this project began with previous research presented above to create a comprehensive list of mortuary characteristics that includes the most commonly found traits in mortuary practices within the Maya World. These common characteristics, described below, aim to be inclusive traits that can describe a typical Maya burial practice.

Burial Type

Burial type refers to the nature of the burial within the grave, movement before and after placement, and the purpose of the placement in a specific place. Burial type encompasses general categories of a mortuary practice.

Primary Burials. Primary burials can be of an individual or multiple people that are articulated with no evidence of movement, tampering, or disturbance of the body by human intervention after disposal (Fitzsimmons, 1998; Ruz, 1965; Welsh, 1988). Several sub-types of primary burials exist and are described below. Primary burials can span multiple causes of death such as sacrifice, natural causes, and warfare. They can also be intrusive burials, which are those burials that intrude into architecture or previous graves with no evidence of architecture being built specifically for the grave (Welsh, 1988). For instance, digging into a stair block to place a burial is considered intrusive, or digging through plaza floors.

The most common location for a primary burial is within a grave, but they can also be found in rock shelters and caves. These are very distinct types of burials that involve placing an individual in the lighted area (rock shelter) or dark area (cave) of a natural geological formation. Tiesler (2007) describes primary burials in a rock shelter as purposeful burials dug into the ground, where burials within a cave tend to be placed on the top of natural platforms or within alcoves. Cave burials tend to be sacrificial in nature (based on body placement and demographic representation), or secondary based on fragmentary remains and partial skeletons (Cucina and Tiesler, 2007; Domenici, 2014; Gibbs, 1997, 1998; Owen, 2005; Tiesler, 2007). Sacrificial burials, while commonly found in cave, are also found in plazas and within structures (Awe, 2013; Garber et al., 2007).

Pot-skull burials, mentioned by Welsh (1988), are often considered primary burials because they consist of an individual with a pot placed either on top of or below the head. This interment is considered primary if the post cranial skeletal elements are present. This is sometimes referred to as a “head in bowl” burial by archaeologists, but that reference can be confused with a cranium that is placed in a bowl by itself in a separate burial or cache and is considered a secondary burial.

Another type of primary burial is multiple interments, which consist of two or more individuals within the same grave. Welsh and others note that multiple primary burials tend to come in one of two types: 1. Parent – child which can have a single parent and child or multiple parents and/or children, and 2. Sacrificial with a primary and secondary interment (Cucina and Tiesler, 2007; Welsh, 1988).

Specifically, for the Maya, primary burials of elite individuals tend to be found in eastern temple or shrine structures, within elite living quarters, or under plazas (private and public). These spaces were considered significant both religiously and politically (Audet, 2001; Awe, 2013; Awe and Schwanke, 2006; Gillespie, 2001b; Grove and Gillespie, 1992) and therefore reserved for elite class individuals.

Secondary Burials. Secondary burials are those in which the individual has been intentionally moved or manipulated after death (Welsh, 1988). This results in a disarticulated and/or partial skeleton. For instance, crania found in bowls, between legs, or other skeletal elements such as femurs or mandibles in bowls or placed with a complete skeleton, are considered secondary because they were taken from the individual's primary interment area and placed as a dedicatory offering or cache.

Caches and dedicatory offerings that include human remains and that may be placed with a primary burial for the purpose of accompanying the elite individual into the afterlife, are one kind of secondary burial. Cache and dedicatory offerings do not have to contain human remains, but are intentional placements of objects (Becker, 1992; Coe, 1959; Welsh, 1988). Caches do not have to accompany primary interments, in fact most caches are found outside of burials. The problem with the recording of caches and offerings is that, depending on the archaeologist, some caches containing human remains were not recorded as burials, while some were. This discrepancy must be noted when caches and dedicatory offerings with human remains are encountered.

Another sub-type of secondary burials is an urn burial, which is one where the body or at least portions of it are placed in a vessel after their primary deposition (Welsh, 1988). Urn burials are also associated with ancestor veneration or worship as well as possibly sacrifice (Cucina and Tiesler, 2014; McAnany, 2014). Urn burials can also be confused with caches, the difference lying in the amount or type of skeletal elements present. Caches also do not have to contain any human skeletal elements, while all urn burials contain human remains.

Chultun Burials. Chultuns hold a special place in the burial typology because of their indeterminate range of uses. Chultuns are cavities in the limestone formations found beneath the ground surface that were originally natural but altered by human effort (Thompson, 1897). Even though excavation of chultuns has taken place for over a hundred years, their use is still debated today. Some scholars feel they were water cisterns and catch basins, while other believe they were for food storage (Peters, 1983; Puleston, 1971; Tozzer, 1912). What cannot be debated is that human remains have been found within these features. Their use as a place to deposit human remains is likely not its original purpose (Gray, 2001; Griffith et al., 2000; Iannone et al., 1994; Lee et al., 2000; Powis, 1992). The remains within these structures tend to be poorly preserved and scattered, leading to speculation that they could be disturbed primary burials, secondary burials, or dedicatory offerings. Due to the lack of knowledge and disagreement among scholars as to their use and function, chultuns remain a mystery of Maya mortuary practice.

Figure 2.1. Late Classic Maya ceramic vessel with Chaak the rain God sacrificing a jaguar baby. (http://www.mexicolore.co.uk/aztecs/home/lightning-in-mesoamerica/kids).

Sacrifice. Sacrifice is when an individual is killed to fulfill some purpose for the living community. It is evident in Maya artwork and iconography that sacrifice was a common ritual for the Maya (Freidel and Schele, 1988; Schele, 1984; Schele et al., 1986). A good example of sacrifice in Mayan art work is from a Late Classic ceramic vessel that has a depiction of Chaak (Rain God) holding an ax about to sacrifice a jaguar baby (Figure 2.1). The jump from art to actual sacrifice is not large considering that there are both ethnohistoric accounts and the discovery of human remains that are consistent with sacrifice. Several reasons for the practice of human sacrifice are: to appease the gods, to sanctify a space, to illustrate power over newly conquered peoples or enemies, and/or to accompany an important individual into the afterlife (Cen et al., 2007; Cheetham et al., 1994; Domenici, 2014; Owen, 2005; Tiesler, 2007). Ricketson (1925) first suggested that cave burials tend to suggest sacrifice because the individuals buried or deposited in the caves were considered special in some way. Working with the Yucatan data, Ricketson points out that the evidence for the use of caves in the Yucatan does not support their use as a customary burial place, as had been suggested by Mercer’s (1896) study of caves used during the “New Empire“ (e.g. Postclassic). James Brady further supports Ricketson’s theory of cave use by noting that the majority of burials in Naj Tunich cave represent what he believes to be either elite or sacrificial victims (Brady, 1989). These cave burials are considered special burials or alternative mortuary practices saved for a select few. It is noted that if cave burials were a typical mortuary context then caves would yield significant numbers of human remains, but instead archaeologist rarely find more than a limited number of individuals buried in any given cave (Brady and Prufer, 2005; Gibbs, 1997; Mercer, 1896; Ricketson, 1925; Welsh, 1988). This seems to be the consensus of Maya archaeologists as it is of sound logic. With a few exceptions (Brady, 1989; Pendergast, 1971) the problem with identification of Mayan sacrifice is that most modes of sacrifice do not leave evidence on skeletal remains. The lack of trauma on the physical remains means that the only evidence of sacrifice is the burial location, body placement, and the deduction that cave burials represent an alternative mortuary practice.

Grave Type

A grave is any excavation into the ground used for the purpose of human remains disposal. Welsh's (1988) grave typology is still used today (Awe, 2013; Awe and Schwanke, 2006; Chase and Chase, 1996b; Garber et al., 2007; Piehl, 1997, 2008) and includes characteristics such as size, dimension, and the materials used in grave construction. Over the years, grave types have been described in many ways and sometimes contradictory definitions of the same grave type have occurred (Smith, 1937, 1950, 1973). Welsh describes grave types by site and below is a consolidated list of these grave types along with additions made by authors since 1988 (Awe et al., 1998; Tiesler, 2007):

- Simple – within the ground with only earth or rubble covering, unlined hole in the ground, human remains found in construction fill.
  - Pit: a presumed hole with no discernable outline remaining.
  - Ceiling Slab: when the interment rests on the slab or capstones of a pre-existing grave.

    - Blocked-up Room: similar to a simple grave because it uses an existing room, no new architecture is built.
    - Bench or Existing architecture: interments placed between benches, walls, or existing stone lined graves.
- Slab – remains or body placed on a slab.
- Cist – hollowed out space with a defined boundary, can have mortar, stone, or plaster walls, consists of human remains and other objects, can be used as a location for caches or for storage, generally smaller than an extended body requiring the body to be flexed or disarticulated (also written as cyst or ciste). How a cist is covered and what is found inside is added to the label:
    - Haphazard Cist: intentionally, but randomly piled stones placed directly on the remains (same as a Cap).
    - Head Cist: material lining either on, under, or around the cranium only (same as a Head Crypt).
    - Capped Cyst: unlined or partially walled cyst with capstones resting on one or both walls.
    - Uncapped Cist: lined cist with no capstones.
- Cap – unlined pit with capstones laying directly on the body.
    - Cap-Slab: remains sandwiched between two slabs.
- Crypt – coffin shaped grave built with cut stones with capstones, can have a plastered floor, may or may not be filled with earth, dry wall masonry, capstones resting on the sidewall stones (also written as covered cist, tombe, pit crypt, grave).

    - Unspecified Crypt: defined as a crypt but construction is uncertain.
    - Simple Crypt: crypt possibly with walls and/or floor covered in plaster, height of 10-75cm.
    - Elaborate Crypt: crypt with cut and dressed capstones, may have niches in walls, benches, stone floors, and sometimes covered in plaster, height 40-135cm.
    - Head Crypt: when the built space surrounds the cranium only.
  - Chamber – rooms built especially for burials and sealed after the interment, often with high ceilings.
    - Chamber A: large rooms specifically for mortuary purposes.
    - Chamber B: large rooms built for purposes other than burial.
  - Tomb – chambers built of either slabs, cut stone, or boulders sometimes containing niches in the walls; with a flat, corbeled, or vaulted roof, larger than required for a single interment; almost always an elite interment that includes grave goods and offerings (also written as tombeau).
    - Unspecified Tomb: described as a tomb but construction is uncertain.
    - Rock-cut Tomb: large chamber cut out of bedrock with a shaft and steps leading to an entrance, walls and ceiling covered in plaster with possible decoration.
    - Stone Lined Tomb: large chamber lined with stones, with a vaulted ceiling or capped with stone slabs, possible shaft and/or steps.

Authors of previous studies gave names to grave types based on individual sites, making standardization of grave typology difficult. The above list is by no means comprehensive because there are no doubt unique, sub-regional grave types throughout the Maya area, but it is a compilation of the most frequently encountered types. In this research grave type is used for interpretation as a line of evidence to identify an individual's status. For example it is known that tombs, crypts, and chambers are reserved for the elites, including rulers, priests, and elite family members (Ashmore, 1989; Awe, 2013; Chase and Chase, 1996b; Grove and Gillespie, 1992; LeCount, 2001; Ruz, 1965; Rice, 2004). On that same note, cave burials tend to be considered sacrificial in nature showing the status of the individual as either an elite worthy of sacrifice or a captive or slave (Awe et al., 1998; Ferguson and Gibbs, 1999; Gibbs, 1997, 1998; Glassman and Villarejo, 2005; Halperin, 2000; Owen, 2005; Pendergast, 1971).

Grave type helps identify the status of the individuals, as well as tells us about the resources available to the community. The labor required for construction of tombs and chambers is more extensive than the labor required for a simple grave. Also, the energy required to sacrifice an individual or travel distances to place a body within a cave or rockshelter might tell us about the importance of that particular place in the community. As mentioned before, the location of a burial speaks to the status of the individual as well as to the importance (or lack thereof) of a particular space. For example, an elaborate public ritual and new architecture for an individual burial would cost a great deal of energy from the community.

Grave Goods. Mortuary practices can provide a wealth of information regarding who the individual was during life, what role they may have played within the community (status), and where they came from (origin). Both status and origin can be discovered using different aspects of the mortuary practice, for instance status can be evidenced by the kind and quality of grave goods. Specifically, the type of grave goods may show the individuals rank within the society and/or possibly their occupation.

The most common grave good in the Maya region is pottery, either whole vessels or pieces (Awe, 2013; Golden, 2000; Helmke, 2000; Ishihara et al., 2000; Rice and Forsyth, 2004; Zweig, 2010). Welsh (Welsh, 1988) compiled a list of typical Maya grave goods from the burial collection he used and came up with a list of sixteen goods listed below:

- Ceramic serving vessels (dishes, bowls, plates, etc.)
- Polychrome or stuccoed pottery, includes stuccoed clay or wood
- Small jade objects (beads, discs, earflares, etc.)
- Large jade objects (figurines, pendants)
- Small shell objects (beads, discs, earflares, etc.)
- Large shell objects (figurines, pendants)
- Flint and obsidian (utilitarian and eccentric)
- Groundstone, manos and/or metates
- Bone, teeth, animal shells (i.e. turtle carapace)
- Clay or ceramic objects, not pottery (i.e. whistles or figurines)
- Pearls, pyrite, mica, or coral
- Textiles, animal pelts, wooden objects
- Stingray spines
- Codices
- Mosaic masks, plaques, or vessels
- Copal

Just like grave types, this list of grave goods is by no means exhaustive. Typical grave goods can vary by site, individual, different locations within the site, age and/or sex, and definitely status. That said, there are a good number of graves that do not include grave goods, but are located in typically high status structures (i.e. eastern shrines). The lack of grave goods can tell us something about the individual such as they may fall into one of the sub-categories of the elite. There is also the possibility that an individual found without grave goods may have had goods that disintegrated such as textiles or other organic materials. Grave goods also give evidence to trends of that specific time period and allow for archaeologists to map these changes over time.

Body placement and orientation. Body placement is the way that the body is positioned within the grave and usually categorized as extended/flexed, prone/supine, scattered, or bundled. Placement can also refer to the locatio within the grave in relation to other individuals or other features. For example, was the body placed up against a wall, next to a water feature in a cave, or scattered at the entrance of a tomb? Differences in body placement can be used as arguments for alternative mortuary practices for non-local individuals and/or sacrificial victims (Wrobel et al., 2014).

Orientation refers to the direction of the body in relationship to an external reference, such as the four cardinal directions, direction toward a body of water, or direction in respect to ceremonial architecture. Orientation specifically looks at the direction the head is toward and the way the cranium is facing. As outlined above, Maya cosmology and religion centered on a world tree with the sun rising in the east and setting in the west, so the expected pattern is an individual facing east toward the rising sun.

For the elite Maya, typical body placement and orientation is extended, prone, head to the south, and likely facing east (Awe, 2013; Freiwald, 2011; Welsh, 1988). The direction of the face tends to be difficult to ascertain because of the poor preservation. Exceptions to the typical Maya burial pattern are burials within caves and rockshelters that tend to be placed in flexed or seated positions due to limited space (Glassman and Villarejo, 2005; Owen, 2005). There are also scattered or disarticulated remains seen in caves as well as outside tombs and in chultuns. They can be interpreted as secondary burials and ritualistic in nature (Wrobel et al., 2014).

Differences in mortuary practices can vary in time and space, making mortuary archaeology in the Maya world similar to a fluid web that changes with every new discovery and analysis. Some of the central questions that mortuary analysis tries to answer are what aspects of the mortuary practice are changing and why. Comprehensive reports such as Welsh and others (Awe, 2013; Cucina and Tiesler, 2014; Fitzsimmons, 1998; Freiwald, 2011; Freiwald et al., 2014; Glassman and Villarejo, 2005; Kokkalis, 2005; McAnany et al., 1999; Piehl, 2008) have aided in answering these questions. The characteristics of each mortuary practices, coupled with bioarchaeology are multiple lines of evidence used to answer questions of individual and group identity, justification for changes in sociopolitical structures on a city, state, and regional level, overall health and wealth of a community, marital patterns and kinship relationships, warfare, and religious structure.

Issues. There are many shortcomings and problems with implementing mortuary archaeology all over the world, but the Maya world does have a specific set of problems. Poor preservation is the biggest obstacle effecting mortuary analysis in the Maya region, and leads to small collections with fragile, incomplete sets of human remains. In particular, the erosion of cortical bones and the deterioration of many skeletal elements makes it difficult to identify trauma and pathology in the archaeological record. It also can cause lack of integrity for chemical and molecular analysis of the remains, which limits the research questions that can be ascertained from the data. The poor preservation is due to the acidic soil, humid climate, and limestone that eats away biological material. Preservation is also effected by collapsed (purposeful or otherwise) graves, looting which causes collapse and degradation, as well as rodent, bat, and scavenger activity.

Excavation techniques also limit the data available. As mentioned above, early research and excavation was exploratory and did not focus on burials. Excavation goals focus heavily on large city-states, large ceremonial centers, and temples complexes that tend to yield only burials of elite individuals, therefore a biased sample. The excavation methods also varied and cause loss of information, such as salvage/recovery excavations due to buildings and road construction, use of explosives or large machinery, and looting. Earlier excavations also did not include osteologists or bioarchaeologists on site. Osteologists and bioarchaeologists bring the expertise of *in situ* analysis of critically important marginally preserved individuals, recording of remains, excavation techniques unique to burials, and interpretation of the mortuary context that most archaeologists lack. This loss of information is detrimental to the mortuary record.

According to previous research, the typical mortuary practice for elites in the lowland Maya region is in a tomb, cyst, or crypt that is oriented north-south (axially) with the individual extended, prone with their head to the south and more than likely facing east (Awe, 2013; Freiwald, 2011; Welsh, 1988). The most common grave goods include a jade bead in the mouth to represent corn and ceramic objects, either whole vessels or sherds. This typical description comes with the caveat that there are always exceptions to the rule and alternative practices favored in some times and locations, as seen by Gann's (1918) description of burials in Belize that are just as commonly found sitting as they are extended. Site type is also a major factor effecting mortuary practices, proving that regional variation may be just as important to differences in mortuary practice as time period. Knowing what burial types and mortuary practices are expected for individual sites helps in identifying outliers or unique burials within the site, as well as allows comparison between sites. It can also help map changes over time or space to the "typical" mortuary practice and see if those changes correspond to changes in sociopolitical structures, religious structures or fads, ecological shifts, and/or catastrophic shifts in health.

Maya mortuary practices are of particular interest because of the wide variety of patterns and behaviors that may reflect complex social and political structures. Studying Maya mortuary practices is an exercise in constant flux. As more information and research becomes available, what we know of the mortuary behaviors continues to become more defined, and yet there is always the possibility of finding new practices and patterns. It is the goal of this research to distinguish mortuary patterns at the site of Cahal Pech and identify trends in time and/or space.

Previous Studies in the Belize Valley and Cahal Pech

The Upper Belize River Valley is in the western area of modern day Belize (Figure 2.2). The Belize River Valley has been extensively researched, excavated, and documented since the late 1800's, known then as British Honduras. Thomas Gann first explored British Honduras conducting excavations on mound sites and reporting on his reconnaissance of new or rediscovered sites (Gann, 1894, 1900,

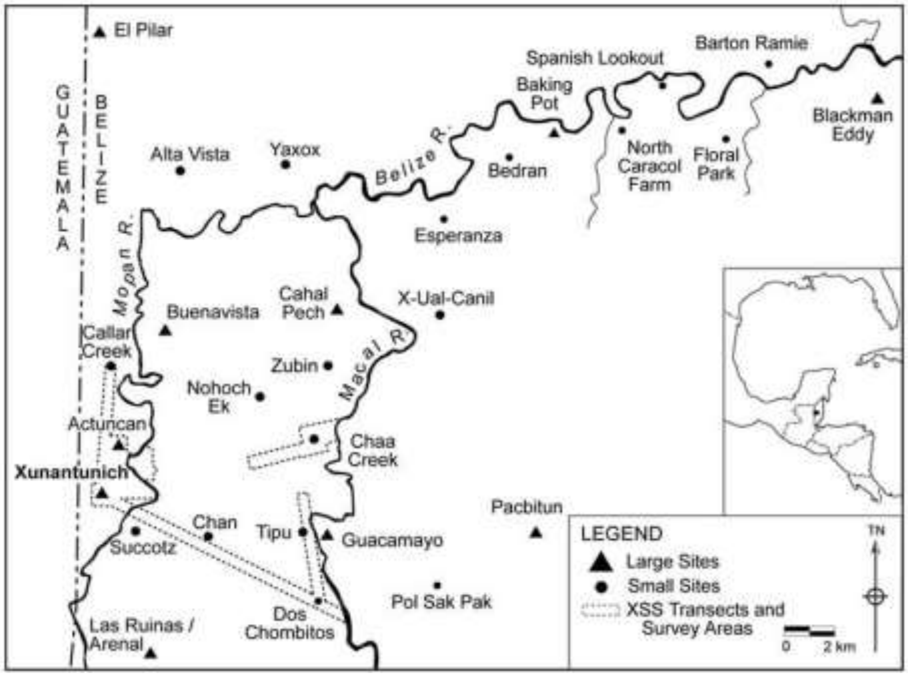


Figure 2.2. Map of Belize Valley sites.

1918). Since Gann's investigations there have been many studies done in the Belize River Valley including those focused on geology (Ower, 1928), ecology (White et al., 2001), climate studies (Haug et al., 2003; Kennett et al., 2012; White, 2001), and especially anthropological archaeology (Gillespie, 2001b; Piehl, 2005). Seminal works include Gordon Willey's (1965) research at Barton Ramie that identified and defined prehistoric Maya settlement patterns, and Thompson's (1971) research on population density, mortuary practice, and migration during the Late Classic.

Archaeological investigations of the area became more prevalent in the 1960's with a renewed focus of preservation and conservation of sites for tourism. The sites within the Belize River Valley, in particular, benefitted from this push to conserve and projects sprang up all over the valley including, but not limited to: Belize Valley Archaeological Reconnaissance Project (BVAR), Caracol Archaeological Project (CAP), Belize River Area Settlement Survey (BRASS), Xunantunich Archaeological Project (XAP), Western Belize Regional Cave Project (WBRCA), and the Belize Valley Preclassic Maya Project (BVPMP). Most projects started out with a focus on conservation of buildings while answering site specific questions about communities (Hoggarth, 2009), households (Powis and Hohmann, 1995), power structures (Freidel and Schele, 1988; McAnany, 2014), and social structures (Iannone, 1994; White et al., 1993). Eventually the research focus changed to more regional questions regarding population movement and migration (Aubry, 2009; Freiwald, 2011), abandonment of sites, collapse of the Classic Maya socio-political structure (Aimers, 2007; Demarest et al., 2005a), and the Maya's interaction with their environment (Rosenmeier et al., 2002; Turner and Sabloff, 2012).

The documentation of the earliest investigations of Cahal Pech are limited, but the first mention of the site is in the 1950's by Linton Satterthwaite. Gordon Willey et al. (1965)

published a brief description of the site as part of their Belize Valley research. An early excavation completed by Peter Schmidt in 1969, then Commissioner of Archaeology, focused on salvaging a burial in structure B1, but no report exists. Ball and Taschek (Ball and Taschek, 1991) excavated the site briefly in 1986-1987 as part of the much bigger Mopan-Macal Triangle project. The Mopan-Macal project's goal was to delineate the spacial boundaries of several closely related sites as well as test models of political organization between the sites (Ball and Taschek, 1991). This project also received USAID funding to excavate and conserve Cahal Pech in order to develop it for tourism (Ball, 1993). These previous studies lacked standard reporting and documentation for the site which lead to Dr. Jaime Awe's comprehensive investigation of the site in order to better understand Cahal Pech as well as understand its role within the larger Belize River Valley archaeological complex.

The first major investigation of the site was conducted by Dr. Jaime Awe in 1988 (Awe, 1992b). Excavations have taken place continually at Cahal Pech from 1988 to the present via the Belize Valley Archaeological Reconnaissance (BVAR) project directed by Dr. Jaime Awe and Dr. Julie Hoggarth. There have been other projects, such as UM-BVAR overseen by Dr. John Douglas and American Foreign Academic Research (AFAR), spearheaded by Mat Saunders, that have conducted archaeological research projects at Cahal Pech, under BVAR supervision, adding to the extensive knowledge and history of the site. Excavations have focused on middle Preclassic occupation (Awe et al., 1990; Garber and Awe, 2008; Garber et al., 2008), main public buildings such as the B structures (Awe and Campbell, 1990; Cheetham, 1992), elite areas (Audet, 2001; Grove and Gillespie, 1992; Santasilia, 2012), and terminal classic structures (Awe and Helmke, 2007; Douglas et al., 2015). These excavations have yielded an unprecedented amount of data and information about the site of Cahal Pech relevant to the larger issues of the

Belize River Valley and beyond. This data includes burials and their associated artifacts and architecture.

Current research in the Belize River Valley includes incorporating new methods such as stable isotope analysis, Accelerated Mass Spectrometry (AMS) dating, and LiDar imaging. These new techniques have allowed for some of the unknowns in previous research to be answered, such as migration on both and individual and community scale and direct dating of burials.

The depopulation and disintegration of certain sites or areas within the Belize River Valley is substantiated by mortuary analysis and direct dating of burials. The Accelerated Mass Spectrometry ^{14}C (AMS) dating method has allowed researchers such as Hoggarth et al. (2014) and Ebert et al. (2016) to accurately date the occupation(s) of sites by providing precise dates of burials. Direct dating is used in conjunction with ceramic chronology and architecture to elaborate shifts in the socio-political structure within and between sites in the Belize River Valley. Hoggarth et al. (2014) discovered an approximate 500 year gap of occupation based on direct dating of burials and mortuary practices at the site of Baking Pot, which is traditionally the site considered to have the strongest continuity from the Classic through Postclassic in the Belize River Valley (Willey et al., 1965). The occupation gap is from AD 770 to 1280 (Hoggarth et al., 2014) and demonstrates a reoccupation of the site that may be reflected in the change in use of other sites in the area, including Cahal Pech, that may have been previously unrecognizable. A second study using AMS direct dating of human remains is Ebert et al.’s (2016) research that found continuous occupation at the site of Tzutziiy K’in in the Cahal Pech settlement area from the Late Preclassic (300 BC) through the Terminal Classic (AD 900). The differences in site use and occupations strategies between sites close in proximity may provide more questions than answers for now, but it is this type of research that may answer some of those questions regarding regional political alliances and individual polity power structures in the future.

Previous studies in the Belize River Valley area, specifically those that impact the site of Cahal Pech, have led to a general understanding of political alliances, socio-political structures, and human-environment interaction. But, like most research, more questions have arisen and given the new technology and methods more answers can now be ascertained from the data we already have. It is the goal of this research to use stable isotopes and mortuary data to build upon previous work to answer more complex questions regarding migration and the human-environment interaction.

Stable Isotope Analysis in the Belize River Valley

Stable isotope analysis has played a major role in archaeology since the 1980's (Ehleringer and Rundel, 1989; Gerry, 1997; Katzenberg, 2007; Tykot, 2002). This technique compliments osteological studies by contributing environmental, health, and dietary information from human and faunal remains. In particular, there has been extensive research done on diet in the Belize Valley (Freiwald, 2010; Rand et al., 2013; White et al., 1993), which focuses on faunal analysis and the use of stable isotopes to identify diet variety in order to infer status. Traditionally, diet studies emphasized morphological and chemical identification of faunal bones and plant remains (Emery et al., 2000; Freiwald, 2010; Rand et al., 2013; White et al., 1993) in order to reconstruct the Maya prehistoric diet, but these have now been supplemented by chemical analysis of human remains (Metcalfe et al., 2009; Tykot, 2002; White and Schwarcz, 1989) in order to identify the quantity of certain types of food. Distinguishing differences in diet has allowed researchers, such as Tykot (2002), to map geographic and temporal shifts in diet that correspond to environmental and socio-political shifts in the Maya world. Tykot (2002) found that there are significant shifts in diet between the Preclassic and Early Classic periods as well as between the Late Classic to Post Classic periods. This is evidence of shifts in diet taking place at the boundary of major socio-political shifts. Specifically, this demonstrates the effect on subsistence during the Late Classic disintegration. Diet studies also coincide with modeling of food production, in particular the production of maize and how it increased over time and space from the Preclassic to the Late Classic (White et al., 2010).

Variations in diet go hand in hand with origin and migration studies in the Maya region (Freiwald, 2011; Hodell et al., 2004; Wright, 2005b), which also use stable isotope analysis to identify location of individuals via their food and water sources. This can speak to mobility of individuals or groups of people as well as movement within one's lifetime depending on the analysis run. Previous studies include Hodell et al. (Hodell et al., 2004) who mapped strontium isotope values for groundwater, plants, and animals from the Yucatan through Belize to the Pacific Coast of Guatemala. They established baseline values to assist future research in the identification of local versus non-local humans and animals. Interestingly, Hodell and colleagues' research found that the different strontium geographic zones loosely coincided with Maya cultural areas. This allows for identification of migration from specific cultural areas. Freiwald (2011) collected strontium isotope values throughout the Belize River Valley in order to set baseline strontium values for both animals and humans. Freiwald's research refined the previous work done by (Hodell et al., 2004) and illuminated region specific strontium values for the Southern Lowlands. The creation of this baseline has allowed researchers to specifically identify individuals who have moved in and out of the Belize River Valley and has aided in understanding shifts in socio-political alliances between sites.

Stable isotope studies in the Belize River Valley have also shed light on temporal climate shifts. Hodell et al. (Hodell et al., 1995) used oxygen stable isotope data from a Lake Chichancanab core in order to identify climatic shifts. While Lake Chichancanab is in the Yucatan, Hodell et al.'s findings coincide very well with similar findings in Belize, particularly those of Doug Kennett and colleagues (2012). They found evidence for a drought by identifying variations in oxygen isotope values of stalagmites in caves in the Belize River Valley (Kennett et al., 2012). They identified a significant drop in oxygen that occurred between AD 820-870, which corresponds to the transition from the Late to Terminal Classic. The drought that both researchers found would have severely limited food resources and put stress on the socio-political structures of the Late Classic Maya (Chase and Chase, 1996a; Turner and Sabloff, 2012). Limited food resources likely led to a reorganization of communities, and may have included depopulation throughout the Belize River Valley.

The previous stable isotope work has laid a foundation for future work, including this research, by creating expected values and baseline ranges for various isotopes in the Belize Valley region. This research builds on this by adding new isotopes, implementing a comprehensive stable isotope plan that includes multiple biological materials, and further defining the site specific isotope values for Cahal Pech.

CHAPTER 3 - MODELS

Model Creation

In order to achieve the main research goal of this dissertation, this research is designed to identify the origin and status of individuals buried at the epicenter of Cahal Pech, as well as find changes in mortuary practices that correspond to the transition from the Late to Terminal Classic. I will use mortuary patterns that consist of archaeological data, stable isotope values, and biological analysis to identify temporal and/or spacial trends that can then be used as a proxy for changes in the socio-political framework. The combination of lines of evidence creates mortuary practices unique to a specific time and place. Identifying trends in the mortuary practices will allow statements to be made regarding the re-occupation strategies of the Terminal Classic Maya, their ancestral connections with ceremonial sites, and their social structure after the socio-political disintegration of the Late Classic systems. Finally, I will identify how the site core was used during the transition from the Late to Terminal Classic periods. This will put Cahal Pech in the larger context of the Belize River Valley and allow comparison of the use of the site with other similar sites in different regions of Belize and whether or not the use changed over time.

While there are dozens, if not hundreds, of scenarios possibly playing out at Cahal Pech, the three models below represent the most likely and inclusive possibilities. The models seek to investigate: who the individuals were at Cahal Pech during the Late and Terminal Classic periods, migration and population movement over time, and site use at Cahal Pech during the Terminal Classic. The models take into account the archaeological evidence that indicates people occupied the site in some capacity during the Terminal Classic period (Douglas and Brown, 2014; Santasilia, 2012), as well as current AMS dating information (Ebert et al., 2014, 2016;

Hoggarth et al., 2014), and isotope values from the surrounding area (Freiwald, 2011; Freiwald et al., 2014; Novotny, 2015).

Assumptions, Limitations, and Biases

There are several assumptions, limitations, and biases that accompany the following models due to excavation methodologies, reporting bias, limitations of analysis, and preservation of material. The first assumption is that the burials excavated within the epicenter of Cahal Pech are of high status individuals based on their burial location, presence of grave goods, and/or grave type. The validity of this assumption will be tested through isotope analysis of diet, the expectation being individuals buried within the core site of Cahal Pech will have varied diets because they are all of high status and had access to a broader diet. Status will also be evidenced by the quantity and quality of grave goods. The presence of exotic or unique grave goods are indicators of high status according to Hammond et al. (1992) and Welsh (1988). Common grave good types for this region include ceramic vessels and figurines, jade bead and pendants, obsidian, and chert artifacts. Unique grave goods for this region would include coastal goods such as shell pendants and remains of sea turtles, as well as chert or obsidian eccentrics, ceramics with glyphs and elaborate pottery. Carbon and nitrogen isotope values represent an individual’s diet and therefore reflect their status. A varied isotope signature, and/or one that includes unique foods, supports the idea that higher class or elite individuals had better access to a wider variety of food

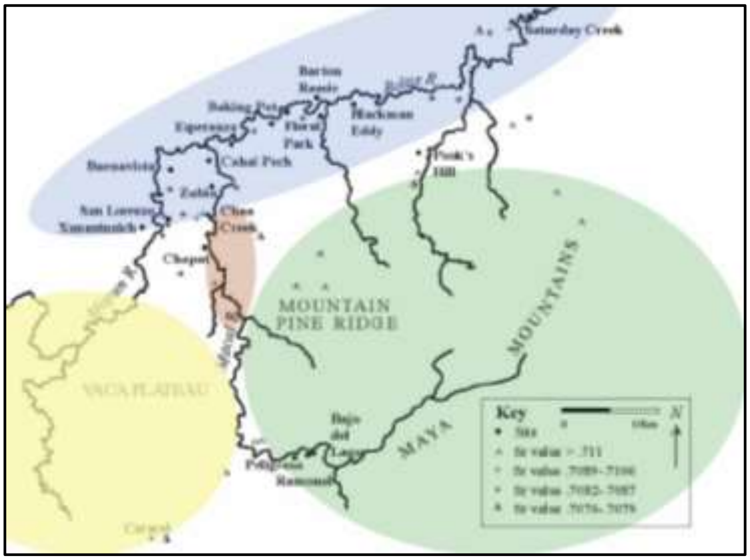


Figure 3.1. Strontium isotope regions in Belize (Freiwald, 2011).

(Ambrose et al., 2003; Conlon et al., 1994; White, 2005; White et al., 1993). If this assumption does not hold true, then the differences in status, either elite or non-elite, will be included as a characteristic in the mortuary analysis. The following models are also subject to the limitation of isotopic signatures. Freiwald (2011) states that the Belize River Valley has different strontium isotope signatures occurring approximately every 25km (Figure 3.1). Because of this limitation, the following models reference Cahal Pech, as well as the isotopic region that includes Cahal Pech, its settlement sites (Figure 3.2), and extends as far as Xunantunich and Saturday Creek. The models referring to individuals from outside the region include any area outside the blue isotope zone identified in Figure 3.1. Oxygen has a similar distribution to strontium, which is why it is also used to identify location. The range for oxygen isotopes is more fluid than strontium because it depends on distance from a water source and altitude. The Belize River Valley (including the site of Cahal Pech), identified in Figure 3.3 as the red box and

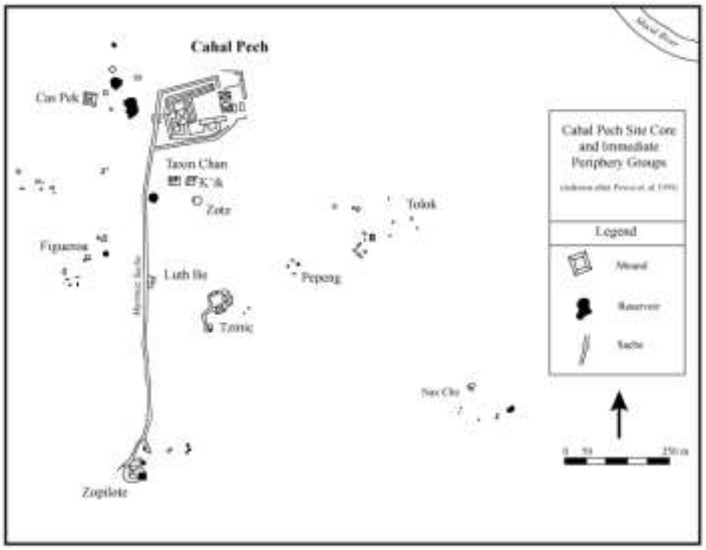


Figure 3.2. Cahal Pech settlement area (Powis et.al, 1999)

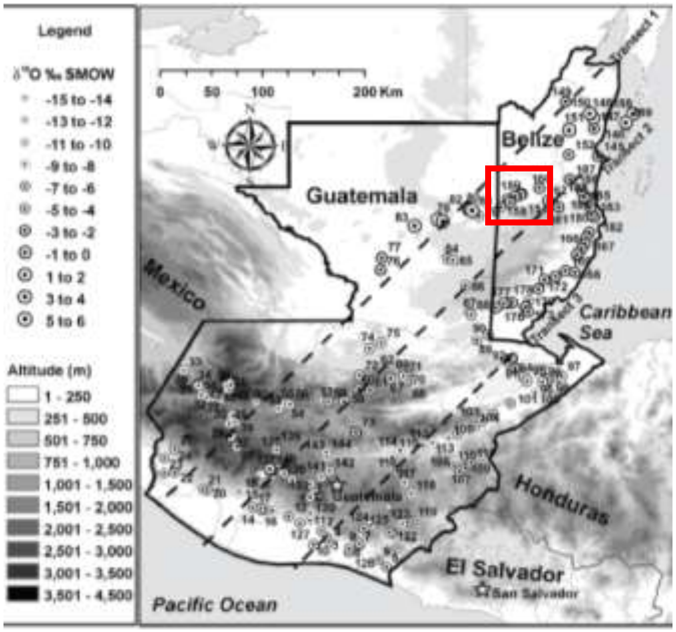


Figure 3.3. Oxygen isotope distribution of the Maya area (Lachniet and Patterson, 2009).

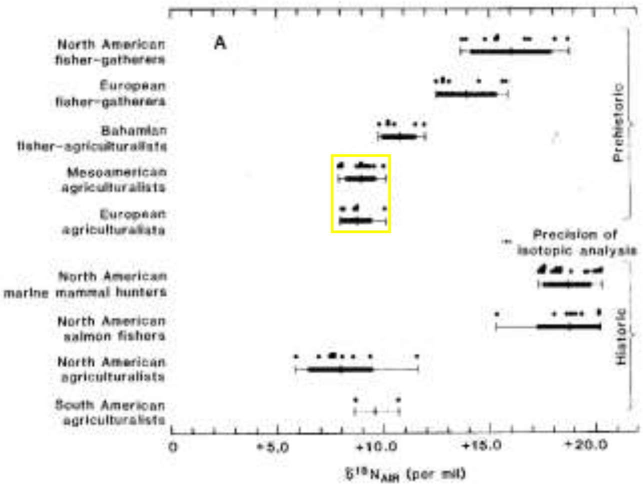


Figure 3.4. Nitrogen graph from Schoeninger (1985). Yellow box highlights Mesoamerican and Bahamian samples.

which range from -3 to -2, is similar to the southern Caribbean coastal sites (-3 to -2) but different from the northern Belize area (3 to 6)and southwestern Guatemalan highlands (-9 to -6) (Figure 3.3, Lachniet and Patterson, 2009). Carbon and nitrogen isotope values change depending on diet so this research will use these isotopes to identifying differences between individuals from the same site in order to address status. Nitrogen has a geographical component to its distribution. Schoeninger (1985) states that the nitrogen levels of Bahamian fisher-agriculturalist, which are similar to coastal Belizean's, have values of 10‰ – 12‰, whereas Mesoamerican agriculturalists have values 8‰ – 10‰ (Figure 3.4). That being said, differences in nitrogen values may indicate movement as well as diet when used in conjunction with strontium and oxygen.

One additional limitation of the isotope analysis specific to this research is the use of sulfur. Sulfur isotopes have not been widely studied in Mesoamerica and therefore no comparative data or distribution maps exists. That means that the interpretation of the sulfur results may change after this dissertation with the introduction of new data. For this research, sulfur is used as an indicator of both origin and diet. Sulfur is similar to strontium because there is little to no trophic level change and it seems to be effected by proximity to the ocean, therefore a good indicator of distance from the coast. Sulfur is also an indicator of protein in the diet; high protein diets give higher sulfur values. This research will use sulfur as a supplement to information gathered from strontium, oxygen, carbon, and nitrogen. General statements about the sulfur results and interpretation will be limited to the information available at the time of this dissertation.

A limitation that effects the interpretation of the isotope results is the constraint of bone biology. Bone turns over every 10 – 15 years of life, therefore bone isotope analysis will yield results from the individual's location and diet within 10 years of death. Teeth, on the other hand, do not turn over; after they are formed they trap the isotope signature of the individual at the time of tooth formation, typically birth to 15 years depending on the tooth used. This effects the interpretation of isotope values because questions regarding movement or origin must be made using the same biological material. An individual with only a tooth sample cannot be directly compared with an individual with only a bone sample. Also, an individual with only a bone sample cannot have a definitive statement made about their origin, instead it is considered a likely finding with the caveat that they may have moved during childhood.

Excavation and recording bias is due to the archaeologist's propensity to excavate large temple-like structures, as pointed out by Welsh (1988), instead of smaller household areas. Temple structures are easier to locate and tend to draw tourism and economy to sites so they are chosen for excavation and conservation first. These structures are also known to produce significant finds, such as chambers and tombs. Burials found in excavating these areas are then expected to represent individuals of elite status, based on the assumption that ceremonial centers and temples were saved for burials of high status individuals (Ashmore, 1989; Ball and Taschek, 1991; Grove and Gillespie, 1992; McAnany et al., 1999; Rathje, 1970; Webster, 2002; Welsh, 1988).

Preservation of materials has also led to sampling bias. Because biological preservation in Belize is extremely poor, there are a limited number of samples with enough integrity for stable isotope analysis. Preservation also limits bioarchaeological analysis of remains; for example, sex and precise age may be difficult or impossible to determine given the lack of bone present. Therefore, general age indications (adult, subadult) and conservative sex indicators (male, female, indeterminate) are used. Preservation also affects the amount of viable bone and leads to inconsistent analyses on samples. For example, sulfur analysis takes a large amount of bone collagen to run and there are only a few samples with enough collagen, therefore not all samples will have sulfur analysis. This makes intra-sample and intra-site comparisons difficult to perform and trends difficult to identify.

Models

Model 1 – Continued Occupation. This model states that Cahal Pech was continually occupied through the transition from the Late to Terminal Classic. Specifically, the inhabitants of Cahal Pech stayed within the geographically unique isotope region before, during, and after the Late Classic period extending into the Terminal Classic (Figure 3.1). If the findings are consistent with this model it will demonstrate that there is no significant emigration or immigration occurring at Cahal Pech during this time period.

There is evidence of new construction and architectural styles during the Late and Terminal Classic periods (Douglas and Brown, 2014; Santasilia, 2012), as stated in the previous chapter. One way to interpret the Terminal Classic architecture is that it may be representative of possible migration with people moving from public and elite structures to smaller plazas from within the site core, or people moved to and from the settlement areas (Figure 3.2). This would mean that the inhabitants of Cahal Pech continued to occupy the site with a limited degree of migration in and out of the site core. They also continued to use the existing buildings as places for religious ceremonies, ancestor worship, and mortuary facilities. If this holds true, I expect to see no difference in strontium, oxygen, or sulfur isotope values between burials from the Late Classic and Terminal Classic periods due to the individuals inhabiting the same geographic region. Carbon, nitrogen, and sulfur will stay consistent over time because it is expected that individuals at Cahal Pech will have the same diets and access to foods even during drought periods. This is expected because, while the Classic Maya socio-political structure may have disintegrated, there would still be individuals and families considered higher class and therefore have better access to a variety of foods. I also expect to see substantial continuity in mortuary characteristics between all Classic time periods proving that the Classic Maya cultural patterns, that were specific to mortuary rituals, continued after the political disintegration at the end of the Late Classic. This will be tested through statistical comparison of the mortuary data, specifically the sharing of characteristics and the lack of clustering of burials by location and time period. Further, it is not expected to have an increase in the reuse of graves (intrusive burials) or alternative mortuary programs. This will be due to either the knowledge of ancestral burials locations that will have been passed down from generation to generation, or the possibility that the Terminal Classic inhabitants chose not to bury their dead in previous graves.

Model 2 - Re-occupation. This model states that the residents of Cahal Pech left the geographically unique isotope region (Figure 3.1) during the transition from the Late to Terminal Classic. The reoccupying population built smaller plazas (i.e. Plaza H) and structures around the outside of the core public buildings for living spaces and used the existing ceremonial architecture for mortuary purposes. This model is most restricted by the limitation of isotopic signatures in bone changing every 10-15 years as bone turns over. With that understanding, if this model holds true, then I expect to find differences between tooth and bone samples over time in strontium, oxygen, and sulfur isotope values.

The model incorporates three different scenarios. The first scenario is that the original Late Classic inhabitants of Cahal Pech left the region and returned within their lifetime, but died within 10 years of returning to the site. This will be evident through the Late and Terminal Classic burials having differing strontium, oxygen, and sulfur isotope values between tooth and bone samples, which represents movement within a lifetime. Late and Terminal Classic burials will have carbon, nitrogen, and sulfur isotopes that show a difference between bone and tooth samples which will denote individuals that left the area and likely changed diets. Since this scenario states that the individuals died within 10 years of returning to the site, their bone isotope would reflect the diet of the region they went to, not the region where they originated. It is also expected that mortuary patterns would change over time and space due to influences from outside the region. Specifically, grave type and grave goods, such as stingray spine and shell, are likely the characteristics to change over time. These changes will reflect differential access to certain socially valued goods due to the change in the socio-political landscape. There will be no increase in intrusive burials because the amount of time passed is limited to less than a lifetime, therefore I expect a continuity of ancestral knowledge regarding burial placement.

Scenario two is that the individuals never inhabited the geographic isotope region of Cahal Pech, instead they are newcomers who chose to move to the area after it was depopulated, and died at least 10 years after moving to the area. This will be seen through strontium, sulfur, oxygen, carbon, and nitrogen isotope values in the teeth that are different from the bone samples within Terminal Classic burials only. This will also be represented in differences in all isotope values for tooth samples. It is expected that burials from the Preclassic through the Late Classic will exhibit local signatures and the Terminal Classic burials will display non-local signatures. This scenario also expects that mortuary patterns will change over time and space at the site due to influences from outside the region. Specifically, there will be differences between the burials before (Late Classic) and after re-occupation (Terminal Classic) due to the shift in social and political structure that will affect the transmission of cultural knowledge over generations. In addition, the changes in grave good types will be reflective of differential access to certain socially valued goods such as jade, stingray, and obsidian that may be due to the change in social structure or social alliances/influence. Scenario 2 includes the expectation of more intrusive burials after re-occupation because there will be limited knowledge about ancestral burial locations as well as no new ceremonial construction. One can infer that the individuals from scenario two understand Cahal Pech is an ancient sacred place, but they do not have an ancestral connection to it. Therefore, it can be posited that they are less likely to feel connected to the individuals previously buried at the site and more likely to disturb those burials.

The third scenario is a mixture of one and two. The re-occupation population may be a mixture of new and old people moving in and out of the city from places beyond the geographic isotope region. This scenario expects continual migration of varying degrees throughout all time periods. This means that some people will have local strontium, sulfur, and oxygen isotopic signatures while other have non-local signatures. Carbon, nitrogen, and sulfur isotopes will also demonstration differences based on regional variances in diet and access to foods. The mixture of local and non-local isotopes may increase during the Terminal Classic due to the influx of migration after the socio-political shift of the Late Classic. The mortuary patterns, similar to the isotope values, are expected to be a mixture of old and new practices, but they are not expected to significantly change over time and space. This is due to limited continuity of occupation and therefore continuity of religious ritual tradition at the site.

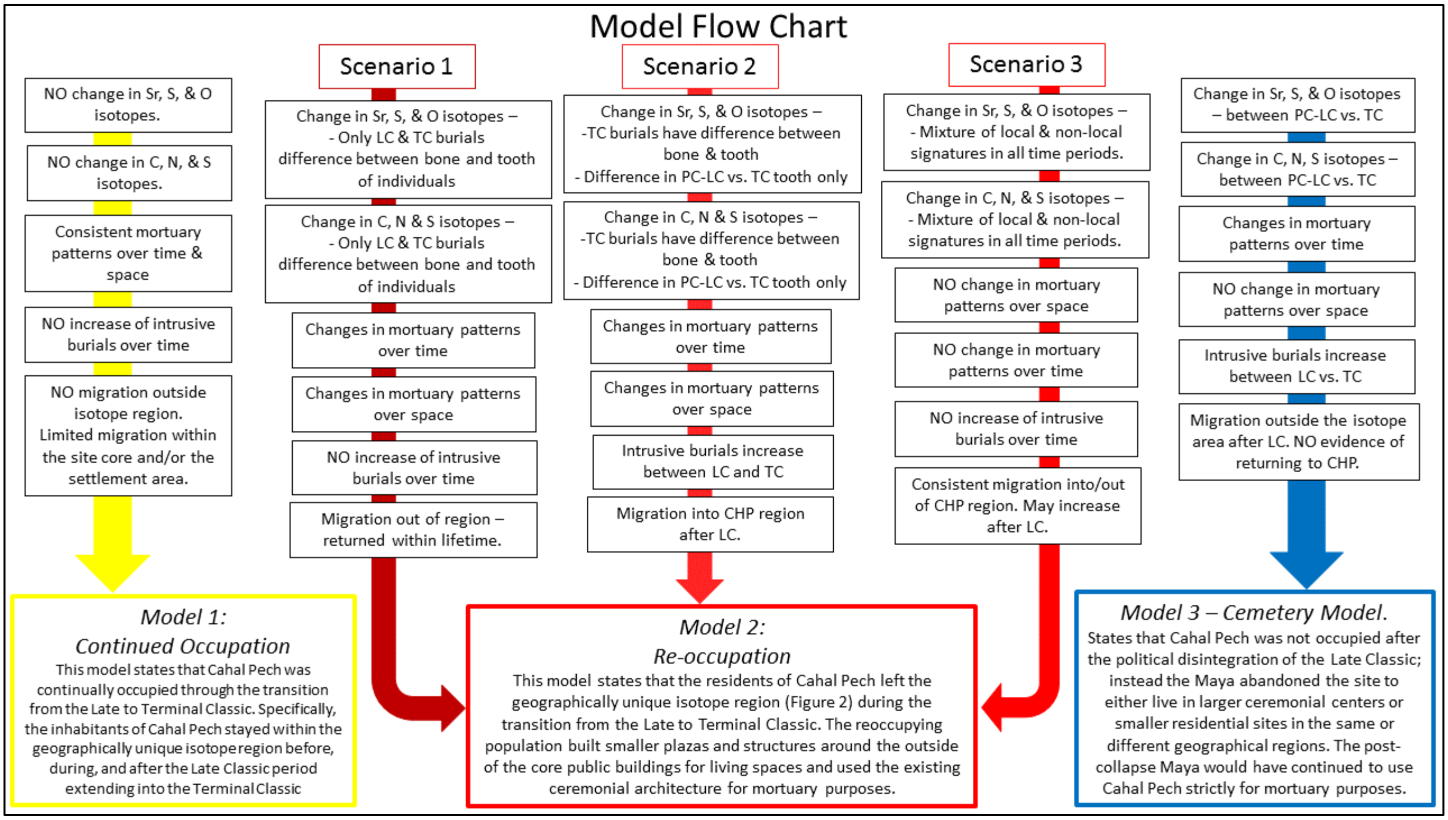
Model 3 – Cemetery Model. This model states that Cahal Pech was not occupied after the transition from the Late to Terminal Classic; instead the Late Classic Maya left the site in order to live in either one of the remaining ceremonial centers, such as Caracol, or moved to smaller residential sites outside the geographically unique isotope region (Figure 3.1). The Terminal Classic Maya used the structures in the site core of Cahal Pech strictly for mortuary purposes. For this model to hold true I would expect there to be differences in the strontium, sulfur, and oxygen isotope values between individuals from the Late Classic and the Terminal Classic periods due to the Terminal Classic Maya living outside the Cahal Pech isotope region. There may also be a difference in nitrogen, carbon, and sulfur isotope values based on different region's food resources and a change in access to food after the socio-political disintegration. The archaeology tells us that there are Terminal Classic structures at Cahal Pech (Douglas and Brown, 2014), but in this model they were used for periodic, limited habitation connected with mortuary practices. Other mortuary characteristics, including grave type, orientation, and body position, will change due to the introduction of new rituals and customs from the elite class in different regions. These patterns will cluster based on time period and show significant differences between the Late Classic and Terminal Classic. Intrusive burials will become more frequent during the Terminal Classic period because there would have been no new ceremonial construction after the Late Classic. There would also be individuals entering the city on a periodic basis that may not have had ancestral ties and therefore no knowledge of previous burials as well as no relationship with the previously deceased making it easier to disturb those burials.

To summarize (Table 3.1 & Figure 3.5), Model 1 will show no change in any of the stable isotope values or mortuary practices over time and space. Model 2, scenario 1 will show a change in stable isotope values and mortuary practices over time and space, but intrusive burials are not expected to increase over time. Model 2, scenario 2 will show change in isotope values, mortuary practices will change over time and space, and intrusive burials will increase over time. Model 2, scenario 3 will show a change in isotope values, but no change is expected in mortuary practices over time and space as well as no increase in intrusive burials. Model 3 will exhibit changes in isotope values and mortuary practices over time, but mortuary practices will not change based on location within the site. An increase in intrusive burials is expected over time.

Testing these three models against the trends identified in the mortuary and the isotope analyses will build new insights into how Cahal Pech was used during the Late and Terminal Classic periods, including population mobility during the socio-political disintegration in the Late Classic and how the social structure changed through time. It is important to note that it is a combination of the multiple lines of evidence that will point to one specific scenario over another (Table 3.1 & Figure 3.5).

Table 3.1. Expectations of each model.

	Change in Sr/S/O	Change in C/N/S	Change in mortuary patterns over time	Change in mortuary patterns over space	Increase intrusive burials
Model 1	no	no	no	no	no
Model 2 – scenario 1	yes	yes	yes	yes	no
Model 2 – scenario 2	yes	yes	yes	yes	yes
Model 2 – scenario 3	yes	yes	no	no	no
Model 3	yes	yes	yes	no	yes



Model 1: Continued Occupation

This model states that Cahal Pech was continually occupied through the transition from the Late to Terminal Classic. Specifically, the inhabitants of Cahal Pech stayed within the geographically unique isotope region before, during, and after the Late Classic period extending into the Terminal Classic

Model 2: Re-occupation

This model states that the residents of Cahal Pech left the geographically unique isotope region (Figure 2) during the transition from the Late to Terminal Classic. The reoccupying population built smaller plazas and structures around the outside of the core public buildings for living spaces and used the existing ceremonial architecture for mortuary purposes.

Model 3 – Cemetery Model.

States that Cahal Pech was not occupied after the political disintegration of the Late Classic; instead the Maya abandoned the site to either live in larger ceremonial centers or smaller residential sites in the same or different geographical regions. The post-collapse Maya would have continued to use Cahal Pech strictly for mortuary purposes.

Figure 3.5. Model Flow Chart. Key: stable isotope (SI), Preclassic (PC), Late Classic (LC), Terminal Classic (TC), strontium (Sr), sulfur (S), oxygen (O), carbon (C), nitrogen (N), and Cahal Pech (CHP).

CHAPTER 4 - MATERIALS & METHODS

MATERIALS

Location

The samples used in this research come from the epicenter of the Maya site of Cahal Pech, which is a medium sized ceremonial site situated atop a hill overlooking the modern day town of San Ignacio (Figure 4.1). Occupation at Cahal Pech spans the Early Middle Preclassic (1250 BC) through the Terminal Classic (AD 900) (Awe, 2013; Cheetham, 1992; Douglas and Brown, 2014; Garber and Awe, 2008; Garber et al., 2007; Healy and Awe, 1995). Excavations have taken place continually at Cahal Pech from 1988 to the present through the efforts of the Belize Valley Archaeological Reconnaissance (BVAR) project directed by Dr. Jaime Awe and Dr. Julie Hoggarth.

Cahal Pech lies within the foothills of the Maya Mountains and within a fertile landscape surrounded by a plethora of natural resources and larger city-states. The Belize River Valley that houses Cahal Pech consist of closely packed medium and small ceremonial centers as well as settlement sites. This area is unique due to the density of ceremonial centers and because the sites within the valley seem to be independent of each other, acting as independent kingdoms or city-states (Conlon et al., 1994; Hoggarth, 2009). Specifically, Cahal Pech is located next to the Macal River just south of the confluence of the Macal and Belize rivers. The latter allowed goods to be brought in from the coast such as shells, sea turtle, and salt. The environmental setting is lowland foothills with dense vegetation and varied terrestrial animals including peccary and deer. The area just outside the site core is a patchwork of fertile farms and ranches. The climate is tropical and humid with alternating periods of rain and drought throughout the year.

Geologically, the Maya Lowlands are on the Cretaceous Period Yucatan Peninsula made of marine limestone (Freiwald, 2011).

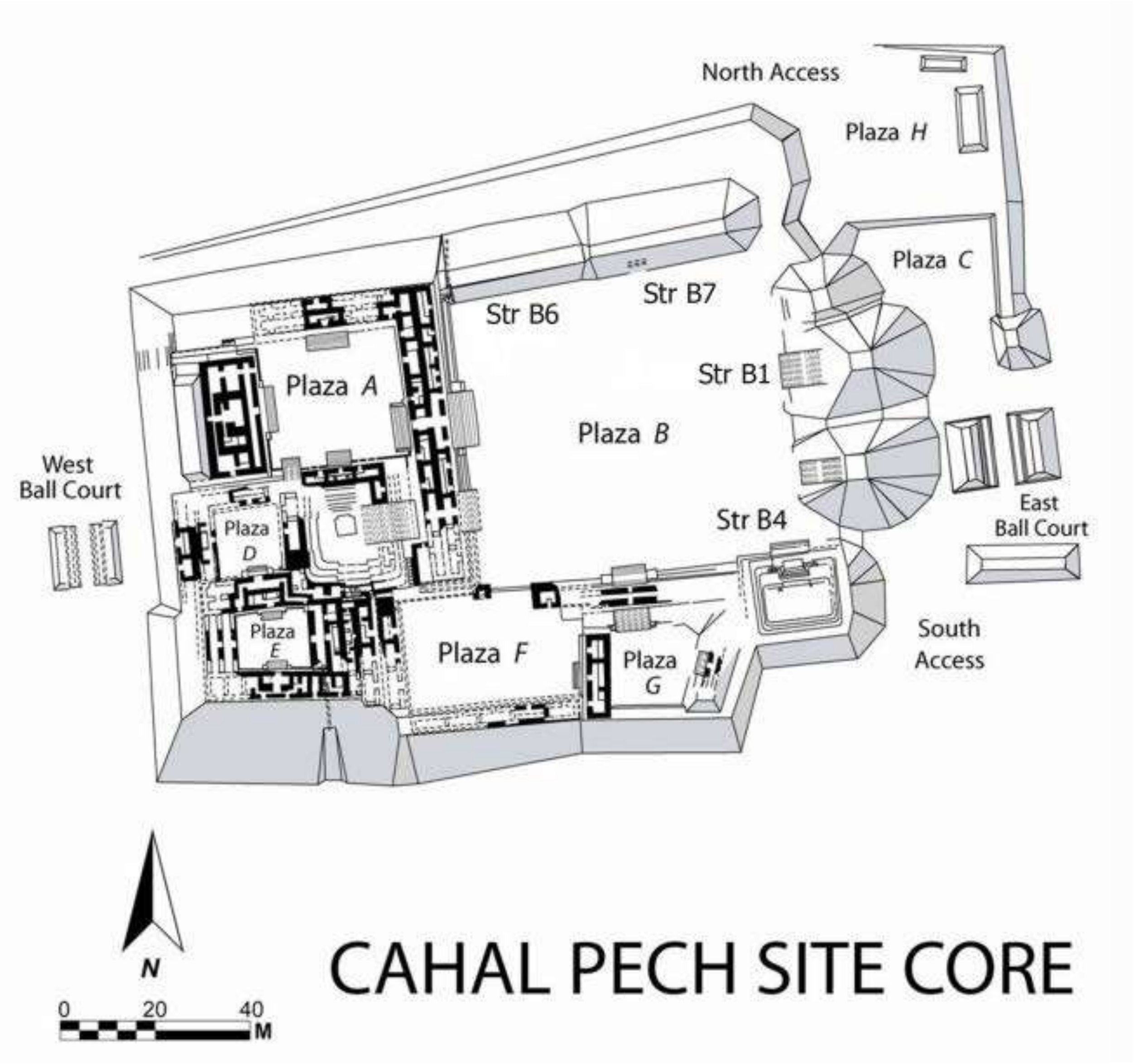


Figure 4.1. Cahal Pech site core map.

The layout of site core of Cahal Pech and its placement in the larger Belize River Valley seems to indicate that Cahal Pech likely played a role in power structures and alliances between the larger nearby sites of Caracol, Naranjo, El Pilar, and Xunantunich to name a few. Cahal Pech lies approximately 10 kilometers northeast of Xunantunich and approximately 83 kilometers north of Caracol. Cahal Pech's axis is aligned east/west with a large triadic structure on the eastern border of the public plaza and the elite structures on the western border. The site is atop a large hill and is naturally defendable.

The strategic location of Cahal Pech and its layout hint at the importance of the site in the larger Belize Valley Maya political and social system. This research aims to create models to explain migration into and out of the site that will add to an understanding of Cahal Pech's place in the Classic Maya political and social structures. It will also identify how the community of Cahal Pech responded to changes in the socio-political structure. Finally, this research will aid in a better understanding of the transition from the Late to Terminal Classic periods in the Belize River Valley by creating models that can be applied to sites within the region.

Samples

The burials used in this research come from the core site of Cahal Pech and includes human remains from structures A3, B1, B2, B3, B4, C2, H1, Plaza B, and Plaza G (Figure 4.2). All burials were excavated between 1988 and 2014 and are housed with the collections from Cahal Pech either at Dr. Awe's house or at the Cahal Pech lab. Some cleaning and basic osteological and bioarchaeological analysis was done by previous researchers (Freiwald, 2011; McKeown and Bongiovanni, 2013; Novotny, 2012; Piehl, 2005; Pritchard et al., 2011; Song et al., 1994). Working as a team with Dr. Ashley McKeown and Dr. Rosie Bongiovanni, I conducted new age and sex determinations, photographs, and documentation for a portion of these individuals (N=18), research that was completed during the summer of 2013 (McKeown & Bongiovanni), 2014 (McKeown, Bongiovanni, & Green), and January 2015 (Green).

The complete sample used in this research consists of a total of 27 individuals; the 18 individuals that were sampled by myself and 9 individuals reported in previous research. The 27 individuals date from the Early Classic through Historic period (Appendix A, Table A.1 & A.2). For the 18 individuals that I examined, a sample tooth, if present, and bone was taken from each individual and exported to the United States with permission of the Belize Institute of Archaeology. This research includes data from 41 samples that were collected from 27 individuals. Table 4.1 shows the number of individuals from each time period broken down by age and sex. The burials include two individuals buried in an elite structure (Str. A2 and A3), four buried in a public or semi-public plaza (Plazas B, C, and G), five individuals buried in a public structure (Structures B4, C2, and H1), and 17 buried in an eastern triadic structure (Structures B1, B2, and B3).

Table 4.1. Distribution of burials for each time period based on age and sex.

	Late Preclassic	Early Classic	Late Classic	Terminal Classic	Historic	Unknown Time Period	**TOTALS**
Adult Male	3	3	3	1			**10**
Adult Female	1	1	3	2		1	**8**
Adult Indeterminate	2	2	1	1			**6**
Subadult Indeterminate			1	1	1		**3**
TOTALS	**6**	**6**	**8**	**5**	**1**	**1**	**27**

Which samples contributed to the various isotopic analyses is found in Appendix A, Table A.1. Not every individual had teeth or bone present for sampling, either because there were no teeth present, preservation was poor and the teeth lacked integrity, or the previous research plan did not sample both biological materials.

A total of 26 out of 27 individuals in this sample had time periods associated with them. Of the 26 dated burials, 21 used the Accelerator Mass Spectrometry C^{14} dating method by Claire

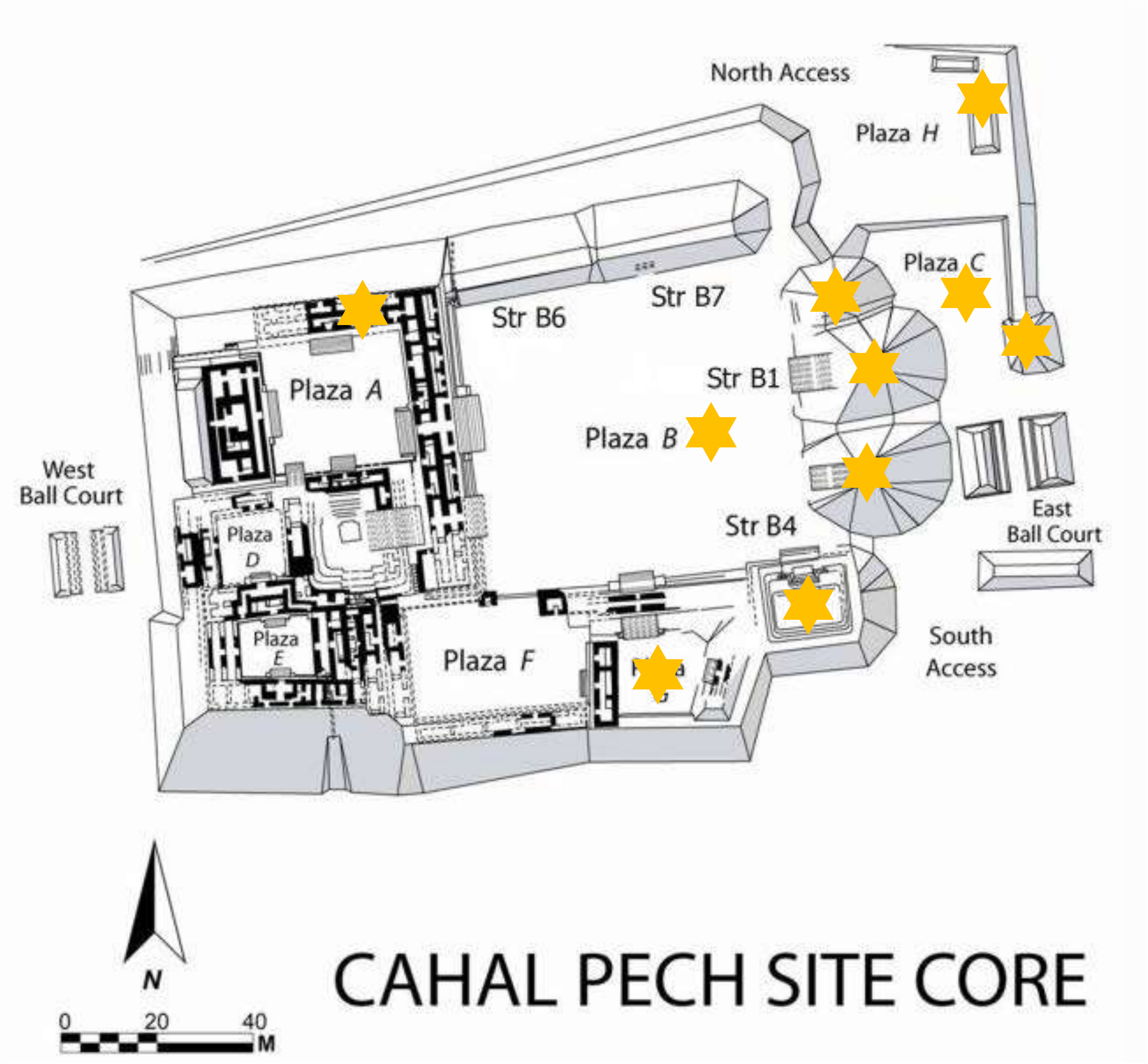


Figure 4.2. Cahal Pech site core map with burial locations highlighted with stars.

Ebert at the University of Pennsylvania (personal communication) and Anna Novotny at Arizona State University (Novotny, 2015). The remaining six individuals were dated using traditional archaeological techniques of ceramic chronologies and architecture.

This research requires the sampling of two different biological materials because the research design seeks to identify an individual's movements throughout life. The use of multiple types of material allows for samples with lower integrity to be used and included in the database.

This is because teeth tend to preserve better than bone, so even if an individual's bone sample is not viable the probability is that their tooth sample will be. The two biological materials are bone and tooth. Each type of material can give different values of isotopes, each of which tells different parts of the individual's isotopic history. Chemically, bone turns over every 10-20 years; therefore, the isotope values in the bone sample give the isotopic signature associated with approximately the last decade of life for an individual. Tooth dentin and enamel is laid down at the time of tooth creation and does not turn over periodically throughout life, therefore tooth dentin and enamel are ideal samples to look at the beginning stages of life from infancy to approximately 18 years old (depending on the tooth sampled).

METHODS

Mortuary Analysis

This research required a mortuary database (Appendix A, Table A.1) to be created in order to complete the mortuary analysis. This database was created under the direction of Dr. Ashley McKeown and based on information from the published and unpublished sources provided by BVAR (Appendix A, Table A.1). These sources include articles, site reports, theses and dissertations, conference papers, and books. The database includes demographic information such as age and sex, osteological elements present, location at the site, radiocarbon dates, ceramic chronology, grave type, burial mode, orientation, body position, placement of head, and types of grave goods.

The characteristics recorded for each burial are found in Table 4.2. The coding of the characteristics, modeled after Hoggarth (2012), is meant to take into account the varying types of graves goods present as well as the location of the burial within the site. There are two limitations when it comes to creating and coding a retrospective database on burials excavated over a 30+ year period. First, the amount and type of burial information is dependent on the report written and can be lacking significant burial and/or biological information. For example, you may have one burial that was excavated by an archaeologist that only recorded archaeological information about the grave type and grave goods, where on the other hand you may a burial excavated by an osteologist that would focus exclusively on age, sex, and osteology present. Second, the database does not take into account the quantity of certain grave goods. However, the detailed separation of grave good types does allow for unique grave goods to be weighted during the statistical analysis therefore lessening the effect of not accounting for quantity of each type.

Table 4.2. Mortuary database characteristics and their associated codes.

Code	**Description**	**Code**	**Description**	**Code**	**Description**	**Code**	**Description**
A	Adult	EPS	Elite plaza or structure	Tmb	Tomb	ShD	Shell decoration
SA	Subadult	Pr	Primary	HS	Head to South	Sh	Other shell
AInd	Indeterminate or unknown age	Sc	Secondary	HN	Head to North	JdO	Jade ornament
M	Male	Int	Intrusive	Prn	Prone	JdB	Jade Bead
F	Female	Ind	Individual	Sup	Supine	Jd	Other jade
SInd	Indeterminate or unknown sex	Mlt	Multiple	FE	Facing East	ObB	Obsidian blade
LPC	Late Preclassic	Ext	Extended	FW	Facing West	Ob	Other obsidian
EC	Early Classic	Flx	Flexed	CeV	Ceramic Vessels	Sty	Stingray
LC	Late Classic	ScDis	Scattered or disarticulated	CeF	Ceramic Figurine	Fa	Faunal
TC	Terminal Classic	Simp	Simple grave	Ce	Other ceramic	FaC	Carved or worked bone
H	Historic	Pit	Pit	ChE	Chert Eccentrics	LocT	Local tooth isotope value
ETS	Eastern Triadic Structure	Cst	Cyst/Cist	ChP	Chert Points	LocB	Local bone isotope value
PPS	Public plaza or structure	Cpt	Crypt	Cht	Other chert	Elt	Elite isotope value

The database was coded binomially, where a characteristic that is present is coded as 1 and absent is coded as 0. When a characteristic was not recorded it was coded as 0 except in the case of age and sex where separate "indeterminate or unknown" categories were created (Appendix A, Table A.2). Characteristics not present in any of the burials were removed from the final analysis (Appendix A, Table A.3). In order to assess the effects of time, location, origin, age, and sex on the mortuary practice these traits were not included in the analyses so as to not bias the outcome.

Stable Isotope Analysis

Stable isotope analysis for the purposes of this work is the measurement of the ratio for two isotopes of the same element in the body, generally then compared to the same element from local water and food sources. It takes into account trophic level decrease for all but strontium and sulfur, for which there is no or minimal decrease. This research compares stable isotope values in both bone and tooth samples in order to create a life history for individuals which can potentially identify movement between isotope regions during life.

Stable isotope analysis was completed for all the samples deemed viable by Dr. Jelmer Eerkens of the University of California, Davis and the author. This research employs oxygen ($^{16}O/^{18}O$), carbon ($^{12}C/^{13}C$), and nitrogen ($^{14}N/^{15}N$), sulfur ($^{34}S/^{32}S$), and strontium ($^{87}Sr/^{86}Sr$) isotopes in order to identify status (via diet), origin, and movement of burials at Cahal Pech (Price and Burton, 2011; Tykot, 2006). I completed preparation of the samples for carbon, nitrogen, and sulfur isotope determinations under the direction of Dr. Eerkens. The preparation methods for collagen followed the Longin (1971) and Schoeninger and DeNiro (1984) method, and the method for hydroxyapatite followed the Lee-Thorpe et.al (1989). Preparation of samples for strontium was completed by Dr. Carolyn Freiwald at the University of Mississippi and follows the method laid out in Deniel and Pin (2001). Extraction of both collagen and apatite allows for different stable isotopes to be analyzed and therefore allows for multiple lines of evidence for the interpretation of migration, origin, diet, and status. The specifics of each isotope preparation method can be found in Appendix B.

The stable isotope analysis in this research uses hydroxyapatite from bone and tooth enamel samples. Hydroxyapatite is the inorganic material comprising approximately 70% of dry bone and nearly 95% of tooth enamel (Bethard, 2013). Hydroxyapatite can survive difficult environmental and depositional contexts (Lee-Thorp and van der Merwe, 1991) and it is this survivability that allows hydroxyapatite to be used when a sample may not yield collagen due to degradation. Hydroxyapatite is formed by the dissolved biocarbonate in the blood, which in turn comes from proteins, lipids, and carbohydrates that are ingested. This full spectrum of sources allows researchers to infer total or whole diet (Bethard, 2013; Katzenberg, 2007; Lee-Thorp et al., 1989). Hydroxyapatite was chosen for this research because of its ability to give values for several of the isotopes pertinent to fulfilling the goals of this research, its ability to maintain integrity through a variety of environments, and its unique characteristic of reflecting the whole diet of an individual.

This research also includes extraction of collagen from bone and tooth dentin. Collagen comprises approximately 30% of dry bone and tooth dentin (Ambrose, 1990; Bartelink et al., 2014). Collagen consists mostly of carbon and nitrogen, making this the ideal type of sample to study these two isotopes. This research also includes sulfur stable isotope data from bone and tooth dentin collagen, when a large enough sample was available. In the lab, bone or tooth dentin samples were dissolved to remove all the inorganic material; what is left is the collagen. The isotope values within the collagen are then measured. The isotope values found in collagen come from ingested proteins and therefore only reflect the protein portion of the diet (Bethard, 2012; Walker and DeNiro, 1986; Katzenberg, 2007). Protein sources for inland Belize likely came from terrestrial animals such as deer, peccary, and possibly jute (freshwater snail) (White et al., 1993) as well as from maize and legumes. The collagen and the bone itself can break down and lose integrity quickly in certain environments therefore it is important that the diagenesis of the collagen be taken into account before inferences about the past are made. This can be detected by using the C:N ratios as an indicator of diagenesis or contamination. If the C:N ratio exceeds ±2.5% of the average for the sample, then there is significant degradation and the sample should not be used (Schoeninger and DeNiro, 1984).

This project included 10 tooth samples that were viable for serial sampling. Serial sampling is the process of dissolving the tooth root as a whole and then cutting 1-2mm sections starting at the apex of the root. Each section represents approximately one to two years of life associated with the age at development of each tooth. Sometimes, it is the case that multiple sections mush be combined to meet the required amount of collagen for stable isotope analysis. This method allows for changes in diet over the development of the tooth, which represents anywhere from infancy to young adulthood, depending on the tooth.

After each of the preparation methods was completed the samples were run and analyzed on an isotope ratio mass spectrometer (IRMS). The IRMS consists of four major components: 1. Inlet system, 2. Ion source, 3. Mass analyzer, and 4. Ion detectors (Figure 10). A combined IRMS machines includes a furnace or inlet system that turns the sample that is suspended in a paper card holder into a gas within the machine. Once in gas form, the nitrogen, carbon, and oxygen from the samples is carried by helium gas to the second portion of the mass spectrometer, the ion source. Within the ion source the gases are bombarded with electrons causing them to become ionized and therefore controllable. These ionized gases are focused into a beam and directed into a flight tube and taken to the mass analyzer (component 3). The mass analyzer then separates the beam into smaller beams by shooting the large beam between two magnets. These separate smaller beams have different mass results and create the "mass spectrum" that the machine is named after. The fourth component, the ion collector, measures the intensity of the individual ion beams. This intensity is then reported as a ratio to a standard for each isotope in parts per thousand (‰) using delta notation (δ) to represent the difference between the observed value and the standard value (Ambrose, 1990; Bartelink et al., 2014; Bethard, 2012; Katzenberg, 2007; Tykot, 2002). The standard for oxygen and carbon are VPDB (Vienna Peedee Belemnite), sulfur is V-CDT (Vienna Canyon Diablo Troilite), strontium is the SEA (seawater standard), and nitrogen is AIR (atmospheric nitrogen) (Gonfiantini et al., 1995; Junk and Svec, 1958).

Initial cleaning and sample preparation was conducted by the author under the direction of Dr. Jelmer Eerkens at the UC Davis Stable Isotope Facility. The bone and tooth dentin for $\delta^{13}C$, $\delta^{15}N$, and $\delta^{34}S$ from the collagen was done at UC Davis. Material and isotope specific preparation was completed by the following individuals: preparation of both bone apatite and tooth enamel for $^{87}Sr/^{86}S$ was overseen by Carolyn Freiwald at the University of Mississippi and analysis of the samples was run by Paul Fullagar at University of North Carolina, Chapel Hill; $\delta^{13}C$ and $\delta^{18}O$ tooth enamel preparation was overseen by Carolyn Freiwald at the University of Mississippi and the analysis of the samples was conducted by David Dettman at the University of Arizona; bone apatite was prepared and analyzed by Erin Thornton at Washington State University.

The isotopes measured in this research each provide evidence relevant to the different models. Carbon in the bone or tooth dentin collagen is used to identify aspects of an individual's diet (specifically the amount of food derived from plants that have C_3 photosynthetic pathways versus the C_4 ones) which allows inferences about status and origin (Ambrose et al., 2003; Freiwald et al., 2014; Privat et al., 2002) based on access to and availability of food resources during any given time period. Nitrogen in an individual's bone and tooth dentin collagen is useful in diet reconstruction because it expresses differences in marine versus terrestrial diets (McCutchan et al., 2003; Pearson et al., 2015; Rand et al., 2013; Salesse et al., 2013; Schoeninger et al., 1983). Nitrogen can also speak to differential stress within and between populations due to water and resource availability which becomes less significant in the diet during drought periods or during times of limited trade (Schoeninger et al., 1983). This is partly due to communities relying more heavily on drought foods that do not require large amounts of water, as well as limiting marine animal consumption based on trade. Nitrogen is used to identify status, via diet, because it gives evidence toward differential access to specialty foods and water resources. Finally, nitrogen is also useful in distinguishing an individual's trophic level within the food chain.

Oxygen from the bone apatite and tooth enamel is used to identify water sources and is directly correlated with a person's water source, therefore can be used to identify an individual's origin or location during life (Bartelink et al., 2014). Sulfur is found in a person's bone collagen and is obtained by consuming methionine-containing proteins from either plants and animals (Hu et al., 2009). Sulfur isotopic variation is represented by the ratio of ^{34}S to ^{32}S and is linked to bedrock and rainfall. It therefore is a geographical identifier similar to strontium. The trophic decrease for human ingestion of either of these is less than 1‰. For this research, sulfur is used to identify coastal versus inland origin as well as freshwater food consumption (McCutchan et al., 2003).

Strontium is the only heavy isotope in this research and is unique in many ways, including preparation methods and test equipment. Strontium replaces calcium in the bone and is captured in the tooth enamel during creation of the tooth (Bentley, 2006). Variations in the value of strontium is based on the bedrock in the area as well as whether the diet is more marine or more terrestrial (Katzenberg, 2007). Strontium does not fractionate, which means the amount of strontium in the ground water will be the same amount after ingestion by individuals; there are no differences between trophic levels. It directly reflects the local water and food sources, which can be used to identify origins of individuals (Beard and Johnson, 2000; Freiwald, 2011), as well as migration and diet of individuals and populations (Knudson et al., 2004; Price et al., 2000, 2008; Slovak et al., 2009). This research will use strontium to identify an individual’s movement during life as well as compare with other isotopic data concerning diet.

Stable isotope analysis is the primary approach applied in this study for identifying origin, diet, status, and movement of individuals. This research uses those findings to help identify patterns in the mortuary behavior that may be based on status and origin, which may vary by time period or by location.

For the stable isotope analyses in this research each isotope (except sulfur) has baseline ranges and expected values that were discovered in previous research. The oxygen and strontium stable isotope results in a baseline value for the region has been established from previous research (Freiwald, 2011; Lachniet and Patterson, 2009). The expected values are those from the local area, vegetation, and ground water, while the observed values will be from the individual burial. The accepted range is often stated to be two standard deviations from the baseline values, but previous research suggests that one standard deviation is also acceptable when trying to distinguish subtle differences between regions (Freiwald, 2011). The sample values from this research are plotted against the baseline for the region in order to identify outliers. For carbon and nitrogen, the values are plotted on a graph where nitrogen is the y-axis and carbon is the x-axis. These plots are placed next to known vegetation and animal baseline values in the region and distinct clusters provide evidence of individuals that had similar diets. Sulfur is a relatively new stable isotope to interpret and currently no baseline data exists for the region. That being the case, the sulfur values in this research will be graphed to show the distribution of sulfur over time and space for the burials at Cahal Pech.

Statistical Analysis

In this research I use multivariate statistics in order to identify major and minor trends within the mortuary data. The complex multivariate statistics were conducted using Palaeontological Statistics (PAST) software and Splitstree Neighbor Network software. For the analysis of the mortuary characteristics three methods will be employed: principal component analysis (PCA), non-metric multi-dimensional scaling analysis (MDS), and neighbor network unrooted cluster analysis (NN). The mortuary data are turned into binomial data representing presence/absence of each characteristic (Appendix A, Table A.3). This allows for each grave good type to be considered individually by burial. It also allows for a more precise interpretation of what characteristics are changing and how they change over time/space. In order to interpret changes over time, space, age, sex, or origin without bias, these characteristics are not included in the mortuary analysis. PCA is used to narrow down the number of variables within the data that account for most of the variation seen. PCA works by loading each characteristic on multiple components and then graphing the distribution of the burials within the two components.

Loading is the amount of correlation each characteristic has with each component. The loading information identifies which characteristics are accounting for the most variation within the data and are considered the characters with the largest absolute value. For example, a characteristic with a loading score of .95 for principal component 1 is strongly correlated (positively) and the burials that have that characteristic will fall close to the PC1 line. The characters identified by the PCA are used to inform the MDS analysis.

Non-metric multidimensional scaling analysis (MDS) is an ordination technique that allows the user to choose to display the information on either a two-dimensional or three-dimensional graph (Gower, 1971; Holland, 2008). This research uses Euclidean distance for the MDS to find a solution that best explains the trends in the data and then plots the points (individual burials) on a scatter plot. This research will use MDS to group burials by shared mortuary characteristics. The characteristics are weighted so the most influential characteristics are the ones that explain the most variation between burial practices.

Neighbor network created by the Splitstree software is another clustering method that creates an unrooted tree based on similarities and differences between burials. The distances are weighted splits that are then graphed on a splits tree that takes into account both distances as well as groupings in the data (Bryant and Moulton, 2004). The weighted splits are characteristics that are determined and ranked by their influence over the data. The similarities and differences are represented by boxes and branches, which in turn represent borrowing and branching respectively. Neighbor network produces branch clusters that represent common burial practices. Once the data is clustered, I will return to the mortuary database in order to identify the variables that are causing the clustering and branching.

The statistical analyses allow for multiple lines of evidence, mortuary data and stable isotope data, and multiple statistical methods to justify the fit (or lack thereof) of each of the models. The methods in this research are wide-ranging and have been proven valid by previous research (Bartelink et al., 2014; Freiwald et al., 2014; Hoggarth, 2012; Katzenberg, 2007; Rand et al., 2013) and provide appropriate tools to test the models created by this research, as found in Chapter 3. The ability to utilize multiple lines of evidence and statistical methods allows for a more precise determination of the models.

CHAPTER 5 - RESULTS

This chapter presents the results of the stable isotope analyses for each isotope and biological material as well as the mortuary analysis that uses characteristics determined by the stable isotope analysis. These results inform the interpretation of the models in the following chapter. All raw isotope data, including carbon and nitrogen ratio (C:N) information and weights, can be found in Appendix C.

Stable Isotopes

The carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$) stable isotope analysis was performed on bone collagen for eight individuals and tooth dentin collagen for twelve individuals. Of the 12 tooth dentin samples, 10 were serial sampled, which means they were sampled multiple times along the crown and root of the tooth. Table 5.1 shows the results for the $\delta^{13}C$ and $\delta^{15}N$ for the bone collagen and tooth dentin samples and Figure 5.1 illustrates the association between $\delta^{13}C$ and $\delta^{15}N$ for these samples. The $\delta^{13}C$ values for collagen represent the protein portion of an individual's diet. For these data presentations, the tooth dentin samples that were serial sampled were included as an average for the individual.

Table 5.1. $\delta^{15}N$ and $\delta^{13}C$ of each sample. Tooth samples included in this table as averages are indicated with an *. T indicates a tooth and B indicates bone sampled.

	Element Sampled	**$\delta^{15}N$**	**$\delta^{13}C$**
CHP-SI-01T*	Right M^2	10.597	-7.951
CHP-SI-03T*	Left M^3	10.04	-8.034
CHP-SI-06T*	Left PM^2	9.56	-8.26
CHP-SI-07T*	Left PM^1	9.95	-11.97
CHP-SI-09B	Long bone shaft	9.8	-9.3
CHP-SI-11T*	Right PM^1	11.38	-9.23
CHP-SI-11B	Left femur shaft	10.81	-9.28
CHP-SI-12T*	Right M_1	11.08	-9.34
CHP-SI-12B	Long bone shaft	10.68	-9.91
CHP-SI-13T*	Right M_1	9.19	-8.74
CHP-SI-13B	Right femur shaft	8.55	-10.17
CHP-SI-14T*	Right M_1	9.59	-11.24
CHP-SI-14B	Right femur shaft	9.45	-10.69
CHP-SI-15T*	Left PM^1	9.13	-8.48
CHP-SI-15B	Left distal radius	9.92	-8.53
CHP-SI-16T *	Right M^2	10.82	-8.25
CHP-SI-18B	Femur shaft	10	-8.48
CHP-SI-19T	Right M^1	8.4	-8.6

The tooth dentin serial samples for $\delta^{13}C$ and $\delta^{15}N$ are presented below (Figures 5.2 – 5.11). Each tooth was sectioned in parallel horizontal slices at specific points along the tooth root and measure between 1mm and 3mm in thickness. Due to preservation and processing, some sections were combined in order to meet the minimum collagen necessary for stable isotope analysis (1mg). This is the reason for differences in the number and labeling of each section. The sections are read from right to left (youngest to oldest growth), with age ranges associated with each section on the bottom axis. For complete carbon and nitrogen stable isotope data see Appendix C, Table C.1.

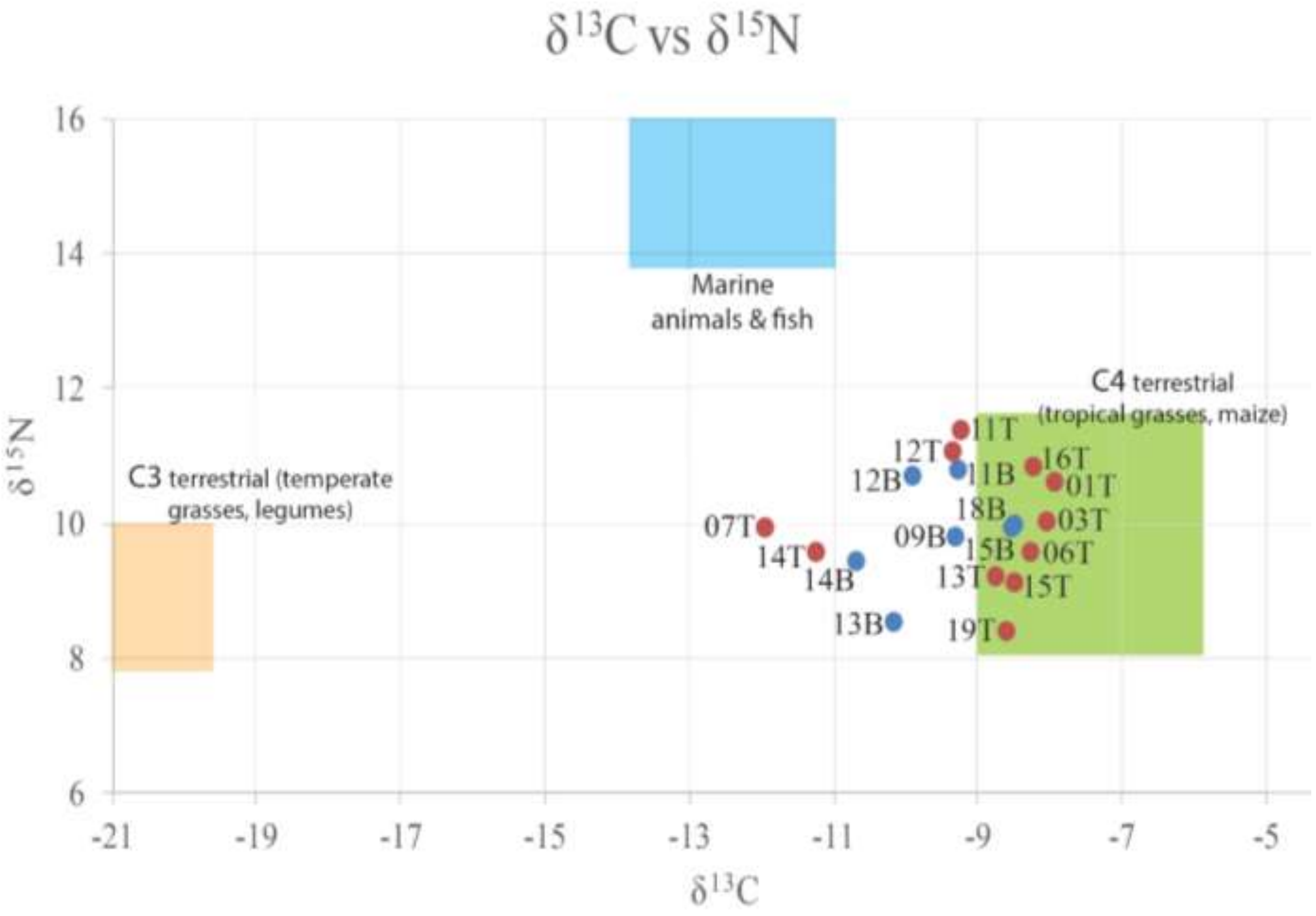


Figure 5.1. δ^{13}C versus δ^{15}N graph of each sample. Bone samples are in blue and tooth dentin samples are in red.

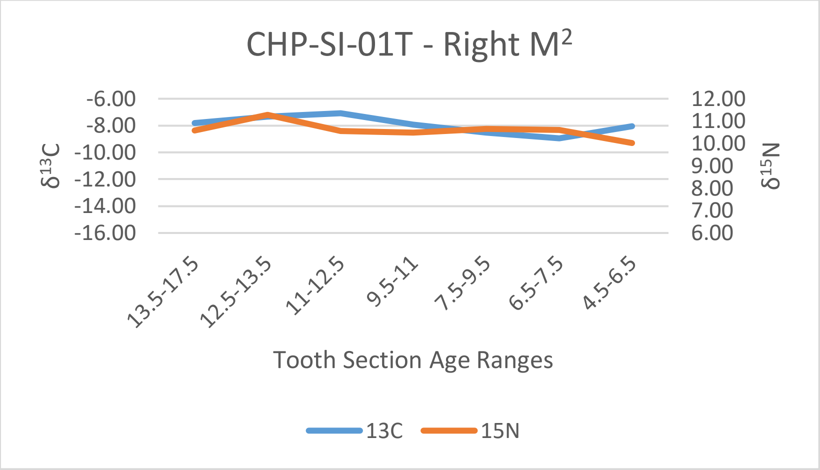


Figure 5.2. Tooth dentin collagen serial sample of CHP-SI-01.

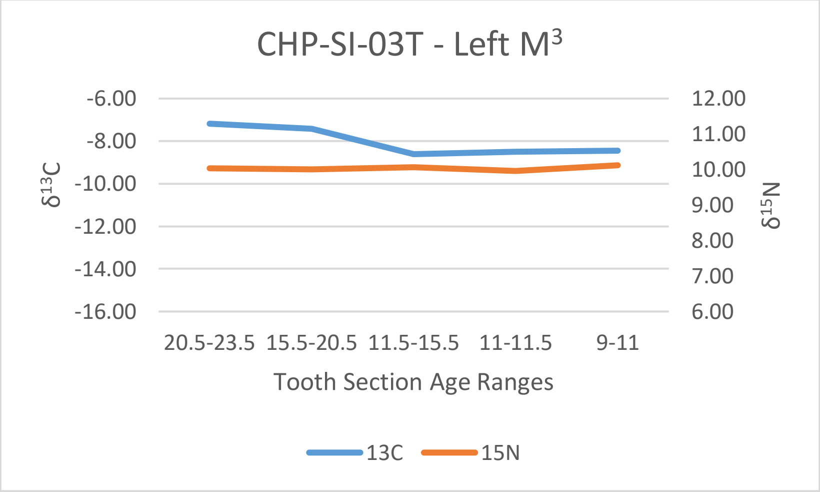


Figure 5.3. Tooth dentin collagen serial sample of CHP-SI-03.

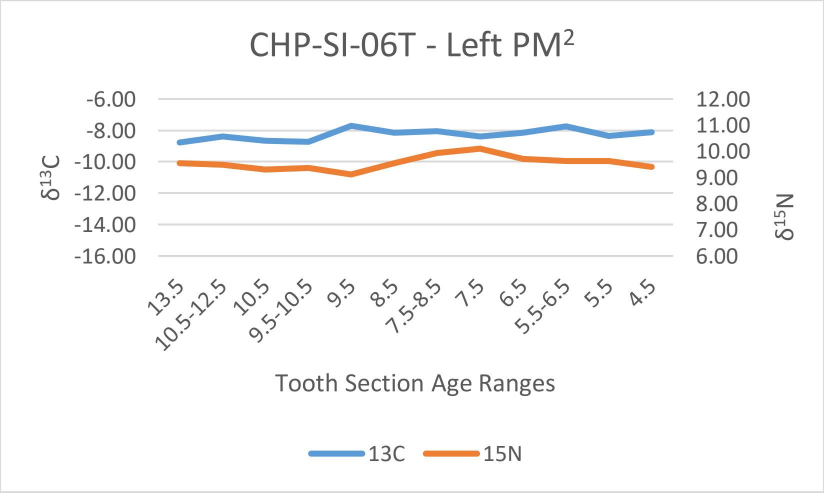


Figure 5.4. Tooth dentin collagen serial sample of CHP-SI-06.

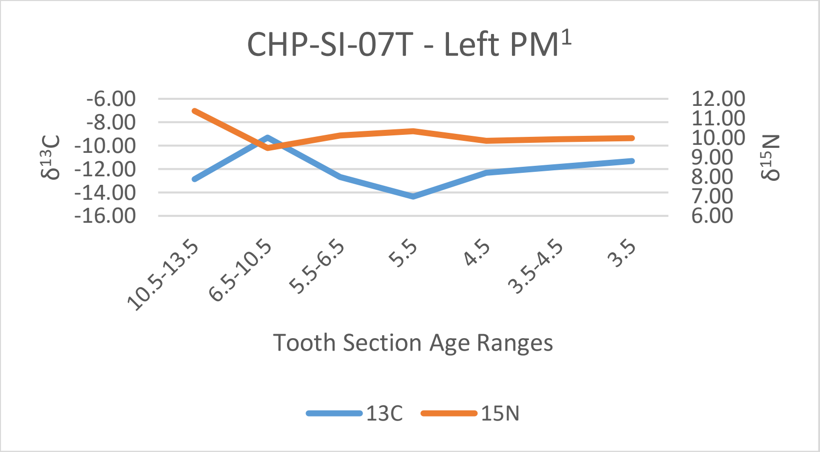


Figure 5.5. Tooth dentin collagen serial sample of CHP-SI-07.

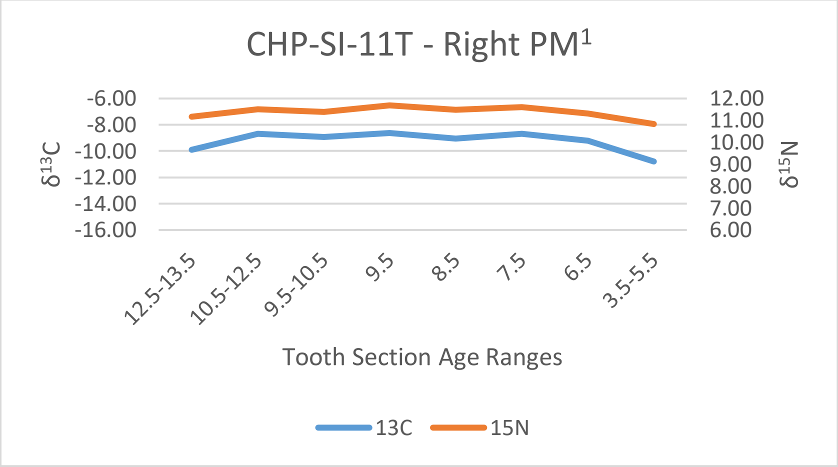


Figure 5.6. Tooth dentin collagen serial sample of CHP-SI-11.

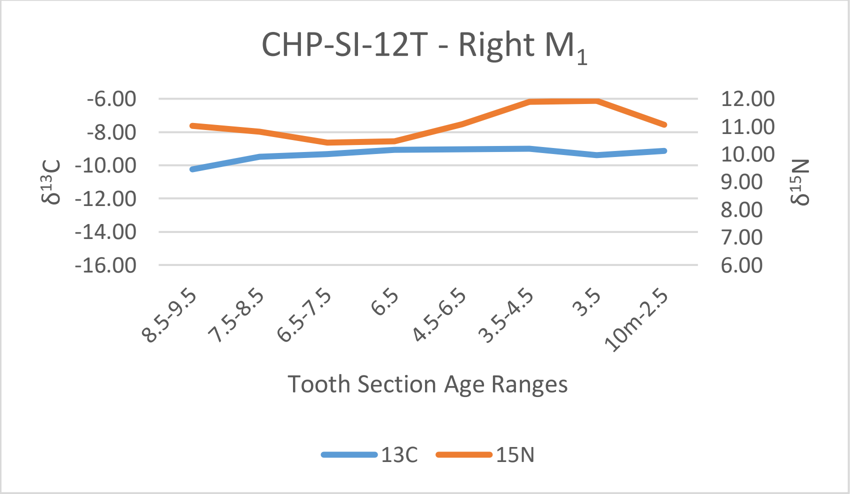


Figure 5.7. Tooth dentin collagen serial sample of CHP-SI-12.

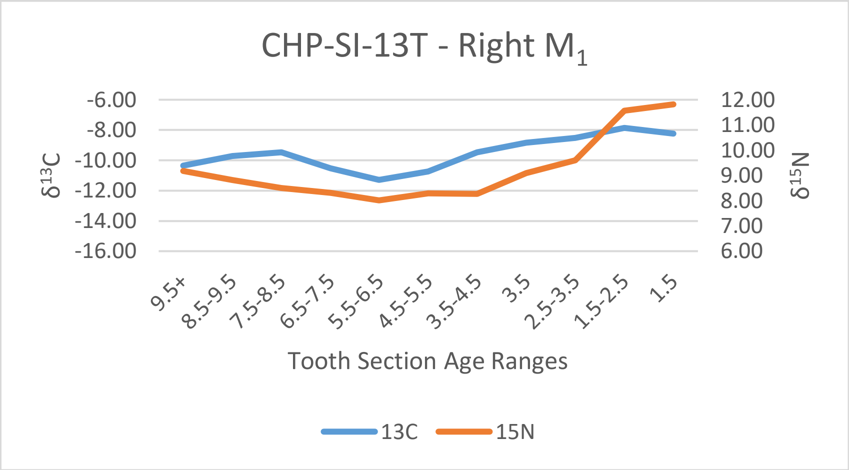


Figure 5.8. Tooth dentin collagen serial sample of CHP-SI-13.

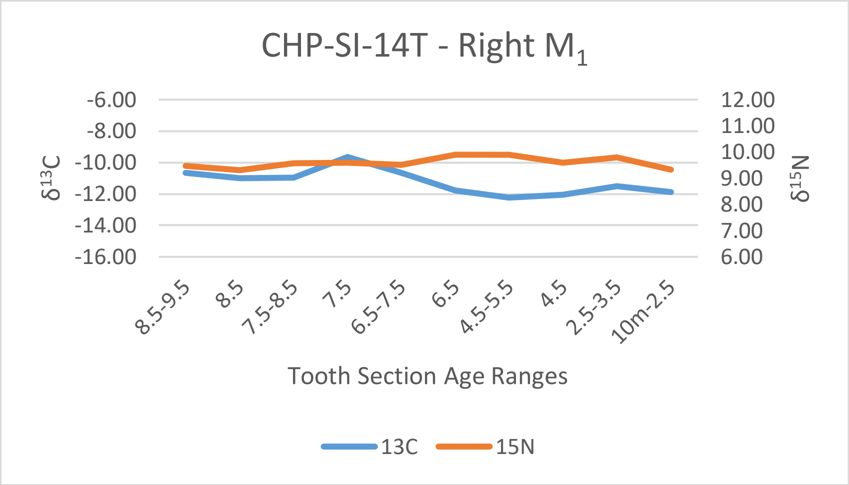


Figure 5.9. Tooth dentin collagen serial sample of CHP-SI-14.

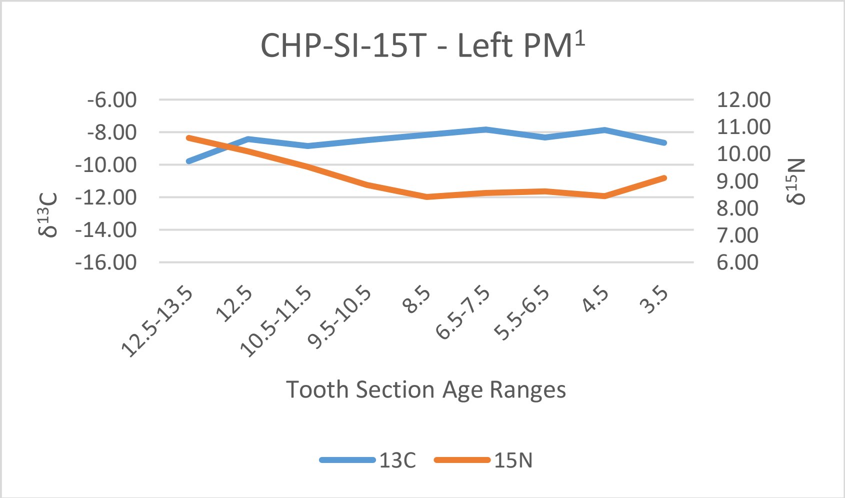


Figure 5.10. Tooth dentin collagen serial sample of CHP-SI-15.

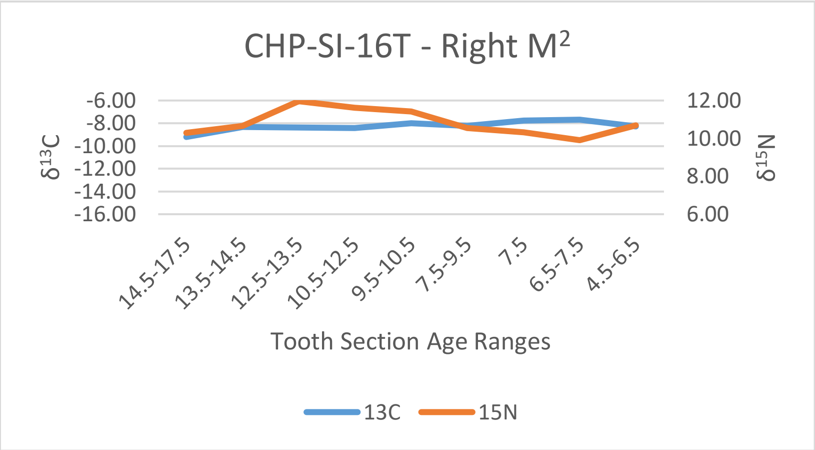


Figure 5.11. Tooth dentin collagen serial sample of CHP-SI-16.

Five bone samples yielded enough collagen, approximately 10mg, to also perform sulfur ($\delta^{34}S$) analysis (Figure 5.12). The $\delta^{34}S$ results are presented in a bar graph because there are limited comparative data and no baseline values for the region. $\delta^{34}S$ does correlate with $\delta^{15}N$ in distinguishing marine versus terrestrial diet where freshwater and riverine fish show a lower $\delta^{34}S$ value versus terrestrial animals. The scatter plot (Figure 5.13) does show a cluster of four individuals with one outlier (CHP-SI-15) for sulfur values. Three out of the four within the

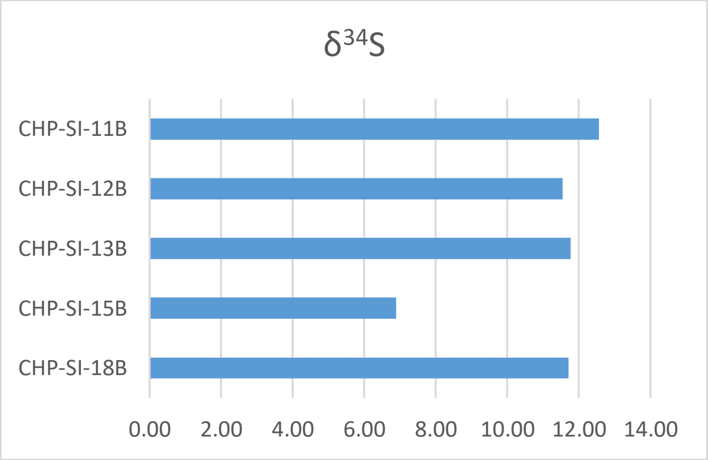


Figure 5.12. $\delta^{34}S$ stable isotope results.

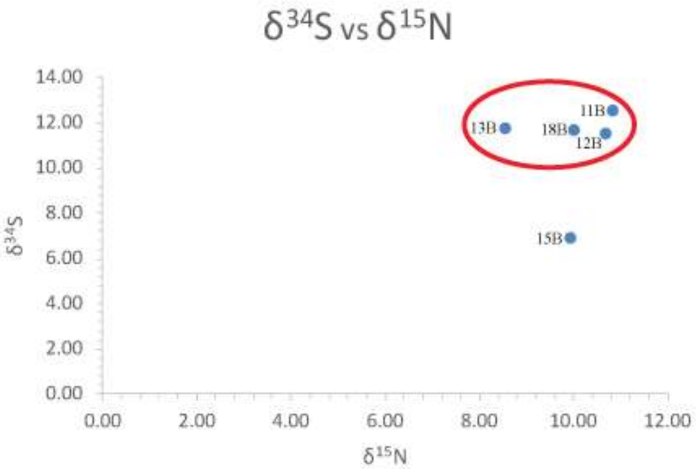


Figure 5.13. $\delta^{34}S$ versus $\delta^{15}N$ stable isotope results. Cluster highlighted by red circle.

cluster have similar nitrogen values with only CHP-SI-13 having a slightly less enriched nitrogen value. This likely causes of these patterns are presented in the Discussion chapter. For complete sulfur stable isotope data see Appendix C, Table C.2.

Strontium (^{87}Sr/^{86}S) was performed on bone apatite for 16 individuals and tooth enamel for 24 individuals (Table 5.2). Fourteen individuals had both a bone and tooth sample available for ^{87}Sr/^{86}S analysis and that is noted in Table 5.2. The graph of ^{87}Sr/^{86}S values found in Figure 5.14 includes a yellow band that highlights the expected ^{87}Sr/^{86}S value ±1 standard deviation (.708246 - .7087596) (Freiwald, 2011). All values within the yellow band are considered local values for Cahal Pech, based on the evironmental baseline developed by Freiwald (2011). For complete strontium stable isotope data see Appendix C, Table C.3.

Table 5.2. ^{87}Sr/^{86}S, δ^{13}C, and δ^{18}O values for the bone apatite and tooth enamel. Sample material is indicated by either a T for tooth or B for bone.

	Element Sampled	**87Sr/86S**	**δ^{13}C**	**δ^{18}O**
CHP-SI-01B	Right femur shaft	0.70892	-4.03	-5.48
CHP-SI-01T	Right M^2	0.70854	-3.24	-3.72
CHP-SI-02B	Right radius shaft	0.70866	-3.7	-5.99
CHP-SI-02T	Right C^1	0.70844		
CHP-SI-03B	Right femur shaft	0.70854	-3.98	-5
CHP-SI-03T	Left M^3	0.70835	-2.91	-4.06
CHP-SI-04B	Right femur shaft	0.70851	-4.3	-6.3
CHP-SI-04T	Left M_2	0.70856	-3.56	-4.02
CHP-SI-05B	Right radius shaft	0.70917	-5.28	-6.03
CHP-SI-06B	Right femur shaft	0.70867	-4.47	-5.63
CHP-SI-06T	Left PM^2	0.70881	-2.66	-3.27
CHP-SI-07B	Left femur shaft	0.70854	-5.97	-6.44
CHP-SI-07T	Left PM^1	0.70901	-6.03	-3.87
CHP-SI-08B	Right femur shaft	0.70965	-3.47	-5.39
CHP-SI-08T	Left Max. PM	0.70852	-3.03	-3.50
CHP-SI-09B	Long bone shaft	0.70864	-3.54	-5.46
CHP-SI-09T	Right M^1	0.70865		
CHP-SI-10B	Left femur shaft		-4.78	-5.77
CHP-SI-10T	Right PM_1	0.7086	-3.68	-3.16
CHP-SI-11B	Left femur shaft	0.70836	-5.8	-6.54
CHP-SI-11T	Right PM^1	0.70851	-5.56	-2.56
CHP-SI-12B	Long bone shaft	0.70848	-6.01	-4.75
CHP-SI-12T	Right M_1	0.70855	-4.30	-3.19
CHP-SI-13B	Right femur shaft		-6.25	-5.59
CHP-SI-13T	Right M_1	0.7093	-3.35	-3.42
CHP-SI-14B	Right femur shaft	0.70855	-5.75	-5.72
CHP-SI-14T	Right M_1	0.70843	-6.20	-3.46
CHP-SI-15B	Left distal radius	0.70825	-8.55	-6.4
CHP-SI-15T	Left PM^1	0.70781	-1.69	-2.11
CHP-SI-16B	Right Tibia shaft	0.70857	-5.86	-6.48
CHP-SI-16T	Right M^2	0.7086	-3.62	-3.78
CHP-SI-17B	Right femur shaft	0.7086	-6.5	-4.79
CHP-SI-18B	Femur shaft	0.70837	-5.16	-5.23
CHP-SI-19T	Right M^1	0.70851	-5.2	
CHP-SI-20T	Right M_1	0.70843		
CHP-SI-22T	Unknown	0.70861		
CHP-SI-23T	Unknown	0.70881		
CHP-SI-24T	Unknown	0.70877		
CHP-SI-25T	Unknown	0.70869		
CHP-SI-26T	Unknown	0.70877		
CHP-SI-27T	Unknown	0.70872		

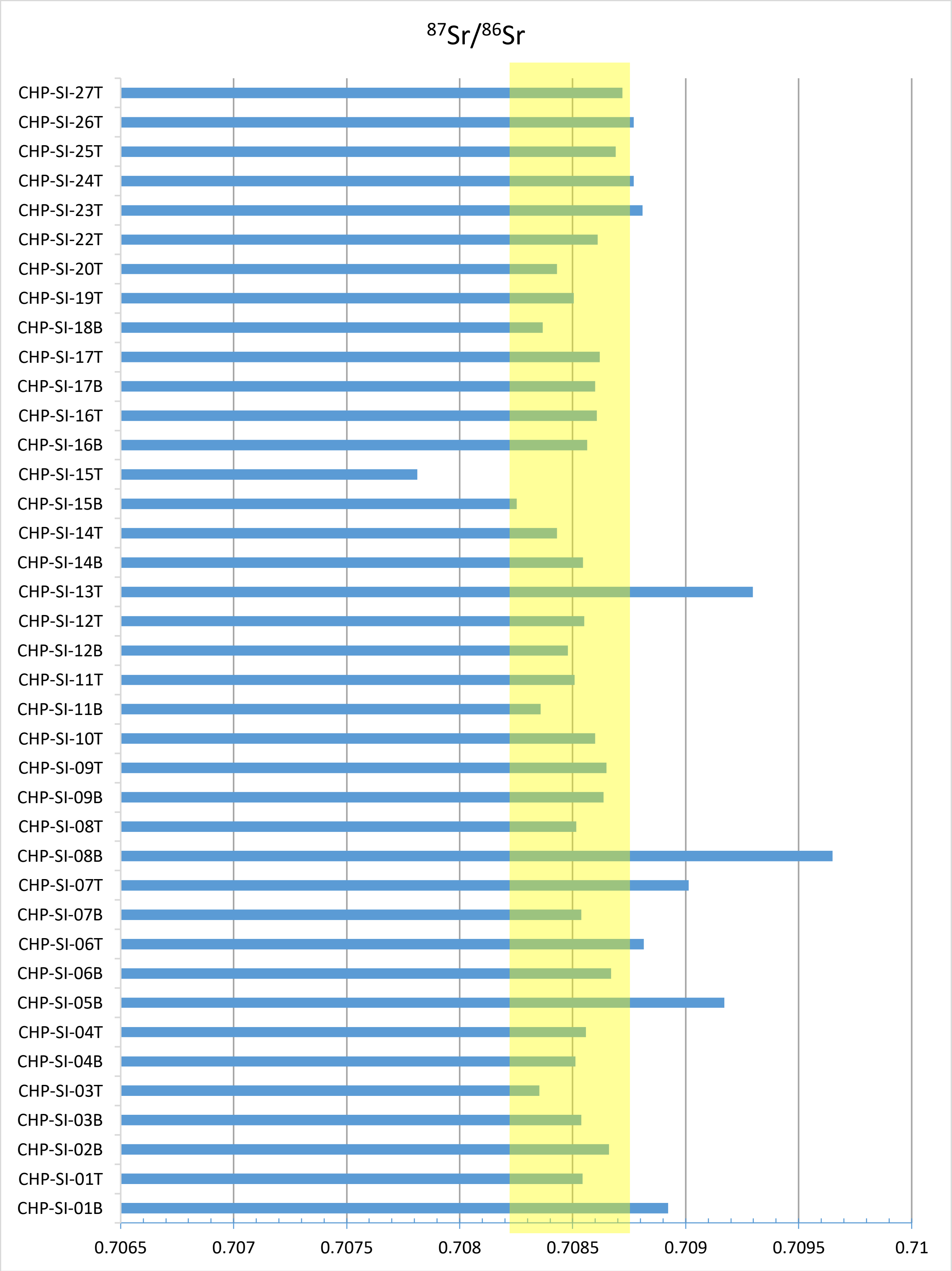


Figure 5.14. $^{87}Sr/^{86}S$ values for all individuals. Sample material type is designated as either a T for tooth or B for bone. The yellow band represents the expected/local value range for the Belize River Valley ±1 standard deviation (Freiwald, 2011).

Bone apatite and tooth enamel also produced stable isotope values for carbon ($\delta^{13}C$) and oxygen ($\delta^{18}O$) found in Table 5.2. The $\delta^{13}C$ in the bone apatite represents the carbon ingestion from the whole diet (proteins, lipids, and carbohydrates), while the $\delta^{18}O$ is directly correlated with rainfall and therefore an individual's water source. The correlation between $\delta^{13}C$ and $\delta^{18}O$ in apatite and enamel is illustrated in Figure 5.15. This relationship is between an individual's local water source and consumption of carbon from the whole diet and is used to identify local versus non-local individuals. The baseline $\delta^{18}O$ value for tooth samples from several Belize River Valley sites is -2.99 ±1.98 (2 standard deviations; range -4.97 to -1.01 (Freiwald, 2011; Lachniet and Patterson, 2009). This range includes all of the tooth samples in this research as well as two of the bone samples from the lower end of the range. When using one standard deviation (-2.99 ±0.99; range -3.98 to -2.0), several tooth samples fall outside the range, unlike Figure 5.15, where the only tooth and bone sample outside of the two standard deviation range come from CHP-SI-15. The interpretation of the $\delta^{13}C$ and $\delta^{18}O$ apatite and enamel isotope data is found in the Discussion chapter. It must be noted that $\delta^{18}O$ isotope measurements are often not very robust; according to Pestel et al. (2014) there is too much variability in the $\delta^{18}O$ findings between labs to use $\delta^{18}O$ from multiple labs to

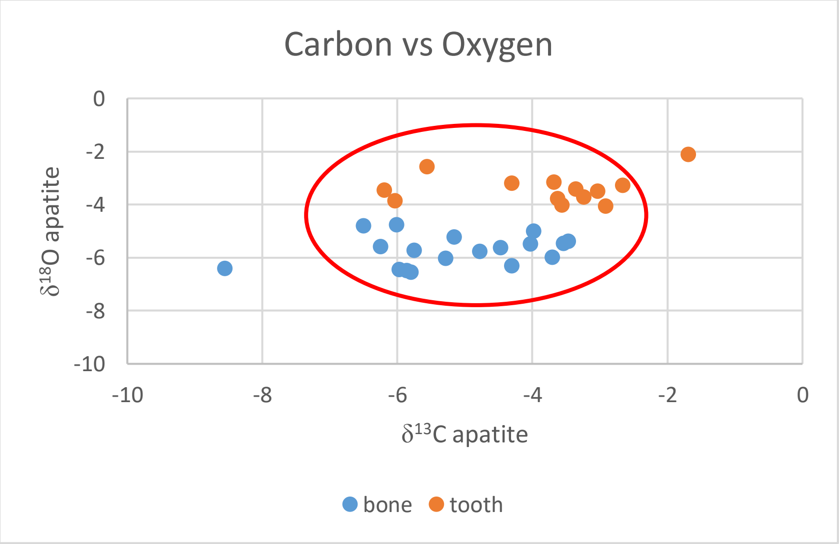


Figure 5.15. $\delta^{13}C$ versus $\delta^{18}O$ stable isotope results. Bone apatite samples are in blue and tooth enamel samples are in red. The two outliers are bone and tooth sample from the same individual (CHP-SI-15). Cluster highlighted by red circle.

examine population patterns. That said, δ^{18}O used in conjunction with δ^{13}C apatite and as a supplement to ^{87}Sr/^{86}S values is acceptable. The oxygen data in this research was performed at two separate labs, the University of North Carolina analyzed all the enamel samples and the lab at University of Washington analyzed the bone samples. For compete oxygen and carbon stable isotope data see Appendix C, Table C.4.

Mortuary Analysis

There were three multivariate analyses performed on the mortuary database found in Appendix A: Principle Components Analysis (PCA), Multidimensional Scaling (MDS), and Neighbor Network (NN). The complete mortuary database that includes all the characteristics that were present in at least one burial as well as time period, origin, and location of burial can be found in Appendix A (Table A.2) and includes the raw data. The database that is used for the statistical analyses that is binomially coded and does not include time period, location of burial, age, sex, and origin in order to interpret trends without biases can be found in Appendix A (Table A.3).

Principle Component Analysis was run in PAST (Paleontological Statistics Program) as the initial analysis in order to identify the possible number of variables that account for the variation within and between burials. The PCA results are found in Table 5.3 and show that three components explain over 50% of the variation in the data. Figure 5.16 is a scatterplot that shows the results of the PCA with three distinct clusters of burials indicated by the circles.

Table 5.3. PCA result percent of variance table for the first three components.

PC	Eigenvalue	% variance
1	1.07825	28.628
2	0.566424	15.039
3	0.321512	8.5364
	TOTAL	52.2034

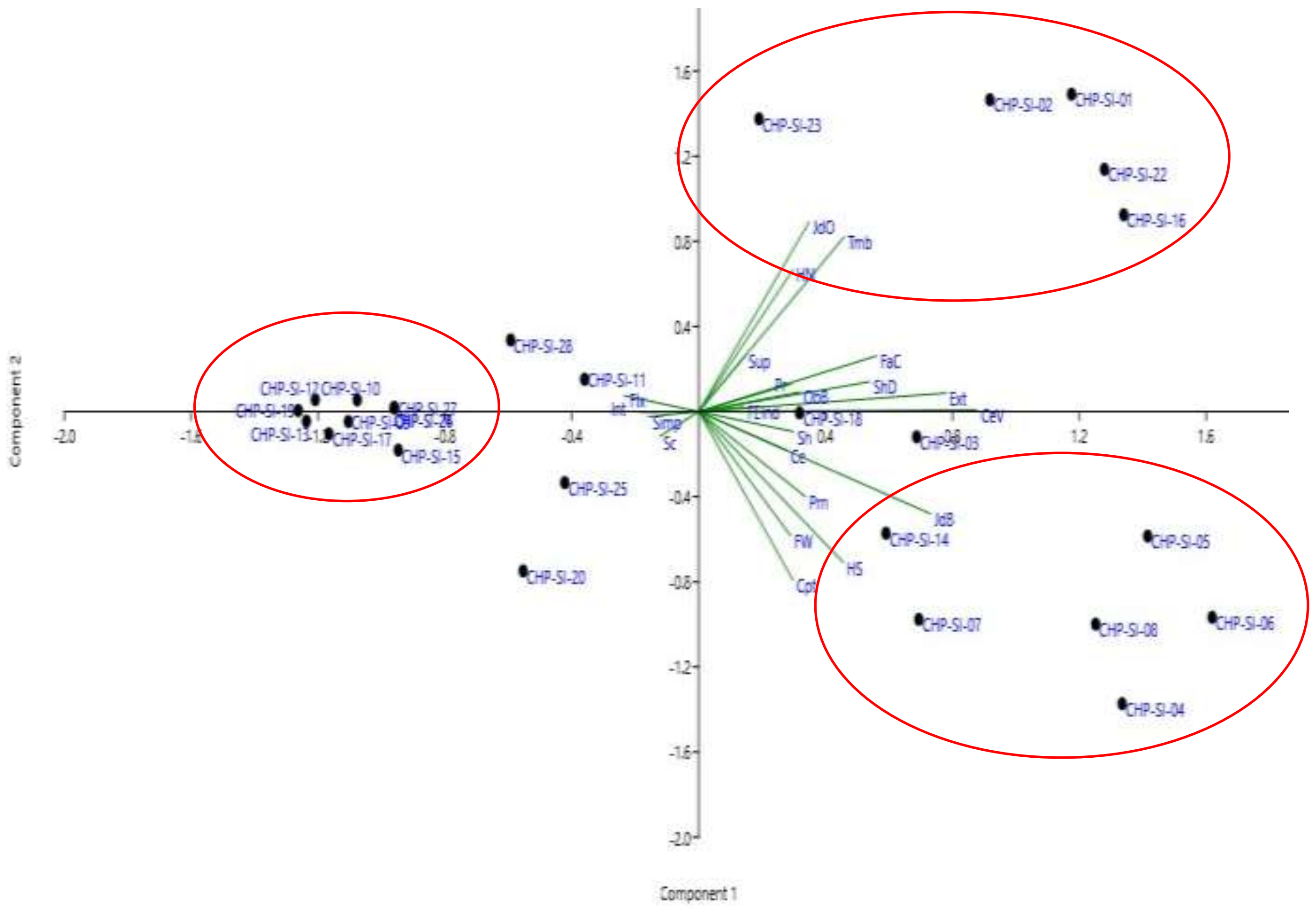


Figure 5.16. PCA scatterplot. Red circles represent distinct clusters of burials.

To figure out what variables are responsible for the clustering I have included the loading information in Table 5.4. The variables that load on the first component with the largest absolute value are extended, ceramic vessels, and jade beads. The second component consists of crypt, tomb, and jade ornament. Finally, other ceramics (items other than vessels, such as sherds or unidentifiable ceramic objects) loads the highest on the third component. The PCA has identified the variables likely causing the most variation within the data. That means the presence of absence of these variables within the data is causing burials to cluster together.

Non-metric Multidimensional Scaling analysis (MDS) was performed in PAST on the dataset found in Appendix A, Table A.3. The purpose of MDS is to identify the goodness of fit (stress) between the variables and the burials. The PAST output shows that two dimensions fit with a stress of 0.2145 and three dimensions fit with a stress of 0.1782. Neither stress level for two or three dimensions is considered good or even fair by statistical standards (Wickelmaier, 2003), but when considering the type of data and the PCA output it is acceptable to use two dimensions (Dr. Ekaterina Smirnova, personal communication).

Table 5.3. PCA result percent of variance table for the first three components.

	PC 1	PC 2	PC 3
Pr	0.1449	0.06415	0.13115
Sc	-0.06135	-0.05792	-0.11072
Int	-0.117	0.037449	-0.30056
Ind	0.13232	-0.0011	0.001351
Ext	0.38946	0.043457	-0.1436
Flx	-0.09169	-0.00161	0.24079
Sup	0.072688	0.131	0.11644
Prn	0.16722	-0.19891	-0.09172
Simp	-0.07885	-0.01191	0.0444
Cpt	0.14819	-0.39487	0.26464
Tmb	0.22878	0.40934	-0.13447
HN	0.14817	0.33265	-0.05512
HS	0.22734	-0.35332	-0.10662
FE	0.070404	0.011013	0.15466
FW	0.1441	-0.29033	-0.2753
CeV	0.43737	0.003589	-0.22342
Ce	0.13807	-0.09067	0.51198
ShD	0.26841	0.069769	0.23071
Sh	0.14896	-0.04681	-0.25673
JdO	0.17341	0.44417	0.096855
JdB	0.36433	-0.23934	0.038918
ObB	0.15944	0.045997	0.36459
FaC	0.2793	0.13037	-0.02072

Several variations of MDS were run in PAST using two dimensions in order to try to illustrate clustering based on time, location, age and sex, and origin (Figures 5.17 – 5.20). These MDS scatterplots illustrate that time, location, age, sex, and origin do not account for the variation in the data. The scatterplots do, however, have the same clusters found in the PCA as seen by the black lines on the graphs that are due to grave type (tomb), ceramics, and jade beads. This indicate that while time, location, age, sex, and origin may not be the variables that explain the variation, there is likely some combination of characteristics such as grave type and grave goods that explains the clusters of burials. In order to strengthen the argument that these clusters, and their associated characteristics, are in fact useful in delimitating differences in burials a third multivariate analysis was performed.

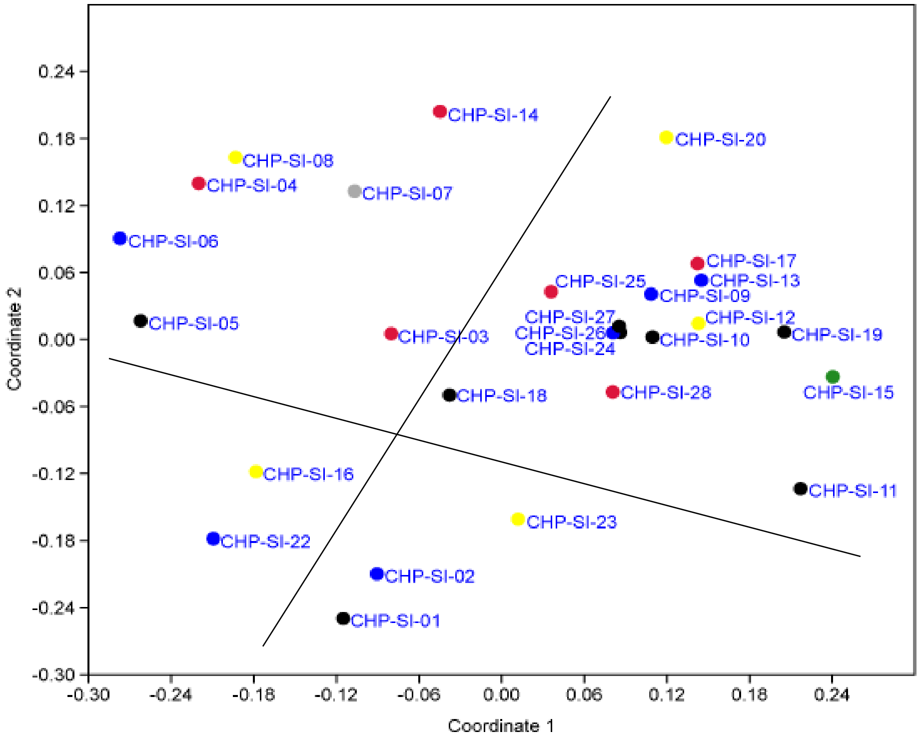


Figure 5.17. MDS scatterplot with burials color coded for time period. Key: Late Preclassic=Red, Early Classic=Blue, Late Classic=Black, Terminal Classic=Yellow, Historic=Green, Unknown=Grey.

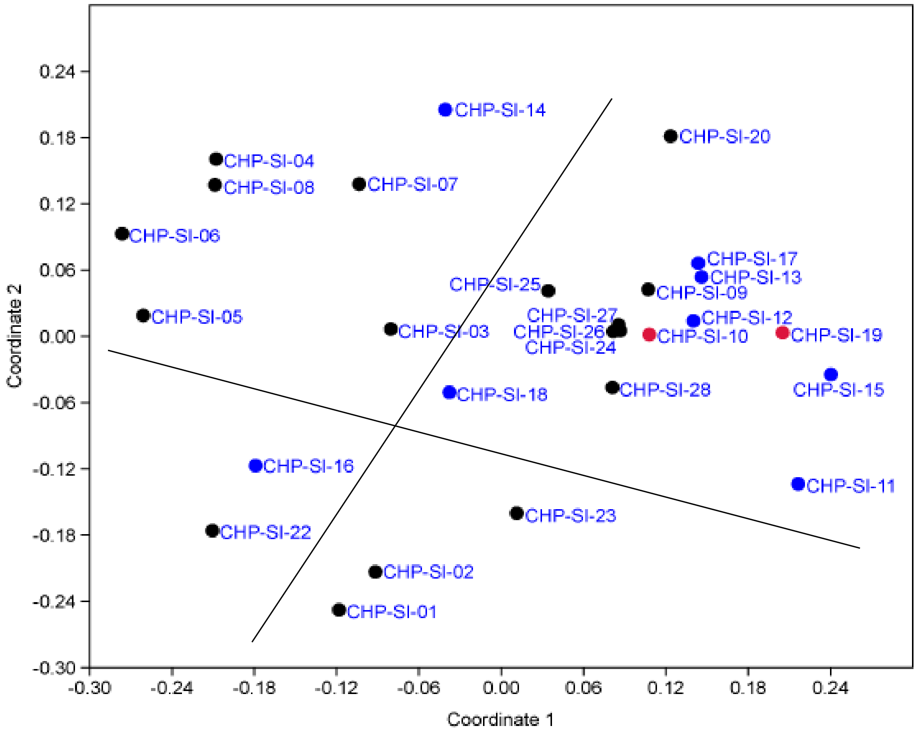


Figure 5.18. MDS scatterplot with burials color coded for their location within the site. Key: Eastern Triadic Structure=Black, Elite Plaza or Structure=Red, Public Plaza or Structure=Blue.

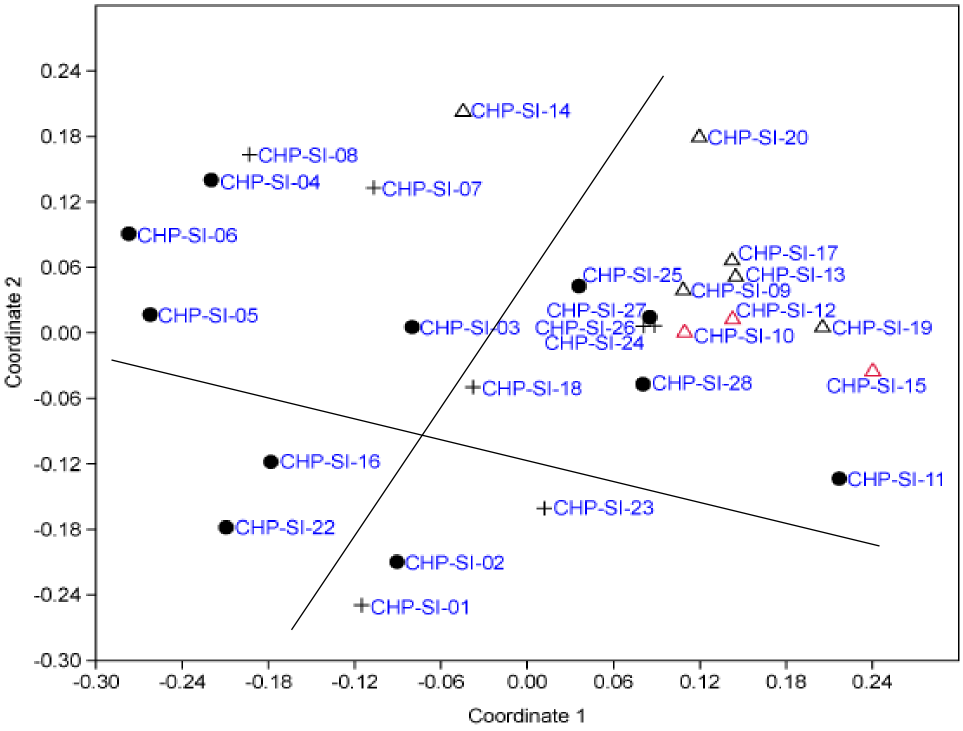


Figure 5.19. MDS scatterplot with burials color coded for both age and sex. Key: Adult=Black, Subadult=Red, Female=Plus (+), Male=Dot (●), Sex Indeterminate=Triangle (Δ).

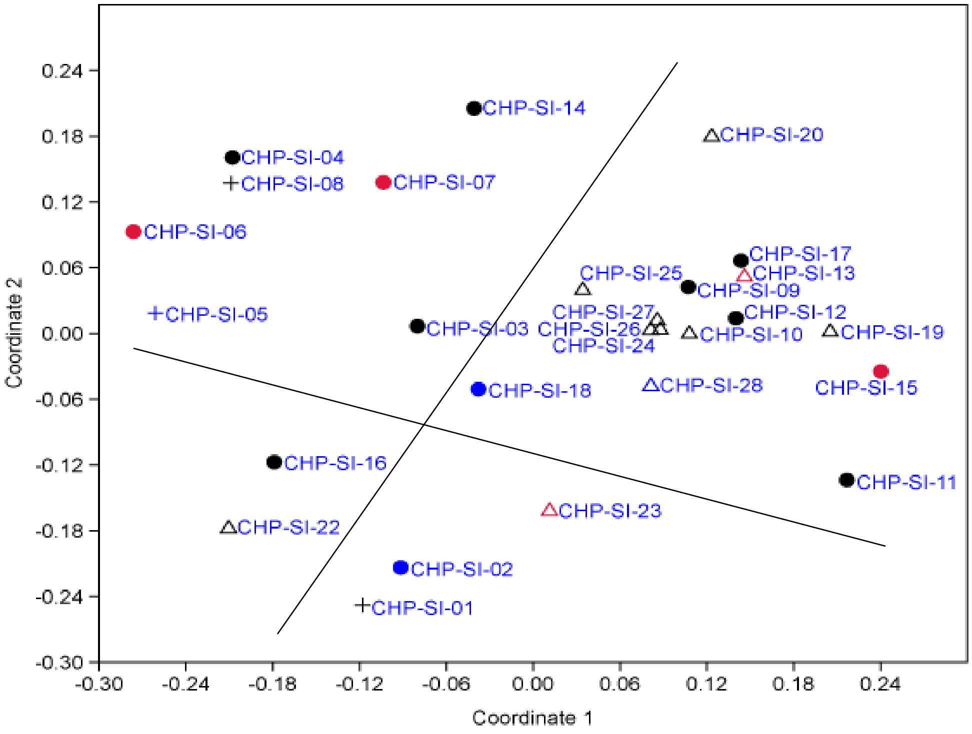


Figure 5.20. MDS scatterplot with burials color coded for origin based on local tooth and bone isotope values. Key: Local Tooth=Black, Non-local Tooth=Red, No Tooth=Blue, No Bone=Triangle (Δ), Non-local Bone=Plus (+), and Local Bone=Dot (●).

The final statistic used on the mortuary data is Neighbor Network (NN) analysis which was also run in PAST. The goal of NN is to illustrate through an unrooted tree clusters of burials based on similarities and distances. The amount, or lack, of similarity is represented by boxes and branches within the tree. The NN results are presented in Figure 5.21 has three distinct clusters separated by the red lines. These clusters consist of the same burials seen in the PCA and MDS analyses. The first cluster consists of burials CHP-SI-04, -05, -06, -07, -08, and -14 (red circle - Cluster #1). These burials all share several characteristics: primary individuals that have ceramic vessels and jade beads as grave goods. The second cluster consists of CHP-SI-01, -02, -03, -16, -22, and -23, which, along with being primary individuals with ceramic vessels, are all tomb burials (blue circle – Cluster #2). Finally, the third cluster is the largest and consists of CHP-SI-09, -10, -11, -12, 13, -15, -17, -18, -19, -20, -24, -25, -26, -27, and -28 (green circle – Cluster #3). This large cluster appears defined largely in negative terms, such as including no individuals with head to the north, and no shell or faunal grave goods. This large cluster does have minor clusters within it, as represented in Figure 5.22.

The first minor cluster (purple circle M1) consists of CHP-SI-24, -26, and -27. These burials are all primary individuals that fall within Cluster 3. What sets them apart is that there are no grave goods present; location and biological similarities include that they are all adults, with a local tooth value, and they are all buried in an Eastern Triadic Shrine. The second minor cluster (yellow circle M2) consists of CHP-SI-09, -10, - 12, -13, and -17, which, within Cluster 3 was the largest group. These burials do, however have a characteristic shared by all: they either have no mortuary information present or all mortuary characteristics are absent. They are also all sex indeterminate. The third minor cluster (pink circle M3) consists of CHP-SI-04, -05, -06, and -08 share characteristics with the large Cluster 1: they are all primary individuals with ceramic vessels and jade beads with an extended body position and their head to the south. These four burials also share the characteristic of being an adult buried in an Eastern Triadic Structure.

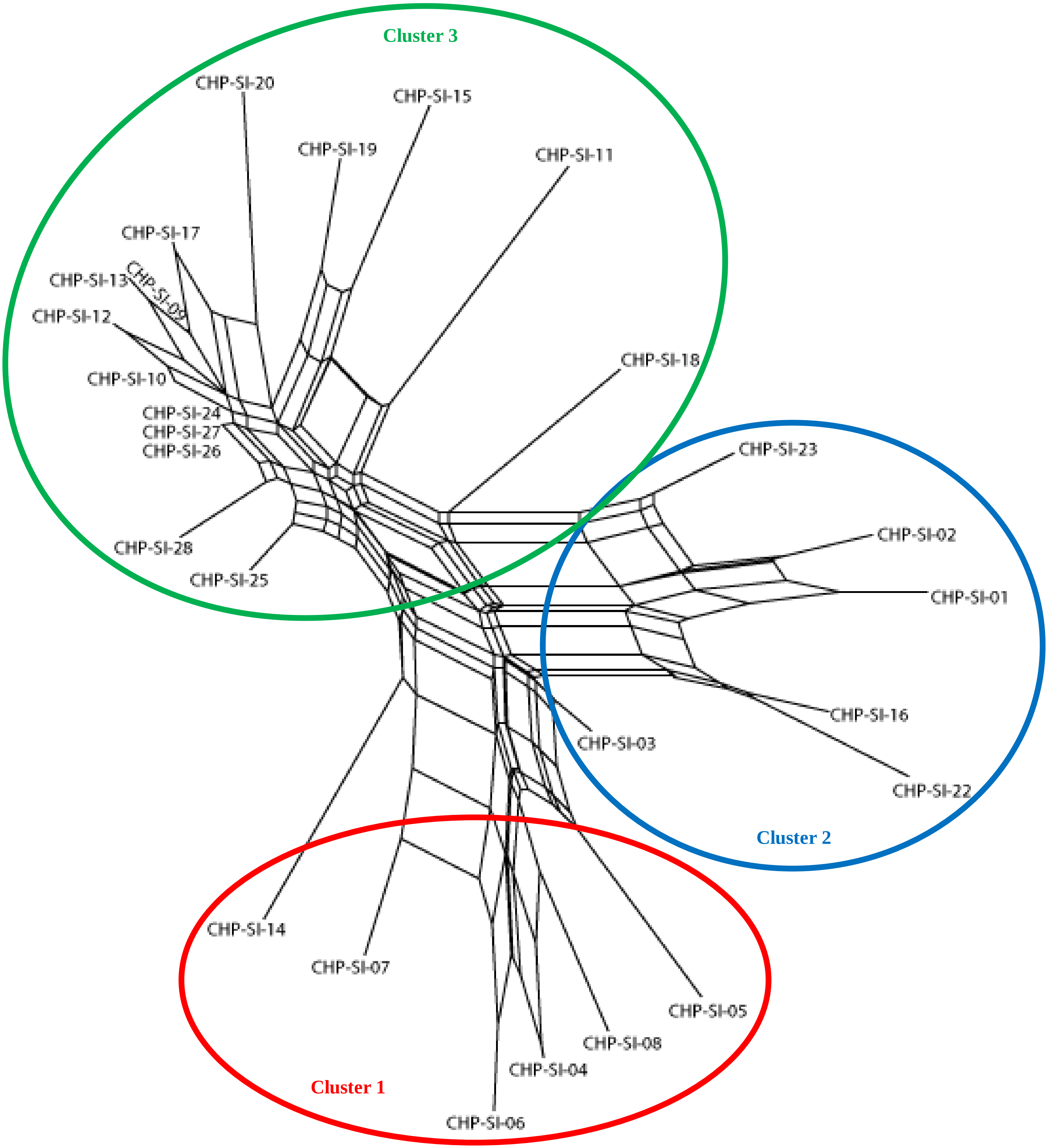


Figure 5.21. Neighbor Network unrooted tree. The red line distinguishes the two major clusters.

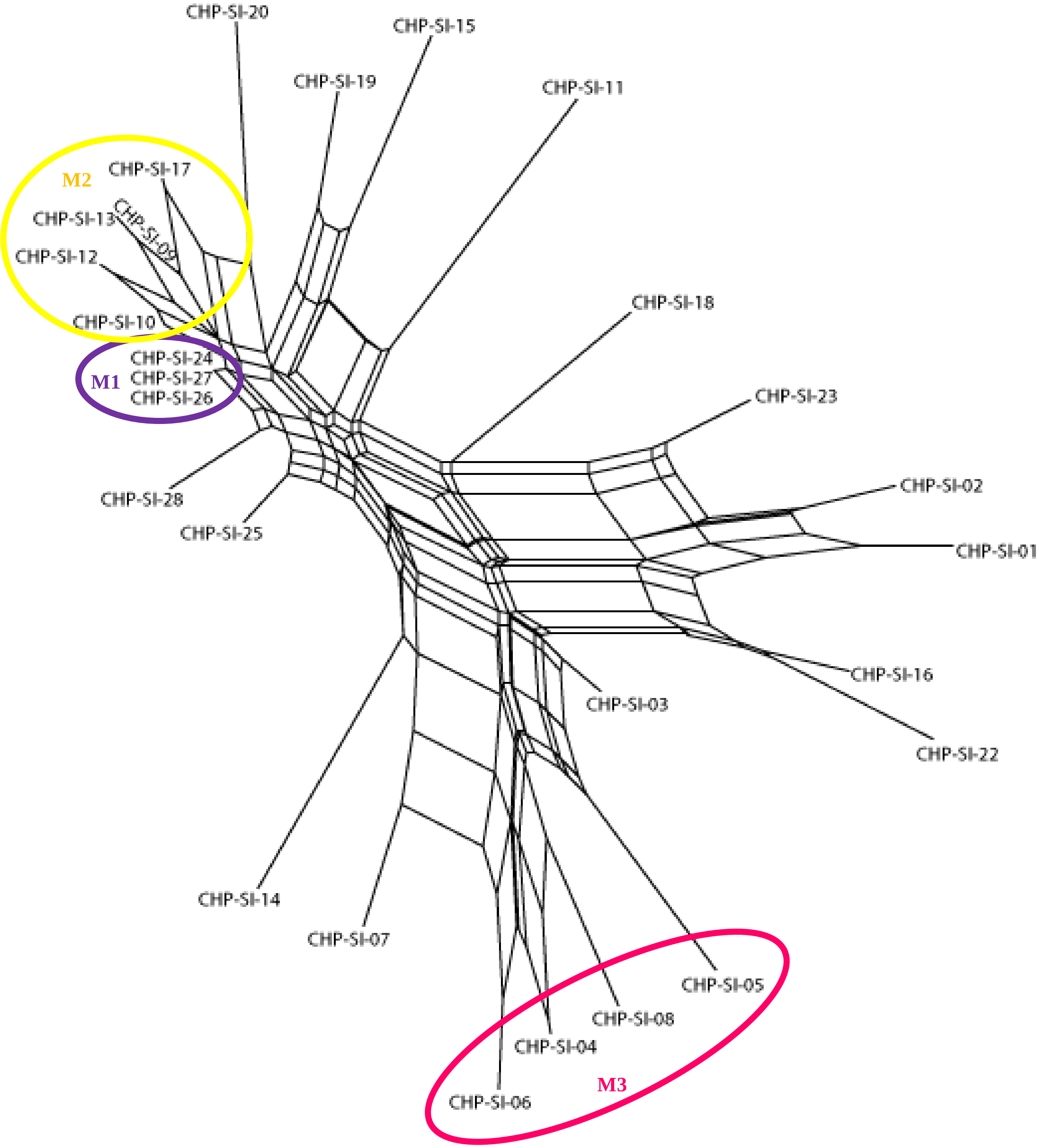


Figure 5.22. Neighbor Network unrooted tree. The colored circles distinguish the minor clusters.

The NN result identifies that the combination of several characteristics, such as grave type (tomb) and grave goods (ceramic vessels and jade beads). These characteristics explain the initial distinction between burials. The secondary distinction between burials indicates that age and sex, location of the burial within the site, and the origin of the individual may be influencing the mortuary practices of the Maya, albeit less significantly then the initial characteristics. Mortuary behavior does not appear to be correlated to time period. The statistical and isotope results outlined in this chapter will inform the model selection, interpretation, and discussion found in the following chapter.

CHAPTER 6 - DISCUSSION

This chapter presents the results of both the stable isotope analyses and the statistical analyses run on the mortuary data. The results are first and foremost used in determine the model that best fits the scenario at Cahal Pech, as first presented in Chapter 3.

Stable Isotope

$\delta^{13}C$ & $\delta^{15}N$ Bone and Tooth Dentin Collagen. The stable isotope results obtained in this research were expected to help interpret diet and status, as well as origin and lifetime movement of individuals. The expected stable isotope result for diet and status was that all individuals would show a mainly maize diet with enriched $\delta^{13}C$ values that ranged from -9.0‰ to -6.0‰ and $\delta^{15}N$ values below 12.0‰. The $\delta^{15}N$ values could range as high as 14.0‰, which would indicate an increase in marine foods within the diet, or consumption of second-order carnivores, and therefore a varied diet with access to high value foods.

The stable isotope results for $\delta^{13}C$ and $\delta^{15}N$ show a community relying mostly on maize, but there is some consumption of C_3 plants or terrestrial animals as seen in Figure 6.1. C_3 plants in Belize include allspice, squash, cashews, and cacao (http://www.folklife.si.edu). Three individuals have stable isotope signatures consistent with greater consumption of C_3 foods; CHP-SI-07 (dentin collagen), CHP-SI-13 (bone collagen), and CHP-SI-14 (bone & dentin collagen). Even though these individuals do show inclusion of C_3 plants or animals that foraged on C_3 plants, the difference from the rest of the group is not large. CHP-SI-07, CHP-SI-13, or CHP-SI-14 are from distinct time periods (Appendix A, Table A.2), which indicates that the drought during the Terminal Classic period did not cause changes in the diet that are visible using the techniques employed here.

The $\delta^{15}N$ results do not show significant consumption of nitrogen-enriched foods for the community, such as marine resources. This is likely due to the location of Cahal Pech being over 100 kilometers away from the ocean. The archaeological research does suggest that individuals living at inland sites such as Cahal Pech did, on rare occasions, consumed marine foods (Rand et al., 2013). Unfortunately, the $\delta^{15}N$ results by themselves neither substantiate nor disprove the assumption that these individuals were of elite status.

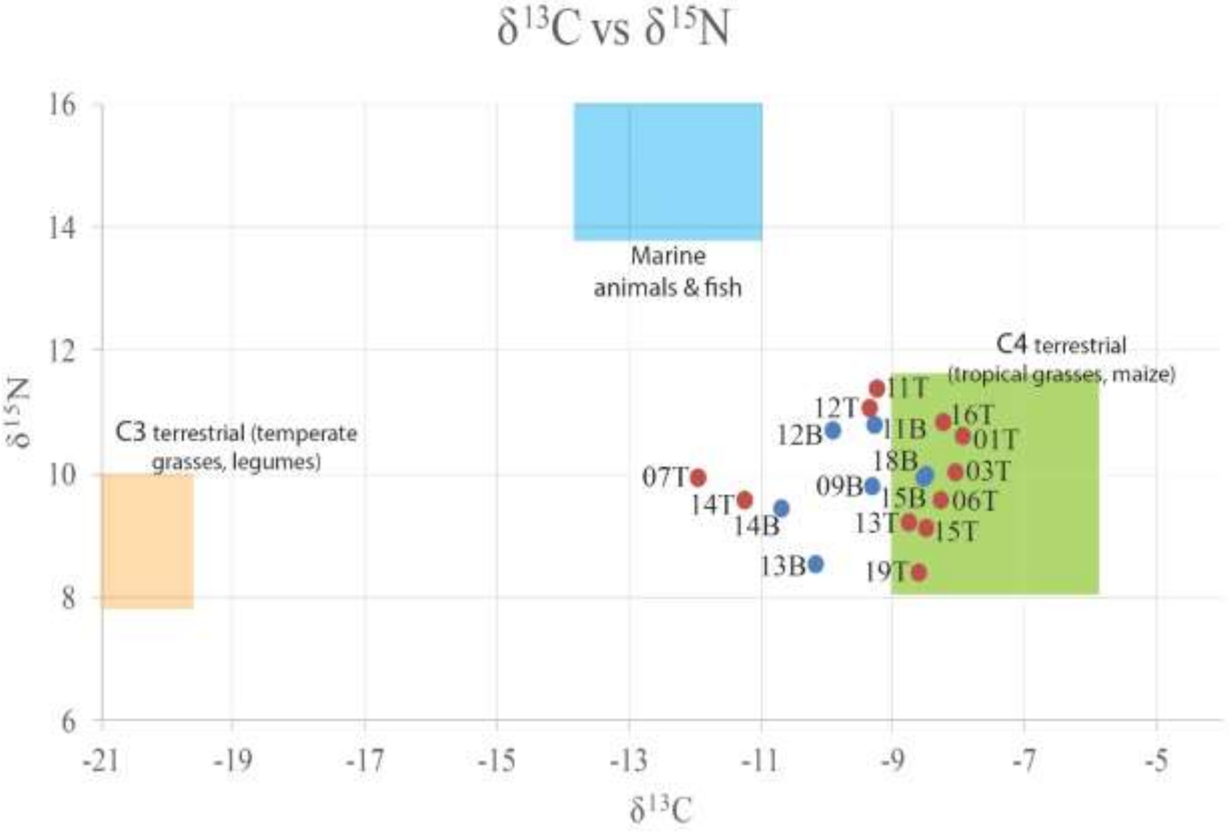


Figure 6.1. $\delta^{13}C$ versus $\delta^{15}N$ graph of each sample. Bone samples are in blue and tooth dentin samples are in red.

It is the finding of this research that the $\delta^{13}C$ and $\delta^{15}N$ results show a consistent diet across the individuals sampled and therefore consistent access to foods even during drought periods. This is nutritional evidence of elite status because it is assumed that elite individuals had better access to foods (Grove and Gillespie, 1992) as well as different types of food during periods of resource stress, therefore their diet would be more likely to be consistent across burials over time and throughout an individual's lifetime. In order to make a definitive statement on elite status this research includes the $\delta^{13}C$, $\delta^{15}N$, as well as the presence of grave goods, and location of burial for interpretation. When including the mortuary characteristics, this research verifies elite status based on the inclusion of at least one type of grave good present in 16 out of 27 burials (60%) as well as 19 out of 27 (70%) individuals buried within an Eastern Triadic Structure or Elite Plaza/Structure at the site. In short, I conclude that all the individuals buried at the epicenter of Cahal Pech are of elite status with the exception of CHP-SI-15 the historic burial (discussed below).

The $\delta^{13}C$ and $\delta^{15}N$ analyses were also run on serial sections of 10 teeth from the sample. When the $\delta^{13}C$ and $\delta^{15}N$ serial samples for each individual tooth are plotted evidence of weaning, changes in diet, and/or migration are made visible at different stages during the tooth development. Only two individuals showed significant changes in $\delta^{13}C$ and/or $\delta^{15}N$; CHP-SI-07 (Figure 6.2) and CHP-SI-13 (Figure 6.3).

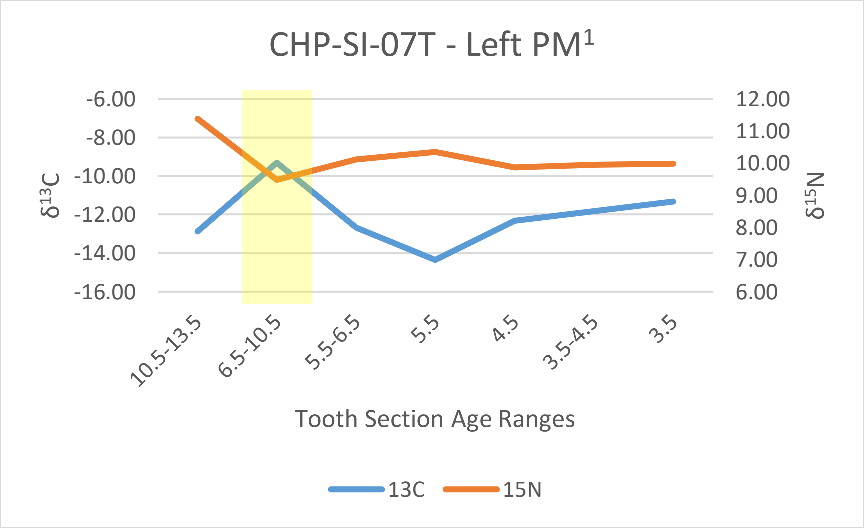


Figure 6.2. Tooth dentin collagen serial sample of CHP-SI-07.

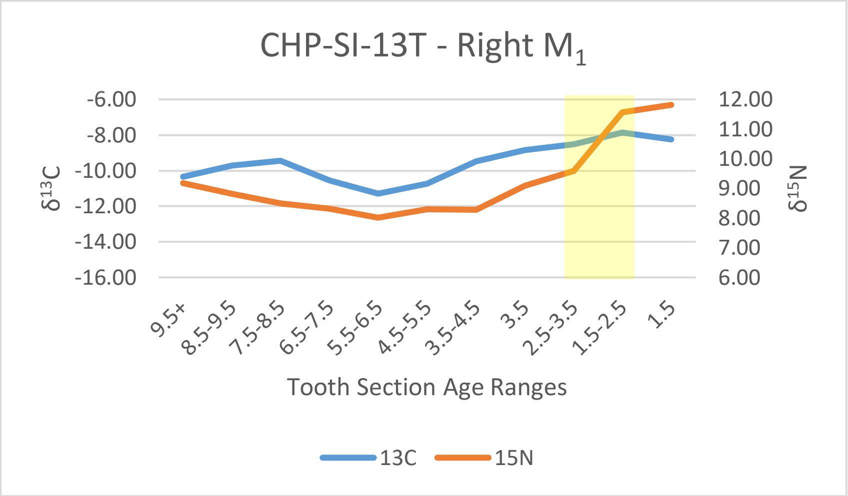


Figure 6.3. Tooth dentin collagen serial sample of CHP-SI-13.

The CHP-SI-07 tooth serial sample shows a consistent source of nitrogen, but a decrease then increase in ingestion of carbon around 7 -10 years old (AlQahtani et al., 2010), as seen in Figure 6.2 and highlighted by the yellow band. This is evidence of a shift in diet during childhood. Why the diet changed could be due to many factors including migration and change in status, but it suggests less access to foods other than maize.

The CHP-SI-13 tooth serial sample shows an decrease in nitrogen at approximately 1 to 3 years old (AlQahtani et al., 2010) (Figure 6.3) and highlighted by the yellow band. This is likely evidence of weaning based on previous studies that state children have enriched δ^{15}N values while breastfeeding and the decrease in δ15N indicates the weaning process and eventual conclusion (Fuller et al., 2006; Richards et al., 2002). This does bring up the question as to why none of the other individuals who had a first molar sampled show signs of weaning. This is due to the fact that weaning signals are only found in the crown dentin, and both CHP-SI-12 and CHP-SI-14 had the crown dentin run as bulk, which would account for the loss of weaning signals in these samples.

Table 6.1. δ^{34}S values for the five samples containing enough viable collagen.

	δ^{34}S
CHP-SI-18B	11.71
CHP-SI-15B	6.89
CHP-SI-13B	11.77
CHP-SI-12B	11.54
CHP-SI-11B	12.56

δ^{34}S Bone Collagen. Sulfur isotope analysis is a fairly new technique in Mesoamerican research and it is used in identifying origin, movement, and diet in individuals. The δ^{34}S analysis takes approximately 10 mg of collagen to process, so the approach was only possible in five individuals (Table 6.1). At the time of writing, there is no baseline value or expected value of δ^{34}S for humans or animals in Belize. Therefore, comparative data are unavailable and interpretation of the result on their own is not possible.

It is the finding of this research that the sulfur values of individuals CHP-SI-11, CHP-SI-12, CHP-SI-13, and CHP-SI-18 are all similar and likely represent a normal sulfur value for the region. CHP-SI-15 is an outlier of the group. This burial is historic and a subadult, which may indicate a difference in sulfur values is based on changes in diet or migration of the individual.

^{87}Sr/^{86}Sr Bone Apatite and Tooth Enamel. Previous research suggests that stable isotope results for ^{87}Sr/^{86}Sr would show increased movement of individuals during the Late (AD 600-800) to Terminal (AD 800-900) Classic Periods (Awe and Helmke, 2007; Demarest et al., 2005b; Hughes, 1999; Lucero, 2002). The current research design was further meant to identify non-local origin of individuals that may have differing mortuary practices. The ^{87}Sr/^{86}Sr value regions found in Figure 6.3 and are reproduced with the permission of the author.

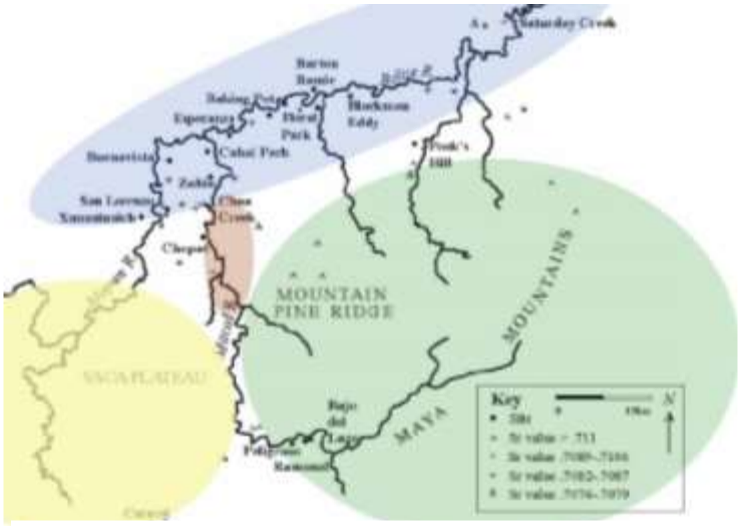


Figure 6.3. ^{87}Sr/^{86}Sr stable isotope regions from Freiwald (2011).

The $^{87}Sr/^{86}Sr$ results show movement by individuals to and from Cahal Pech, as well as migration within the lifetime of several individual's. This study found eight individuals that show a non-local $^{87}Sr/^{86}Sr$ value for either bone and/or tooth (Table 6.2).

Table 6.2. Eight individuals with non-local $^{87}Sr/^{86}Sr$ values, table includes demographic and time period information.

Sample ID	Structure	Burial #	Age	Sex	Chronology	Sr - bone apatite	Sr - enamel
CHP-SI-01	Str. B1	Burial 7, ind. 1	adult	female	Late Classic	0.70892	0.708543
CHP-SI-05	Str. B1	Burial 11	adult	male	Late Classic	0.70917	
CHP-SI-06	Str. B1	Burial 12	adult	male	Early Classic	0.70867	0.708814
CHP-SI-07	Str. B1, EU B1-7West	Burial 13	adult	female		0.70854	0.709013
CHP-SI-08	Str. B3	Burial 1	adult	female	Terminal Classic	0.70965	0.708516
CHP-SI-13	Plaza B EU-13	Burial 1	adult	indeterminate	Early Classic		0.709297
CHP-SI-15	Plaza G/4th, Unit 51	Burial 1	subadult	indeterminate	Historic	0.70825	0.707813
CHP-SI-23	CP-89-B2 (Str. B1)	Burial 2	adult	female	Terminal Classic		0.70881

CHP-SI-01 and CHP-SI-08 are the two individuals that have a local tooth value and a non-local bone value. The $^{87}Sr/^{86}Sr$ bone value is consistent with values found in the Macal River region to the south (maroon area in Figure 6.3) and the tooth value is consistent with those from the Belize River region (blue area in Figure 6.3). This indicates that the individuals were born and spent their childhood in the Belize River region and then moved after childhood to the Macal River region. What is interesting is that these individuals returned to their place of origin within 10 years of death, likely due to familial and ancestral connection to the site. The mortuary patterns are similar for these two individuals as well as seen in Table 6.3, even though they do not cluster together in the statistical analyses.

CHP-SI-05 only has $^{87}Sr/^{86}Sr$ value for bone so no interpretation of this individual's movement during life can be made. That said, the bone value is non-local and comes from the

Macal River region, indicating this individual came to the Belize River region to be buried possibly because of familial or ancestral ties to the site. This individual is an adult male from the Late Classic and buried in an Eastern Triadic Structure. This individual was the only one with a stingray spine as a grave good.

CHP-SI-13 and CHP-SI-23 only produced tooth samples so no statement can be made on movement during life for these individuals. This research found that their tooth values were non-local and consistent with the Macal River region. This leads to the conclusion that both these individuals came to the Belize River region sometime after childhood. Unfortunately, no definitive statements can be made as to when they arrived in the Belize River region while living or whether their bodies were brought to Cahal Pech for burial. The mortuary characteristics for these two individuals can be found in Table 6.4. These two individuals do not share much in common, which may be due to their different time periods, differences in status, or differences in recording of the burials.

CHP-SI-06 and CHP-SI-07 both have $^{87}Sr/^{86}Sr$ tooth values consistent with the Macal River region, indicating a non-local origin. They also both have $^{87}Sr/^{86}Sr$ bone values that are local to the Belize River region. This is evidence that both individuals moved after childhood to the Belize River region and lived in the area for over 10 years prior to death. This indicates that these individuals called Cahal Pech home and were buried there. The mortuary characteristics for these two individuals are extremely similar because they share their grave type (crypt) and body orientation as well as most of their grave goods and the fact that they are buried within an Eastern Triadic Structure.

CHP-SI-15 is the only individual with $^{87}Sr/^{86}Sr$ tooth sample that comes from the Central Lowland region north of the Belize River region. The findings are additionally intriguing due to this individual's bone value being barely within the local ^{87}Sr/^{86}Sr range for the Belize River region. The individual is also a subadult and ^{14}C dating indicates that it is a historic burial. This sample also had a δ^{34}S value that fell outside the cluster of individual's that likely indicate the local expected values. The inconsistencies in this burials data may stem from it being historic, and the reason for its burial at the Cahal Pech epicenter may well be incidental to its function as a Maya center.

δ ^{18}O & δ^{13}C Bone Apatite and Tooth Enamel. The bone apatite and tooth enamel also produced δ ^{18}O and δ^{13}C values that represent water source and whole diet respectively. The expectation of these results was that evidence of movement would be seen in the δ ^{18}O and would confirm the ^{87}Sr/^{86}Sr results. The δ^{13}C from apatite would indicate a heavy reliance on maize and be similar to the findings of the δ^{13}C/δ^{15}N from the collagen.

The δ ^{18}O and δ^{13}C results shows a cluster of individuals representing the expected values for this region (δ ^{18}O = -4.48 to -3.06 for tooth samples; Freiwald, 2011) with the exception of one bone and tooth sample outlier. The outlier is, not surprisingly, CHP-SI-15's bone and tooth samples, which is more proof that this individual was not part of the community at Cahal Pech. When looking at Figure 6.4, there is a distinct difference in oxygen between the tooth and bone samples indicated by the red line. This is likely due to diagenesis of the bone samples. As noted in the results chapter δ ^{18}O isotope values are not very robust and are easily altered by the environment (France and Owsley, 2013; Nelson et al., 1986; Pestle et al., 2014).

There is no evidence of migration of individuals based on water sources, which differs from the ^{87}Sr/^{86}Sr findings. This can be explained by the geography of the region. Cahal Pech lies at the intersection of the Belize and Macal rivers therefore making it a transitional locale and

Table 6.3: CHP-SI-01 and CHP-SI-08 mortuary characteristics.

	A	**F**	**LC**	**TC**	**ETS**	**Pr**	**Ind**	**Ext**	**Sup**	**Cpt**	**Tmb**	**HN**	**HS**	**FW**	**CeV**	**Ce**	**ShD**	**Sh**	**JdO**	**JdB**	**FaC**	**LocT**	**Elt**
CHP-SI-01	1	1	1	0	1	1	1	1	1	0	1	1	0	0	1	1	1	0	1	0	1	1	1
CHP-SI-08	1	1	0	1	1	1	1	1	1	1	0	0	1	1	1	0	0	1	0	1	1	1	1

Table 6.4: CHP-SI-13 and CHP-SI-23 mortuary characteristics.

	A	**F**	**Sind**	**EC**	**TC**	**ETS**	**PPS**	**Pr**	**Int**	**Ind**	**Tmb**	**HN**	**CeV**	**JdO**	**FaC**	**Elt**
CHP-SI-13	1	0	1	1	0	0	1	0	0	0	0	0	0	0	0	1
CHP-SI-23	1	1	0	0	1	1	0	1	1	1	1	1	1	1	1	1

Table 6.5: CHP-SI-06 and CHP-SI-07 mortuary characteristics.

	A	**M**	**F**	**EC**	**ETS**	**Pr**	**Ind**	**Ext**	**Prn**	**Cpt**	**HS**	**FE**	**CeV**	**Ce**	**ShD**	**JdB**	**Jd**	**ObB**	**FaC**	**LocB**	**Elt**
CHP-SI-06	1	1	0	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1
CHP-SI-07	1	0	1	0	1	1	1	0	0	1	1	1	1	1	1	1	0	0	0	1	1

likely individuals from this area will look similar to both the Belize River oxygen values and the Macal River oxygen values.

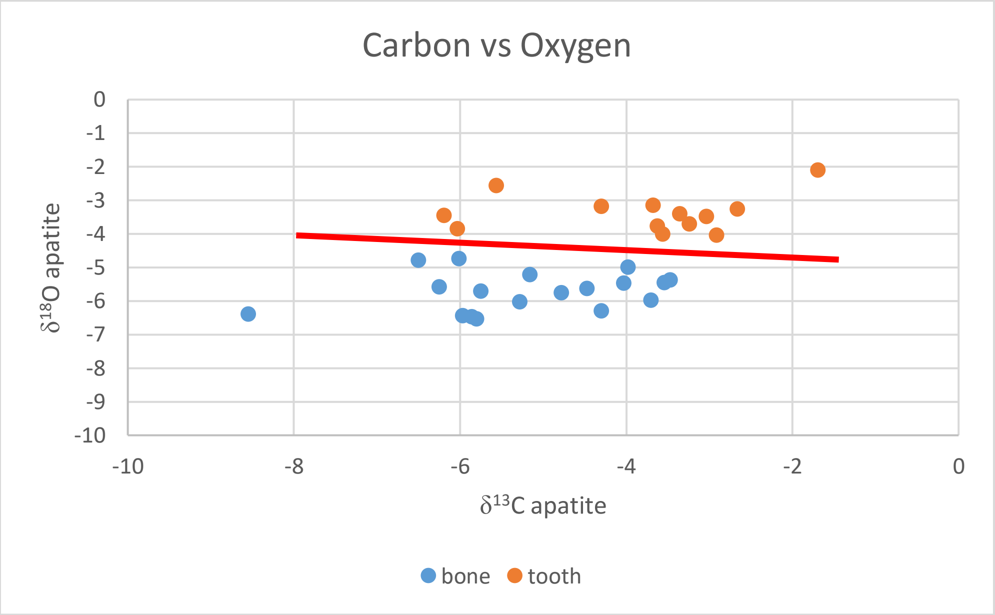


Figure 6.4. d13C versus d18O stable isotope results. Bone apatite samples are in blue and tooth enamel samples are in red. The two outliers are bone and tooth sample from the same individual (CHP-SI-15). Red line highlights oxygen distinction between biological material.

The question of migration both into and out of Cahal Pech, the extent that migration rates are patterned by time period, as well as details of the movement of individuals during their lifetime is shown in the results of the ^{87}Sr/^{86}Sr and δ ^{18}O isotope analyses. This research based several models on the idea that migration would increase during the end of the Late Classic to Terminal Classic periods, based on the environmental and political instability of the region. Although the sample size is small, there is no evidence that the amount of migration changing throughout time. The ^{87}Sr/^{86}Sr results have individuals from most time periods represented and if time period were the main factor in migration one would expect to see most immigrants to be found in specific times.

The results do illuminate a trend of migration that is based on geography. Most individuals that showed non-local d86Sr values, which is interpreted as migration, came from the same region; the Macal River south of Cahal Pech and the Belize River region. This is an indication of some connection, be it socio-political, ancestral, and/or familial, between Cahal Pech and sites to the south. There are several similar and larger sites that may have been connected with Cahal Pech including Chaa Creek, Pacbitun, Pusilha, and possibly Caracol. It is important to note that there is no evidence of migration to or from Cahal Pech from sites to the west in Guatemala or north in the Peten and Yucatan contrary to the findings of Demarest et al., (2005b) .

In summary, the stable isotope results show consistent diets of individuals during all time periods, consistent movement during most time periods, and migration from the south. Future stable isotope research will need to include more samples from new or untested burials, a comprehensive isotope plan that includes both bone and tooth samples as well as all stables isotope analysis available. This will ensure a larger more complete sample of the region and allow researchers to definitively answer some of the more complex migration and diet questions.

Mortuary Patterns

This research also looked at mortuary practices and the trends based on time and/or space that could be identified by differences between burials. The expectation was that Terminal Classic burials would be different from the Classic period burials due to influences from shifting socio-political alliances (Awe, 2013; Chase and Chase, 2004; Douglas and Brown, 2014). It was also expected that burials of non-local individuals would be differentiated, for example by being intrusive. Several statistics were employed on the mortuary database found in Appendix A, Table A.3 in order to identify causes and amounts of variation within the data. The statistical analyses were run in such a way that they build on each other by using the information gathered in the first analysis to inform the subsequent analyses.

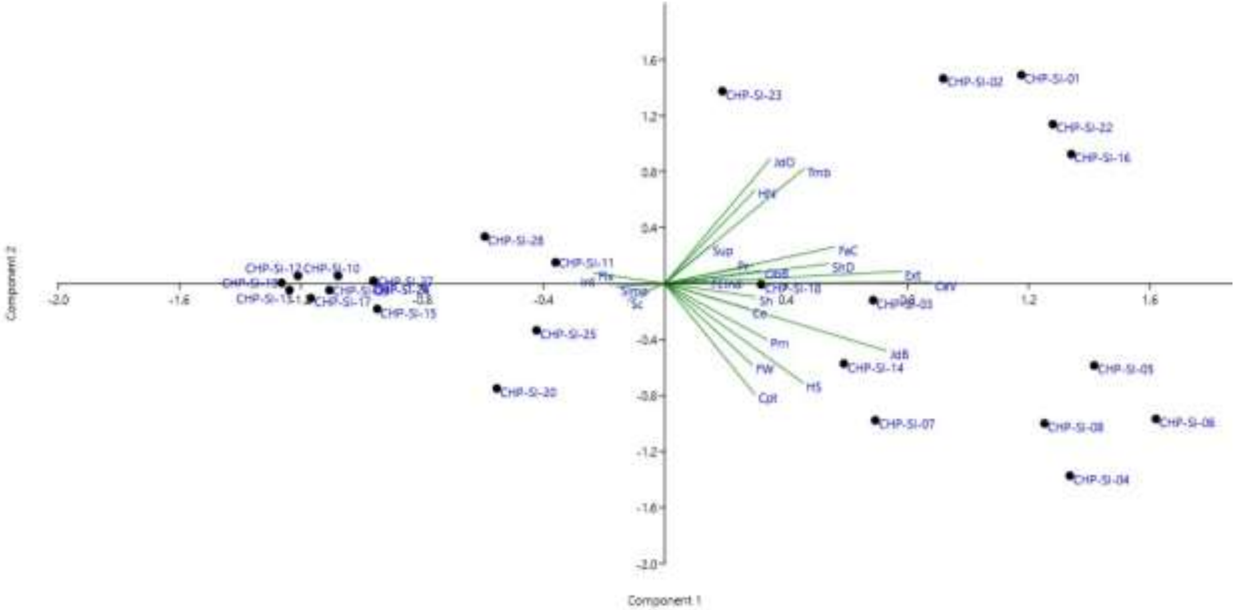


Figure 6.5. PCA scatterplot.

The first analysis was Principle Component Analysis (PCA) that illustrated the variables (characteristics of the burials) that were uninformative in order to not include them moving forward. The PCA also identified the likely variables that account for most (+50%) of the variation in the data. This result shows that the data are highly variable, with loose clusters of burials lacking strong patterning. This is represented by a PCA scatterplot that shows burials in three loose clusters (Figure 6.5) around several specific variables, with multiple burials that are not clustering with any other individuals. The variables that load most heavily on component 1 are extended body, ceramic vessels, and jade beads; crypt, tomb, and jade ornaments load on Component 2; and other ceramics loads on component 3. The presence of absence of these variables is the likely cause for the three clusters in the PCA and this information is used in interpretation of the MDS and NN results.

The second analysis was Non-metric Multidimensional Scaling (MDS) that used the PCA findings from Table A.3. The MDS was run in order to identify similar patterns that mirror the findings from the PCA.

The MDS found that an acceptable fit for the data could be explained by two dimensions. Unfortunately, the stress level (0.214) for the MDS is considered poor, which corroborates the PCA findings that show the similarities between the burials to be weak and therefore the burials are very spread out on the MDS graphs. Four MDS graphs were created (see Results Chapter, Figures 5.17-5.20) in order to try to visually explain similarities between burials based on time period, location, origin, and age and sex. There is a separation of burials on each MDS graph that mirrors the findings of the PCA. Neither time period, location at site, origin, or age and sex, explain the clustering of burials. Instead, the clusters in the MDS are explained by the presence and absence of the same variables that were loading on the three components in the PCA. These analyses again suggest that combinations of grave goods and grave types loosely structure the differences between the burials, but there are also many unique aspects of mortuary practices in the sample, and that basic biological statuses have relatively little effect on the overall structure of the data.

The final statistical analysis is Neighbor Network (NN) which is a clustering method similar to MDS that creates an unrooted tree to illustrate the strength of similarities and differences between burials. The result of the NN analysis does show several loose clusters of burials, three major clusters and three minor clusters. The major clusters are distinguishable by grave type in conjunction with grave goods: tomb versus no tomb, and the presence or absence of ceramic vessels and jade beads. The minor clusters do appear related and distinguishable by sex and burial location within the site. The NN results support the findings of the PCA and MDS in that the above listed variables account for most of the variation within the data.

The identification of the most influential variables as grave type and grave goods does effect the interpretation of the models from Chapter 3. These models were based on the idea that mortuary practices would show trends based on time period. For example, Terminal Classic burials would look different from Classic Period burials, which is not supported by these findings. These findings also do not support the idea that non-local individuals had different mortuary practices.

Model Interpretation. The following is based on the models described in Chapter 3 and summarized in Figure 6.6 and interpreted using the results from Chapter 5. These models represented the most likely scenarios for Cahal Pech based on the current literature, but, as outlined below, there is no single perfect fit with any of the models. It is probably a combination of factors that are working on the community of Cahal Pech that shaped the burial practices and bioarchaeological indicators found in the 27 burials analyzed by this project.

Working from the top down on the flow chart, the change in $^{87}Sr/^{86}Sr$, $\delta^{18}O$, and $\delta^{34}S$ represents the origin of individuals coded as either local or non-local individuals. Based on the results, the samples in this research represent a mixture of local and non-local individuals from all time periods. This fits best with Model 2 Scenario 3, which assumes there will be a mixture of non-local and local isotope signatures from individuals representing all time periods.

Contrary to the Model 2, $^{87}Sr/^{86}Sr$, $\delta^{18}O$, and $\delta^{34}S$ origin results do not match the expectations for the results for the $\delta^{13}C$, $\delta^{15}N$, and $\delta^{34}S$ diet information. These results fit better with Model 1 because they show consistent diet over time for both local and non-local individuals. Not only is there consistent diet within the life history of individuals, but there is also no difference in diet between local and non-local individuals, showing that diets were similar for different areas. This illustrates the idea that using one or even two stable isotope results may alter interpretations, and it is important to include multiple lines of evidence.

Table 6.6: Intrusive burials over time.

Time Period	# of intrusive burials
Late Preclassic	
Early Classic	
Late Classic	2
Terminal Classic	3
TOTAL	5

The mortuary data supports both Model 1 and Model 2 Scenario 3 because it found no significant changes in mortuary patterns over time or space and intrusive burials do not significantly increase over time (Table 6.6), although the sample size is quite small and it is worth noting that no intrusive burials have been found from the earlier time periods. This is contrary to the idea that mortuary practices mirror changes in political and social structures (Binford, 1971; Gillespie, 2001b). According to the assumption that mortuary practices should reflect shifts in socio-political systems, this research expected to see a change in mortuary patterns between the Late and Terminal Classic periods because of the major shift in social and political systems in the southern lowland Maya region. If a difference does exist it is likely lost due to differential recording of burials over time and environmental processes that made burials and their associated artifacts unavailable for study.

To summarize, when looking at the migration portion of the flow chart, the results fit best with Model 2 Scenario 3, which states that there is consistent migration into and out of Cahal Pech throughout the site's occupation. This is expected because migration is directly connected to an individual's local or non-local stable isotope values. The $^{87}Sr/^{86}Sr$ results show movement by individuals for all time periods, suggesting migration was a constant. Unfortunately, these data may not be representative of the population because of its small sample size, making it unclear whether or not migration increased or decreased over time. What is interesting about the migration findings is that people were coming and going from the same area, the Macal River region. This may be due to an ancestral tie to the site, a familial connection through marriage alliances, or political and/or economical alliance with sites in the south. Unfortunately, we cannot know which site in the south had a connection with Cahal Pech until further, more refined research is done.

Summary

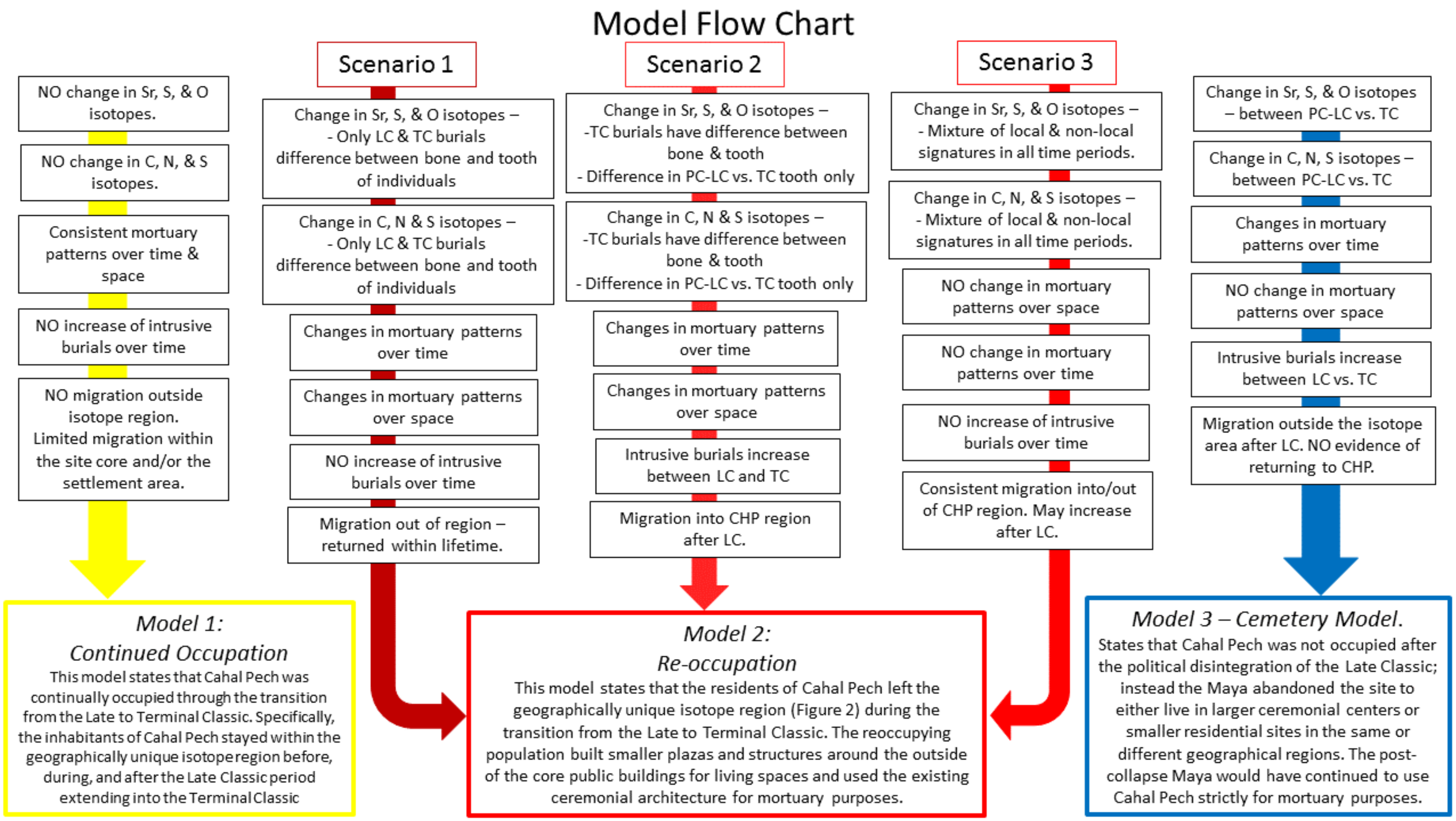
This research finds that the most likely scenario occurring at Cahal Pech is a mixture of Model 1 and Model 2, Scenario 3. Neither one fits perfectly so this I propose that portions of each Model be taken to create a new best fit: Model 4.

Model 4 has non-local and local individuals moving into and out of Cahal Pech throughout its occupation, approximately the Middle Preclassic (1200 BC) to the Terminal Classic (AD 900) as seen by the $^{87}Sr/^{86}Sr$ stable isotope values. Even though some individuals are non-local during all or part of their life, their diets were consistent with diets of mainly maize and other C_4 plants as well as animals that eat C_4 plants based on $\delta^{13}C$ and $\delta^{15}N$ values from bone and tooth collagen, probably illustrating a pattern of similar diet for elites throughout the region. The local and non-local individuals were also drinking water with similar $\delta^{18}O$ values likely due to the Macal River water source. The migration of individuals was also relatively consistent over time and involved migration from one specific area, in this case the Macal River region.

The mortuary practices for Model 4 do not change based on time period or location of burial, instead they are highly variable with no obvious correlation with an external factor. Meaning, the variation of mortuary practices is not dependent on one or even two variables;

instead, there are many variables acting on the practices so much so that the mortuary practices at Cahal Pech cannot be predicted.

The mortuary practices at Cahal Pech, along with the migration from the Macal River region and the fair number of non-local individuals who are buried at the site, does bolster the idea that Cahal Pech has some sacred meaning to the Classic period Maya that extended beyond the immediate boundaries of the polity. Also, the individuals buried at Cahal Pech do not seem to be much effected by the drought as seen in consistent access to foods over time, specifically those burials in the Late and Terminal Classic periods, or by the socio-political upheaval of the Late Classic period. The fertile land may have been able to produce enough food for a small community, but not enough for a large labor force. This may be due to its geography because it sits at the confluence of the Belize and Macal Rivers, there is fertile farmland surrounding the site, it sits atop a large hill with natural fortifications. The site is also centrally located between very powerful polities within the dense Belize River Valley.



Model 1: Continued Occupation

This model states that Cahal Pech was continually occupied through the transition from the Late to Terminal Classic. Specifically, the inhabitants of Cahal Pech stayed within the geographically unique isotope region before, during, and after the Late Classic period extending into the Terminal Classic

Model 2: Re-occupation

This model states that the residents of Cahal Pech left the geographically unique isotope region (Figure 2) during the transition from the Late to Terminal Classic. The reoccupying population built smaller plazas and structures around the outside of the core public buildings for living spaces and used the existing ceremonial architecture for mortuary purposes.

Model 3 – Cemetery Model.

States that Cahal Pech was not occupied after the political disintegration of the Late Classic; instead the Maya abandoned the site to either live in larger ceremonial centers or smaller residential sites in the same or different geographical regions. The post-collapse Maya would have continued to use Cahal Pech strictly for mortuary purposes.

Figure 6.6. Model flow chart

CHAPTER 7 - CONCLUSION

This study found that Cahal Pech was a continuously occupied site at the center of the Maya world. The community of Cahal Pech was made up of individuals born and raised locally and those individuals born or raised in the Macal River region. The people of Cahal Pech relied heavily on maize agriculture and C4 terrestrial animals and likely got their water from the two rivers near the site, the Belize River and the Macal river. The mortuary patterns at Cahal Pech are extremely variable, but consistent in their variation. There is no trend based on time or space and all the individuals in this study are of elite status. The mortuary practices do not reflect a shift in social or political structure, but when looked at in conjunction with the migration and origin data, they do prove that Cahal Pech was considered a sacred destination and worthy of long distance travel for burial.

This research also shows how the Maya buried at Cahal Pech were affected, or not, by the socio-political and environmental instability of the Late Classic period (AD 600-800). The elite status of the individuals in this research intrinsically meant that they had access to the best foods, which is seen by the consistent diet over time. It is likely that individuals of lower status may show changes in diet during drought periods, but this research did not find any of the samples to be of low status. A consistent diet and no evidence of disrupted occupation leads to the conclusion that the individuals buried at the site were not significantly affected by the drought or the socio-political disintegration that effected other sites in the area. Cahal Pech was considered a sacred site and likely insulated geographically and politically from the unrest plaguing the Lowland Maya region during the Late to Terminal Classic periods.

Future Studies

It is the hope of this researcher that future studies will be conducted to build upon the stable isotope and mortuary data in this dissertation by both the author and other researchers. Future studies include conducting stable isotope analyses on the missing data in this research in order to answer research questions more definitively. This would also lead to improvements towards sampling and consistent stable isotope analysis. Filling in the blanks within the database would allow for future research to use information already collected for new analyses instead of sampling from poorly preserved and limited collections.

Future studies must also carefully evaluate the effects of differential lab preparatory procedures and machinery. For example, this research consisted of several stable isotopes that were run as duplicates in different labs that showed some discrepancies in the results. Luckily, all but one result was within an acceptable amount of variation for ^{86}Sr/^{87}Sr (+/- .001), δ^{13}C and δ^{15}N for bone collagen (+/- .9). This demonstrates the importance of understanding that stable isotope values are not all equal if run on machinery that is not calibrated for stable isotope or human remains. Finally, future studies should include the use of sulfur data to help find the sulfur baseline for human remains in the Belize River Valley and the Maya region as a whole. Including the comprehensive stable isotope plan along with mortuary data will allow future research to answer complex questions regarding migration, human-environmental interaction, and how socio-political stress can have differential effects on sites.

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APPENDIX A

MORTUARY DATABASES

Table A.1: Mortuary database with raw data.

Sample ID	Structure	Burial #	Age	Sex	Chronology	Ceramic Chronology	Burial Type	Mode of Burial	Position	Grave Type	Orientation	Ceramics
CHP-SI-01	Str. B1	Burial 7, ind. 1	adult	female	Late Classic - AD 607	Dos Arroyos	primary	individual	extended, supine	tomb	head to north	Vessel 1 (stucco vase), Vessel 2 (largs dish), Vessel 3 (polychrome tripod), Vessel 4 (polychrome basal flange), Vessel 5 (Fluted cylinder), 8 scribe tools,
CHP-SI-02	Str. B1	Burial 7, ind. 2	adult	male	Early Classic - AD 525	Dos Arroyos	primary	individual	extended, supine	tomb	head to north	Vessel 6 (polychrome dish), Vessel 7 (polychrome basal flange), Vessel 8
CHP-SI-03	Str. B1, EU B1-2 East	Burial 8	30-40	male	Late/Terminal Preclassic - AD 50-250	Polvero Black	primary	individual	extended	tomb	head to south	Vessel 1 , Vessel 2, Vessel 3, Vessel 4, ceramic figurine head
CHP-SI-04	Str. B1	Burial 10	30-50	male	Late/Terminal Preclassic - AD 135-325	Sierra Red	primary	individual	extended	crypt	prone, head to south, facing west	6 vessels, potstand
CHP-SI-05	Str. B1	Burial 11	40+	male	Late Classic - AD 550-600	Balanza Black	primary	individual	extended	tomb	prone, head to south, facing southwest	bowl
CHP-SI-06	Str. B1	Burial 12	adult	male	Early Classic - AD 250-600		primary	individual	extended	crypt	prone, head to south	polychrome peccary ceramic vessel, 2 ceramic discs
CHP-SI-07	Str. B1, EU B1-7West	Burial 13	40+	female			primary	individual		crypt	head to south, facing east, on right side	2 vessels, 1 pot stand
CHP-SI-08	Str. B3	Burial 1	adult	female	Terminal Classic - AD 600-700	Tiger Run	primary	individual	extended	crypt	supine, head to south, facing west	vessel 1 (fragmented Mountain pine red plate), vessel 2 (Sotero red/brown bowl), marine shell,
CHP-SI-09	Str. B2-2	Burial 2	adult	indeterminate	Early Classic - AD 200-450			individual				
CHP-SI-10	Plaza A, Str. A3	Burial A3-1	8-10	indeterminate	Late Classic		primary, intrusive	individual				
CHP-SI-11	Str. B4, Lv. 5	Burial 1	young adult, 21-30	male	Late Classic - AD 560-645		primary	individual	flexed, semi-supine	crypt	left arm across chest, facing up and to the south, heading west	sherds
CHP-SI-12	Str. C2, EU 5, Lv. 1	Burial 1	3-5	indeterminate	Terminal Classic - AD 775-890		primary, intrusive					
CHP-SI-13	Plaza B EU-13	Burial 1	older adult	indeterminate	Early Classic - AD 425-565							
CHP-SI-14	Plaza B, Op. 1o-10 Lv. 5	Burial 1	adult	indeterminate	Late Preclassic - 170-45 BC	Kanluk	primary	individual		crypt	facing northwest	Sampoperro Red vessel

CHP-SI-15	Plaza G/4th, Unit 51	Burial 1	9-12	indeterminate	Historic - AD 1660-1950		primary, intrusive	individual	fetal, on left side, supine	simple grave	north/south, head to south	
CHP-SI-16	Str. H, Plaza H/H1	Tomb 1	older adult	male	Terminal Classic		primary	individual	extended	tomb		11 vessels
CHP-SI-17	Str. B4, Plaza B, EU 6	Burial 1/06	adult	indeterminate	Late Preclassic		cache	individual				
CHP-SI-18	B-4	Burial B4-1	40-50	female	Late Classic - AD 680-770	Tepeu 1-2	primary, intrusive	individual	extended prone	cyst	head to south	polychrome vessel
CHP-SI-19	A-2	Burial 1	adult	indeterminate	Late Classic - AD 600-700		primary		fetal	simple		
CHP-SI-20	Str. B1	Burial 9	adult	indeterminate	Terminal Classic	Mount Molony	secondary, intrusive	individual	disarticulated	crypt or cache	facing west	vessel
CHP-SI-22	Schmidt CP-89-B1, Str. B1	Burial 2	18-20	male	Early Classic - AD 400-450		primary	individual	extended	tomb	head to north, facing east	6 polychrome vessels, 2 monochrome vessels
CHP-SI-23	Schmidt CP-89-B2, Str. B1	Burial 1	17-19	female	Terminal Classic		primary, intrusive	individual		tomb	head to north	vessel
CHP-SI-24	Ball CP-89-B3, Str. B1	Burial 3	16-20	female	Late Classic - AD 550-650		primary	individual				
CHP-SI-25	Ball CP-89-B4, Str. B1	Burial 4	35	male	Late Preclassic - pre- AD 150		primary	individual	extended	crypt	north/south	
CHP-SI-26	Ball CP-89-B5, Str. B1	Burial 5	16-24	female	Early Classic - AD 500-550		primary	individual				
CHP-SI-27	Ball CP-89-B6, Str. B1	Burial 6	20-34	male	Late Classic		primary	individual				
CHP-SI-28	Str. B1	Burial 7, ind. 3	adult	possible female	Terminal Preclassic - AD 290		primary	individual		tomb		polychrome sherd, other ceramic

Sample ID	Shell	Jade	Obsidian	Chert	Stingray	Faunal	Sr – bone	Sr - enamel	C – bone collagen	C - dentin collagen	C - enamel apatite	C- bone apatite	N – bone collagen	N - dentin collagen	O - bone apatite	O - enamel
CHP-SI-01	oyster shells, pendants with inlays	2 jade bar pectorals				3285 drilled jaguar teeth, 2 carved bone rings, 1 bone ring	.708923	.708543		-7.08 - -8.95, avg. -7.951	-3.24	-4.03		10.02-11.28, avg. 10.597	-5.48	-3.72
CHP-SI-02	conch ink pot	earspools				shaped bone, carved bone	.708661	.70844 (Novotny)		-8.3 (Novotny & Awe)		-0.37			-5.99	
CHP-SI-03		beads					0.708539	0.708352		-7.18 - -8.61, avg. -8.034	-2.91	-3.98		9.96-10.12, avg. 10.04	-5	-4.06
CHP-SI-04		beads, figurine				carved turtle shell	0.708513	.708559,			-3.56	-4.3			-6.3	-4.02
CHP-SI-05	spondylus shell, 2 perforated discs	6 beads,			spine		0.709172					-5.28			-6.03	
CHP-SI-06	craved oyster shell with jade decoration	fragments and 1 bead	1 blade			antler rings, drilled dog teeth	0.70867	0.708814		-8.77 - -7.7, avg. -8.26	-2.66	-4.47		9.12-10.1, avg. 9.56	-5.63	-3.27
CHP-SI-07	spondylus ear spools	bead					0.708538	0.709013		-14.35 - -9.31, avg. -11.97	-6.03	-5.97		9.48-10.35, avg. 9.95	-6.44	-3.87
CHP-SI-08	marine shell	bead				bone beads	0.709649	0.708516			-3.03	-3.47			-5.39	-3.5
CHP-SI-09							0.708636	.70865 (Freiwald)	-9.30 (Freiwald)			-3.54	9.80 (Freiwald)		-5.46	
CHP-SI-10								.708600			-3.68	-4.78			-0.577	-3.16
CHP-SI-11		tooth inlays	1 blade				0.708359	0.708509	-9.28	-10.79 - -8.62, avg. -9.23	-5.56	-5.8	10.81	10.84 - 11.69, avg. 11.38	-6.54	-2.56
CHP-SI-12							0.708479	0.708551	-9.91	-10.25 - -9.01, avg. -9.34	-4.3	-6.01	10.68	10.42 - 11.93, avg. 11.08	-4.75	-3.19
CHP-SI-13								0.709297	-10.17	-11.29 - -7.86, avg. -8.74	-3.35	-6.25	8.55	8.01 - 11.82, avg. 9.19	-5.59	-3.42

CHP-SI-14	5 tinklers	6 small beads	1 whole blade				0.708546	.708431	-10.69	-12.24 - -9.65, avg. -11.24	-6.2	-5.75	9.45	9.31 - 9.89, avg. 9.59	-5.72	-3.46
CHP-SI-15							0.708253	0.707813	-8.53	-9.79 - -7.84, avg. -8.48	-1.69	-8.55	9.92	8.41 - 10.59, avg. 9.13	-6.48	-2.11
CHP-SI-16	modified conch shell, shell bead	carved pendant, 2 earflares, 2 beads	13 blades			drilled beer bone tubes, antler, dog teeth necklance, small feline remains	0.708565	.708606,		-9.21 - -7.69, avg. -8.25	-3.62	-5.86		9.91 - 11.96, avg. 10.82	-6.48	-3.78
CHP-SI-17							.708600					-6.5			-4.79	
CHP-SI-18		inlay teeth					0.708368		-8.48			-5.16	10		-5.23	
CHP-SI-19								.708505 (Freiwald)		-8.60 (Freiwald)		-5.20 (Freiwald)		8.40 (Freiwald)		
CHP-SI-20				3 bifacial points				.70843 (Novotny)								
CHP-SI-22	mosaic mask with jade, 2 other mosaic masks	mosaic mask, beads, earflares, tube, and celts	multiple blades					.70861 (Freiwald)								
CHP-SI-23		pectoral bars, celts				carved turtle bone		.70881 (Freiwald; Novotny & Awe)								
CHP-SI-24								.70877 (Freiwald; Novotny & Awe)								
CHP-SI-25								.70869 (Freiwald; Novotny & Awe)								
CHP-SI-26								.70877 (Freiwald)								
CHP-SI-27								.70872 (Freiwald)								
CHP-SI-28				chert						-10.0 (Novotny & Awe)						

Table A.2: Mortuary data binomially coded.

	A	SA	M	F	Sind	LPC	EC	LC	TC	H	ETS	PPS	EPS	Pr	Sc	Int	Ind	Ext	Flx	ScDisc	Sup	Prn	Simp	Cst	Cpt	Tmb
CHP-SI-01	1	0	0	1	0	0	0	1	0	0	1	0	0	1	0	0	1	1	0	0	1	0	0	0	0	1
CHP-SI-02	1	0	1	0	0	0	1	0	0	0	1	0	0	1	0	0	1	1	0	0	1	0	0	0	0	1
CHP-SI-03	1	0	1	0	0	1	0	0	0	0	1	0	0	1	0	0	1	1	0	0	0	0	0	0	0	1
CHP-SI-04	1	0	1	0	0	1	0	0	0	0	1	0	0	1	0	0	1	1	0	0	0	1	0	0	1	0
CHP-SI-05	1	0	1	0	0	0	0	1	0	0	1	0	0	1	0	0	1	1	0	0	0	1	0	0	0	1
CHP-SI-06	1	0	1	0	0	0	1	0	0	0	1	0	0	1	0	0	1	1	0	0	0	1	0	0	1	0
CHP-SI-07	1	0	0	1	0	0	0	0	0	0	1	0	0	1	0	0	1	0	0	0	0	0	0	0	1	0
CHP-SI-08	1	0	0	1	0	0	0	0	1	0	1	0	0	1	0	0	1	1	0	0	1	0	0	0	1	0
CHP-SI-09	1	0	0	0	1	0	1	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
CHP-SI-10	0	1	0	0	1	0	0	1	0	0	0	0	1	1	0	1	1	0	0	0	0	0	0	0	0	0
CHP-SI-11	1	0	1	0	0	0	0	1	0	0	0	1	0	1	0	0	1	0	1	0	1	0	0	0	1	0
CHP-SI-12	0	1	0	0	1	0	0	0	1	0	0	1	0	1	0	1	0	0	0	0	0	0	0	0	0	0
CHP-SI-13	1	0	0	0	1	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CHP-SI-14	1	0	0	0	1	1	0	0	0	0	0	1	0	1	0	0	1	0	0	0	0	0	0	0	1	0
CHP-SI-15	0	1	0	0	1	0	0	0	0	1	0	1	0	1	0	1	1	0	1	0	1	0	1	0	0	0
CHP-SI-16	1	0	1	0	0	0	0	0	1	0	0	1	0	1	0	0	1	1	0	0	0	0	0	0	0	1
CHP-SI-17	1	0	0	0	1	1	0	0	0	0	0	1	0	0	1	0	1	0	0	0	0	0	0	0	0	0
CHP-SI-18	1	0	0	1	0	0	0	1	0	0	0	1	0	1	0	1	1	1	0	0	0	1	0	1	0	0
CHP-SI-19	1	0	0	0	1	0	0	1	0	0	0	0	1	1	0	0	0	0	1	0	0	0	1	0	0	0
CHP-SI-20	1	0	0	0	1	0	0	0	1	0	1	0	0	0	1	1	1	0	0	1	0	0	0	0	1	0
CHP-SI-22	1	0	1	0	0	0	1	0	0	0	1	0	0	1	0	0	1	1	0	0	0	0	0	0	0	1
CHP-SI-23	1	0	0	1	0	0	0	0	1	0	1	0	0	1	0	1	1	0	0	0	0	0	0	0	0	1
CHP-SI-24	1	0	0	1	0	0	0	1	0	0	1	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0
CHP-SI-25	1	0	1	0	0	1	0	0	0	0	1	0	0	1	0	0	1	1	0	0	0	0	0	0	1	0
CHP-SI-26	1	0	0	1	0	0	1	0	0	0	1	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0
CHP-SI-27	1	0	1	0	0	0	0	1	0	0	1	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0
CHP-SI-28	1	0	0	1	0	1	0	0	0	0	1	0	0	1	0	0	1	0	0	0	0	0	0	0	0	1

	HN	HS	FE	FW	CeV	CeF	Ce	ShD	Sh	JdO	JdB	Jd	ObB	ChP	Cht	Sty	Fa	FaC	LocT	LocB	Elt
CHP-SI-01	1	0	0	0	1	0	1	1	0	1	0	0	0	0	0	0	0	1	1	0	1
CHP-SI-02	1	0	0	0	1	0	0	0	1	1	0	0	0	0	0	0	0	1	1	1	1
CHP-SI-03	0	1	0	0	1	1	0	0	0	0	1	0	0	0	0	0	0	0	1	1	1
CHP-SI-04	0	1	0	1	1	0	1	0	0	0	1	0	0	0	0	0	0	1	1	1	1
CHP-SI-05	0	1	0	1	1	0	0	1	1	0	1	0	0	0	0	1	0	0	0	0	1
CHP-SI-06	0	1	0	0	1	0	1	1	0	0	1	1	1	0	0	0	0	1	0	1	1
CHP-SI-07	0	1	1	0	1	0	1	1	0	0	1	0	0	0	0	0	0	0	0	1	1
CHP-SI-08	0	1	0	1	1	0	0	0	1	0	1	0	0	0	0	0	0	1	1	0	1
CHP-SI-09	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1
CHP-SI-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
CHP-SI-11	0	0	0	0	0	0	1	0	0	1	0	0	1	0	0	0	0	0	1	1	1
CHP-SI-12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1
CHP-SI-13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
CHP-SI-14	1	0	0	1	1	0	0	0	1	0	1	0	1	0	0	0	0	0	1	1	1
CHP-SI-15	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
CHP-SI-16	0	0	0	0	1	0	0	1	0	1	1	0	1	0	0	0	1	1	1	1	1
CHP-SI-17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1
CHP-SI-18	0	1	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	1
CHP-SI-19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
CHP-SI-20	0	0	0	1	1	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	1
CHP-SI-22	1	0	1	0	1	0	0	1	0	1	1	0	1	0	0	0	0	0	1	0	1
CHP-SI-23	1	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	1
CHP-SI-24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
CHP-SI-25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
CHP-SI-26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
CHP-SI-27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
CHP-SI-28	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	1

Table A.3: Finalized mortuary database for PCA, MDS, and NN analysis. Does not include uninformative columns, time period, structure, age, sex, origin, or status.

	Pr	**Sc**	**Int**	**Ind**	**Ext**	**Flx**	**Sup**	**Prn**	**Simp**	**Cpt**	**Tmb**	**HN**	**HS**	**FE**	**FW**	**CeV**	**Ce**	**ShD**	**Sh**	**JdO**	**JdB**	**ObB**	**FaC**
CHP-SI-01	1	0	0	1	1	0	1	0	0	0	1	1	0	0	0	1	1	1	0	1	0	0	1
CHP-SI-02	1	0	0	1	1	0	1	0	0	0	1	1	0	0	0	1	0	0	1	1	0	0	1
CHP-SI-03	1	0	0	1	1	0	0	0	0	0	1	0	1	0	0	1	0	0	0	0	1	0	0
CHP-SI-04	1	0	0	1	1	0	0	1	0	1	0	0	1	0	1	1	1	0	0	0	1	0	1
CHP-SI-05	1	0	0	1	1	0	0	1	0	0	1	0	1	0	1	1	0	1	1	0	1	0	0
CHP-SI-06	1	0	0	1	1	0	0	1	0	1	0	0	1	0	0	1	1	1	0	0	1	1	1
CHP-SI-07	1	0	0	1	0	0	0	0	0	1	0	0	1	1	0	1	1	1	0	0	1	0	0
CHP-SI-08	1	0	0	1	1	0	1	0	0	1	0	0	1	0	1	1	0	0	1	0	1	0	1
CHP-SI-09	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CHP-SI-10	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CHP-SI-11	1	0	0	1	0	1	1	0	0	1	0	0	0	0	0	0	1	0	0	1	0	1	0
CHP-SI-12	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CHP-SI-13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CHP-SI-14	1	0	0	1	0	0	0	0	0	1	0	1	0	0	1	1	0	0	1	0	1	1	0
CHP-SI-15	1	0	1	1	0	1	1	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0
CHP-SI-16	1	0	0	1	1	0	0	0	0	0	1	0	0	0	0	1	0	1	0	1	1	1	1
CHP-SI-17	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CHP-SI-18	1	0	1	1	1	0	0	1	0	0	0	0	1	0	0	1	0	0	0	1	0	0	0
CHP-SI-19	1	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CHP-SI-20	0	1	1	1	0	0	0	0	0	1	0	0	0	0	1	1	0	0	0	0	0	0	0
CHP-SI-22	1	0	0	1	1	0	0	0	0	0	1	1	0	1	0	1	0	1	0	1	1	1	0
CHP-SI-23	1	0	1	1	0	0	0	0	0	0	1	1	0	0	0	1	0	0	0	1	0	0	1
CHP-SI-24	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CHP-SI-25	1	0	0	1	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
CHP-SI-26	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CHP-SI-27	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CHP-SI-28	1	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0

APPENDIX B

STABLE ISOTOPE PREPARATION PROCEDURES

Cleaning & Documentation

The following cleaning procedure is the same for all stable isotope methods used in this research. There are slight differences in the process for different biological materials. These variations are separated below by bone and tooth.

Step 1: Take photos of each sample. Document bone, burial, and site information.

Step 2: For bone and tooth samples mechanically clean the surface of the sample with a Dremel tool, dental cleaning tool or scalpel. It is important to remove the outside layer of material that is likely contaminated without removing too much material or breaking the root of the tooth. Place in plastic boat and label.

Step 3: Bone – Sonicate the sample in a labeled beaker of distilled water until the water is clear. This removes the contaminants in the bone and the excess material left over from the mechanical cleaning. Tooth – The teeth get cut in half using a slow moving saw. Place the tooth in the saw and start with a slow speed, increase speed as the cut deepens. Ideally the tooth root will stay intact and each half will have both tooth root and enamel. The saw uses water as coolant so the tooth will be wet after cutting.

Step 4: Let all the samples dry under cover. It is important to label the boats that each sample is in. Covering the samples with a paper towel cuts down the possibility of contamination from dust.

Step 5: Once dry, photograph each sample.

Once the initial cleaning process is complete each sample is ready for its specific stable isotope preparation procedure. Below are the different preparation methods for each type of biological material.

Collagen Preparation Method

Collagen preparation procedures vary slightly based on the size of the sample, whether you prefer to grind the sample or keep it whole, and what your time frame is (Katzenberg, 2007). For the purposes of this paper I am focusing on the method created by Longin (1971) for human remains and later modified by Schoeninger and DeNiro (1984). This method was used for both bone and tooth dentin samples.

- Step 1: Samples are first cleaned of all excess dirt and contaminants usually using a Dremel tool or scalpel. Since collagen is only found in the tooth root/dentin removal of the enamel takes places at this step.
- Step 2: The bone or tooth is then ground into a powder using a mortar and pestle and demineralized in an 8% solution of hydrochloric acid (approximately 18 minutes), then rinsed to neutrality with distilled water.
- Step 3 The sample is soaked in 0.1M sodium hydroxide to remove excess organic material for approximately 20 hours and rinsed.
- Step 4: The residue is then heated to 90-95° C in hydrochloric acid. Some replenishment of the acid may be necessary to maintain acidity; this step takes approximately 10 hours.
- Step 5: The sample is now in liquid form and placed in a flask, it is then heated to 80° to concentrate it to 5 ml.
- Step 6: The solution is transferred to a vial, concentrated to 2 ml, and freeze dried. At this point the sample is pure collagen and weighted to determine the percent yield and the integrity of the sample.
- Step 7: For carbon and nitrogen stable isotope analysis; approximately 1.0 mg of collagen was weighed out from each sample and put in tin foil boats for the mass spectrometer.

- Step 8: The glass fiber filters, soils, and sediments are analyzed for ^{13}C and ^{15}N isotopes using an Elementar Vario EL Cube or Micro Cube elemental analyzer (Elementar Analysensysteme GmbH, Hanau, Germany) interfaced to a PDZ Europa 20-20 isotope ratio mass spectrometer (Sercon Ltd., Cheshire, UK).
- Step 9: The samples are then combusted again at 1080°C in a reactor packed with copper oxide and tungsten (VI) oxide.
- Step 10: Following this second combustion episode, oxides are removed in a reduction reactor (reduced copper at 650°C).
- Step 11: The helium carrier then flows through a water trap (magnesium perchlorate). N_2 and CO_2 are separated using a molecular sieve adsorption trap before entering the IRMS.

During analysis, samples are interspersed with several replicates of at least two different laboratory standards. These laboratory standards, which are selected to be compositionally similar to the samples being analyzed, have been previously calibrated against NIST Standard Reference Materials (IAEA-N1, IAEA-N2, IAEA-N3, USGS-40, and USGS-41). A sample's preliminary isotope ratio is measured relative to reference gases analyzed with each sample. These preliminary values are finalized by correcting the values for the entire batch based on the known values of the included laboratory standards. The long term standard deviation is 0.2‰ for ^{13}C and 0.3‰ for ^{15}N. The final delta values, delivered to the customer, are expressed relative to international standards VPDB (Vienna PeeDee Belemnite) and Air for carbon and nitrogen, respectively. Carbon isotopes ratios, $\delta^{13}C$, are reported expressed in permil (‰) notation (parts per thousand) relative to the PeeDee Belemnite standard (arbitrarily set at 0‰), while N isotope ratios, $\delta^{15}N$, are expressed against N_2 in modern atmospheric air (also arbitrarily set to 0‰) (http://stableisotopefacility.ucdavis.edu/13cand15n.html).

- Step 7 (Sulfur): Approximately 10 mg of collagen was weighed out for sulfur isotope analysis. Stable isotope ratios of $^{34}S/^{32}S$ in solid samples are measured using an Elementar vario ISOTOPE cube interfaced to a SerCon 20-22 IRMS (Sercon Ltd., Cheshire, UK).
- Step 8 (Sulfur): Samples are combusted at 1150°C in a reactor packed with tungsten oxide.
- Step 9 (Sulfur): Immediately following combustion, sample gases are reduced with elemental copper at 880°C and subsequently pass through a buffering reactor filled with quartz chips held at 900°C. SO_2 and CO_2 are then separated by purge and trap, allowing for full separation and peak focusing.
- Step 10 (Sulfur): After separation, the SO_2 adsorption trap is heated and the sample SO_2 passes directly to the IRMS for measurement.

During analysis, samples are interspersed with replicates of several laboratory reference materials to monitor and allow for correction of any potential variation in drift and linearity. Final $\delta^{34}S$ values are obtained after adjusting the provisional measurements such that correct $\delta^{34}S$ values for laboratory quality assurance materials are obtained. Laboratory reference materials have been calibrated directly against IAEA S-1, S-2, and S-3, as well as NBS-127, SO-5, and SO-6. The long-term reproducibility of this method is ± 0.4 ‰ (http://stableisotopefacility.ucdavis.edu/34s.html).

The collagen preparation method was provided to the author by Dr. Jelmer Eerkens at University of California, Davis (UC Davis). Dr. Eerkens oversaw the preparation and running of the samples for this research done by the author and lab assistant Bryna Hull.

Hydroxyapatite Preparation Method

Hydroxyapatite preparation methods were first introduced by Lee-Throp (1989; Lee-Thorp and van der Merwe, 1991) and are as follows:

- Step 1: Label 15ml test tube.
- Step 2: Weigh the labeled tube with no lid and record weight on form.
- Step 3: Tare the lidless tube weight on the scale.
- Step 4: Add 0.05g (50 mg) of <0.25mm bone fraction into tube; record sample weight on form.
- Step 5: Add 12ml 2% Bleach solution; vortex; Loosen cap slightly & recline tube on tray with top of tube elevated slightly on tray edge.
- Step 6: Check every 16-24 hours, vortexing occasionally, until bubbling ceases
- Step 7: If still bubbling, change bleach -- Place the tube in centrifuge (make sure it's balanced, using blanks if necessary) & run for 15 mins. The undissolved bone fraction and apatite will be packed at the bottom of the tube. Dump or carefully *pipet* out the dirty bleach (use a separate *pipette* tip for each sample). Refill with clean 2% bleach; vortex. *[bleach solution may go down drain]*
- Step 8: Repeat Steps 6-7 until bubbling ceases, approximately ~48+ hours.
- Step 9: Rinse sample to neutral with dH_2O – Centrifuge for 15 min**.** Dump or carefully *pipet* out liquid (use a separate *pipette* tip for each sample) *[Waste bleach can go down drain]*.

- Step 10: Refill with 12mL dH_2O; vortex for ~10 seconds. Repeat centrifuging and replacing dirty dH_2O with fresh dH_2O 5 times. Check with pH strip to make sure neutral is achieved. *[dH_2O rinse waste can go down drain].*
- Step 11: Add 12mL of 0.1M Acetic Acid; vortex. Let sit for 4 hours reclined (Garvie-Lok et al., 2004; Koch et al., 1997).
- Step 12: Rinse sample to neutral with dH_2O – Centrifuge for 15 min. Dump or carefully *pipet* out liquid (use a separate *pipette* tip for each sample) *[Waste acetic acid goes in hazardous waste bottle].*
- Step 13: Refill with 12mL dH_2O; vortex. Repeat centrifuging and replacing dirty dH_2O with fresh dH_2O 5 times. Check with pH strip to make sure neutral is achieved. *[dH_2O rinse waste can go down drain].*
- Step 14: After sample is rinsed to neutral, centrifuge once more and discard excess dH_2O. Place into the freezer.
- Step 15: After completely frozen, loosen the lid slightly and place the tube in freeze dryer for ~ 2 days until no moisture remains.
- Step 16: Load the apatite for mass spectrometer (located in the Biology and Geology buildings at Washington State University).

The sample preparation method was provided to the author by Dr. Erin Thornton at Washington State University (WSU) and all bone and tooth dentin apatite samples were processed at the WSU Stable Isotope facility.

Strontium Hydroxyapatite & Enamel Preparation Method

The preparation for strontium is limited to only hydroxyapatite and enamel. The preparation methods vary slightly based on my research, but consists of essentially the same steps with differing acidic solutions or dissolving time. The strontium preparation method outlined below comes from Deniel & Pin (2001), Wright (2005), and Richards et al. (2008) which consists of the following steps done in a clean room environment.

- Step one: Samples are sonicated in sterile plastic vials with deionized water.
- Step two: The sample is then soaked in a 5% ultrapure acetic acid at 80°C for approximately 24 hours to dissolve any soluble material and get rid of contamination.
- Step three: The samples are then dried and baked/ashed at 825°C in sterile glass tubes for 8 hours.
- Step four: The ashed samples are hot-digested with ultrapure concentrated HNO_3 (nitric acid) in clean vials.
- Step five: Finally, the samples are dried in a sterile laminar flow drying box, and then re-dissolved in ultrapure 2.5N hydrogen chloride (HCl).

Laboratory set-up also includes wet chemistry and dry chemistry areas, each with their own special equipment. Dry chemistry areas include fume hoods, mortars and pestles, Dremel tools, beakers, freeze dry machinery, and an oven. Wet chemistry areas include a water distillation area, wet chemical storage, fume hood, refrigerator or storage for demineralizing samples, and lots of glass containers for samples (Price and Burton, 2011).

APPENDIX C
STABLE ISOTOPE RAW DATA

Table. C.1: Bone collagen and tooth dentin δ^{13}C and δ^{15}N raw stable isotope data.

Bone									
Sample ID	**Collagen Yield**	**δ^{13}C**	**C Amount (ug)**	**δ^{15}N**	**N Amount (ug)**	**Atomic C/N Ratio**	**Collagen Submitted (mg)**	**SIF-OurLabID**	**Analysis Number**
CHP-SI-18B	3.57%	-8.48	445.09	10.00	157.52	3.30	1.155	952822	333996
CHP-SI-15B	6.47%	-8.53	452.13	9.92	163.32	3.23	1.158	952823	333997
CHP-SI-14B	2.00%	-10.69	303.38	9.45	108.61	3.26	0.985	952824	333998
CHP-SI-13B	3.23%	-10.17	432.03	8.55	154.62	3.26	1.094	952825	333999
CHP-SI-12B	7.06%	-9.91	411.96	10.68	148.80	3.23	1.048	952826	334000
CHP-SI-11B	11.32%	-9.28	470.26	10.81	171.03	3.21	1.13	952827	334001
Tooth									
Sample ID	**Collagen Yield**	**δ^{13}C**	**C Amount (ug)**	**δ^{15}N**	**N Amount (ug)**	**Atomic C/N Ratio**	**Collagen Submitted (mg)**	**SIF-OurLabID**	**Analysis Number**
CHP-01T-AB	-7.82	95.54	10.57	33.14	no		0.981	993295	343405
CHP-01T-C	-7.32	138.22	11.28	49.47	No		0.852	993296	343406
CHP-01T-D	-7.08	324.06	10.56	118.57	No		1.186	993297	343407
CHP-01T-E	-7.91	313.93	10.48	116.60	No		1.149	993298	343408
CHP-01T-F	-8.52	317.98	10.66	117.58	No		1.066	993299	343409
CHP-01T-G	-8.95	371.86	10.61	137.17	No		1.154	993300	343410
CHP-01T-CROWN	-8.06	370.84	10.02	135.22	No		1.054	993301	343411
CHP-03T-AM	-7.18	373.90	10.03	137.17	No		0.905	993302	343412
CHP-03T-BD	-7.43	333.20	10.01	122.50	No		0.869	993303	343413
CHP-03T-CDr	-8.61	346.41	10.07	126.42	No		0.943	993304	343414
CHP-03T-Ec	-8.51	377.97	9.96	139.12	No		0.933	993305	343415
CHP-031-F	-8.44	461.97	10.12	170.03	No		1.09	993306	343416
CHP-06T A	-8.77	343.83	9.55	125.53	No		1.012	1063244	342374
CHP-06T BC	-8.38	311.18	9.49	113.47	No		0.934	1063245	342375
CHP-06T D	-8.67	272.50	9.30	99.49	No		0.833	1063246	342376
CHP-06T EF	-8.74	367.89	9.37	133.88	No		1.102	1063247	342377
CHP-06T G	-7.71	352.85	9.12	128.68	No		0.968	1063248	342378
CHP-06T H	-8.13	387.22	9.56	141.00	No		1.076	1063249	342379
CHP-06TiJ	-8.05	373.47	9.93	135.66	No		1.061	1063250	342380
CHP-06T K	-8.39	329.65	10.10	120.05	No		0.949	1063251	342381
CHP-06T L	-8.15	388.94	9.71	142.37	No		1.019	1063252	342382
CHP-06T M	-7.74	382.92	9.63	139.63	No		1.001	1063253	342383
CHP-06T N	-8.35	402.68	9.62	147.84	No		1.07	1063254	342384
CHP-06T O	-8.12	391.94	9.41	143.74	No		1.046	1063255	342385
CHP-07T root tip	-12.88	41.10	11.38	12.36	No		0.84	1063256	342389
CHP-07T root	-9.31	313.75	9.48	111.14	No		0.968	1063257	342390

CHP-07T CRWN AA	-12.67	264.76	10.11	97.44	No		0.801	1063258	342391
CHP-07T CRWN BCBC	-14.35	243.70	10.35	88.66	No		0.851	1063259	342392
CHP-07T CRWN DD	-12.32	337.39	9.86	123.20	No		1.008	1063260	342393
CHP-07T CRWN EE	-11.83	220.48	9.94	79.88	No		0.851	1063261	342394
CHP-07T CRWN FF	-11.34	391.94	9.97	143.74	No		1.191	1063262	342395
CHP-08T R-T	-17.01	13.25	15.07	3.13	No		1.157	1063263	342396
CHP-08T CRWN	-16.61	36.41	11.54	7.18	No		0.658	1063264	342397
CHP-11T ABC	-9.90	188.05	11.18	65.05	No		0.905	1089692	375509
CHP-11T DE	-8.67	209.57	11.51	72.91	No		1.068	1089693	375510
CHP-11T FG	-8.94	297.10	11.40	104.90	No		1.129	1089694	375511
CHP-11T H	-8.62	285.74	11.69	101.83	No		0.999	1089695	375512
CHP-11T i	-9.04	371.78	11.48	131.71	No		1.163	1089696	375513
CHP-11T J	-8.68	306.41	11.60	108.55	No		0.963	1089697	375514
CHP-11T K	-9.21	249.65	11.32	87.51	No		0.892	1089698	375515
CHP-11T CRWN	-10.79	434.38	10.84	156.25	No		1.182	1089699	375516
CHP-12T AB	-10.25	372.82	11.02	129.37	No		1.181	1089700	375517
CHP-12T C	-9.50	275.42	10.81	97.57	No		0.848	1089701	375518
CHP-12T D	-9.31	300.21	10.42	107.14	No		0.916	1089702	375519
CHP-12T E	-9.07	381.15	10.46	135.23	No		1.115	1089703	375520
CHP-12T F	-9.06	380.10	11.07	135.23	No		1.046	1089704	375524
CHP-12T G	-9.01	406.16	11.90	145.75	No		1.121	1089705	375525
CHP-12T H	-9.41	390.52	11.93	139.91	No		1.038	1089706	375526
CHP-12T Bulk	-9.13	340.60	11.07	121.15	No		0.907	1089707	375527
CHP-13T AB	-10.33	242.45	9.17	85.50	No		0.961	1089708	375528
CHP-13T C	-9.71	218.81	8.82	77.19	No		0.804	1089709	375529
CHP-13T DE	-9.45	247.59	8.49	88.82	No		1.01	1089710	375530
CHP-13T FG	-10.54	298.14	8.31	104.43	No		1.126	1089711	375531
CHP-13T Hi	-11.29	258.92	8.01	88.46	No		1.189	1089712	375532
CHP-13T J	-10.74	215.73	8.30	75.05	No		1.037	1089713	375533
CHP-13T K	-9.47	179.86	8.27	62.90	No		0.831	1089714	375534
CHP-13T L	-8.84	332.31	9.09	118.68	No		1.167	1089715	375535
CHP-13T M	-8.50	318.83	9.59	113.97	No		1.142	1089716	375538
CHP-13T N	-7.86	250.68	11.56	90.12	No		0.954	1089717	375539
CHP-13T O	-8.23	222.92	11.82	78.49	No		0.829	1089718	375540
CHP-13T 2nd D	-10.22	181.91	8.92	64.69	No		0.543	1089719	375541
CHP-14T AB	-10.67	290.90	9.46	99.94	No		1.175	1089720	375542
CHP-14T C	-11.01	315.73	9.31	110.21	No		0.966	1089721	375543
CHP-14T D	-10.98	418.69	9.58	146.92	No		1.202	1089722	375544

CHP-14T E	-9.65	407.21	9.59	142.25	No		1.153	1089723	375545
CHP-14T F	-10.65	368.66	9.51	129.37	No		0.982	1089724	375546
CHP-14T G	-11.79	372.82	9.89	130.54	No		0.997	1089725	375547
CHP-14T H	-12.24	376.98	9.89	134.06	No		1.016	1089726	375548
CHP-14T i	-12.05	371.78	9.58	129.37	No		1.069	1089727	375549
CHP-14T J	-11.50	404.08	9.80	142.25	No		1.154	1089728	375553
CHP-14T CRWN	-11.87	391.56	9.32	139.91	No		1.015	1089729	375554
CHP-15T AB	-9.79	193.17	10.59	66.95	No		0.998	1089730	375555
CHP-15T C	-8.44	204.44	10.09	73.26	No		0.821	1089731	375556
CHP-15T DEF	-8.84	259.95	9.53	93.20	No		0.999	1089732	375557
CHP-15T GH	-8.50	263.04	8.86	94.50	No		1.101	1089733	375558
CHP-15T i	-8.15	223.94	8.41	80.75	No		0.858	1089734	375559
CHP-15T JK	-7.84	240.39	8.55	86.80	No		0.939	1089735	375560
CHP-15T LM	-8.33	211.62	8.61	75.76	No		0.829	1089736	375561
CHP-15T N	-7.86	251.71	8.43	91.07	No		0.921	1089737	375562
CHP-15T O	-8.64	300.21	9.12	106.90	No		0.967	1089738	375563
CHP-16T A	-9.21	301.24	10.30	103.60	No		1.074	1089739	375564
CHP-16T BC	-8.31	237.30	10.67	83.48	No		0.966	1089740	375571
CHP-16T DEF	-8.38	218.81	11.96	74.57	No		1.195	1089741	375572
CHP-16T GH	-8.44	210.60	11.63	73.14	No		1.075	1089742	375573
CHP-16T iJ	-8.01	331.27	11.43	116.56	No		1.192	1089743	375574
CHP-16T KL	-8.24	268.19	10.54	94.62	No		1.081	1089744	375575
CHP-16T M	-7.78	317.80	10.34	113.74	No		0.981	1089745	375576
CHP-16T N	-7.69	337.49	9.91	119.97	No		0.999	1089746	375577
CHP-16T CRWN	-8.27	330.23	10.68	114.68	No		0.853	1089747	375578

Table 6.2: Bone collagen $\delta^{34}S$ raw stable isotope data.

Sample Name	**Collagen Yield**	**Collagen Submitted (mg)**	**SIF-OurLabID**	**Analysis Number**	**mg S**	**%S**	**$\delta^{34}S$**	**Sulfur Run#**
CHP-SI-18B	3.57%	1.155	952822	333996	27.3	0.3%	11.71	22
CHP-SI-15B	6.47%	1.158	952823	333997	24.1	0.3%	6.89	21
CHP-SI-13B	3.23%	1.094	952825	333999	19.0	0.2%	11.77	25
CHP-SI-12B	7.06%	1.048	952826	334000	19.3	0.2%	11.54	24
CHP-SI-11B	11.32%	1.13	952827	334001	21.2	0.2%	12.56	23

Table C.3: Bone apatite and tooth enamel $^{87}Sr/^{86}Sr$ raw stable isotope data.

Number	**Burial information**	**Material**	**$^{87}Sr/^{86}Sr$**	**%Std Err**	**Ratios**	**Raw 87/86**	**Av. of Stds**	**No. Stds**
UM1A	CHP-SI-0IT	tooth enamel	**0.708543**	0.0003	105/110	0.708530	0.710237	13
UM3A	CHP-SI-03T	tooth enamel	**0.708352**	0.0003	105/110	0.708339	0.710237	13
UM4A	CHP-SI-04T	tooth enamel	**0.708559**	0.0003	105/110	0.708546	0.710237	13
UM6A	CHP-SI-06T	tooth enamel	**0.708814**	0.0004	106/110	0.708801	0.710237	13
UM7A	CHP-SI-07T	tooth enamel	**0.709013**	0.0003	106/110	0.709000	0.710237	13
UM8A	CHP-SI-08T	tooth enamel	**0.708516**	0.0003	108/110	0.708503	0.710237	13
UM10A	CHP-SI-10T	tooth enamel	**0.708600**	0.0003	104/110	0.708587	0.710237	13
UM11A	CHP-SI-11T	tooth enamel	**0.708509**	0.0003	104/110	0.708496	0.710237	13
UM12A	CHP-SI-12T	tooth enamel	**0.708551**	0.0003	102/110	0.708538	0.710237	13
UM13A	CHP-SI-13T	tooth enamel	**0.709297**	0.0004	106/110	0.709284	0.710237	13
UM14A	CHP-SI-14T	tooth enamel	**0.708431**	0.0003	105/110	0.708418	0.710237	13
UM15A	CHP-SI-15T	tooth enamel	**0.707813**	0.0004	42/44	0.707800	0.710237	13
UM16A	CHP-SI-16T	tooth enamel	**0.708606**	0.0003	~110/120	0.708587	0.710231	9
UM17A	CHP-SI-01B/B7 I1	bone	**0.708923**	0.0004	83/88	0.708910	0.710237	13
UM18A	CHP-SI-02B B7 I2	bone	**0.708661**	0.0003	106/110	0.708648	0.710237	13
UM19A	CHP-SI-03B B1 Bu8	bone	**0.708539**	0.0002	104/110	0.708526	0.710237	13
UM20A	CHP-SI-04B Str B1 Bu10	bone	**0.708513**	0.0003	106/110	0.708500	0.710237	13
UM21A	CHP-SI-05B Str B1 Bu 11	bone	**0.709172**	0.0003	105/110	0.709159	0.710237	13
UM22A	CHP-SI-06B Str B1 Bu 12	bone	**0.708670**	0.0003	107/110	0.708657	0.710237	13
UM23A	CHP-SI-07B Str B1 Bu 13	bone	**0.708538**	0.0003	94/99	0.708525	0.710237	13
UM24A	CHP-SI-08B Str B3 Bu 1	bone	**0.709649**	0.0003	107/110	0.709636	0.710237	13
UM25A	CHP-SI-09B Str B2 Bu 1	bone	**0.708636**	0.0003	106/110	0.708623	0.710237	13
UM27A	CHP-SI-11B Str B4 Bu1	bone	**0.708359**	0.0003	104/110	0.708346	0.710237	13
UM28A	CHP-SI-12B Str C2 Bu1	bone	**0.708479**	0.0004	108/110	0.708466	0.710237	13
UM30A	CHP-SI-14B Str Plaza Bu 1	bone	**0.708546**	0.0003	105/110	0.708533	0.710237	13
UM31A	CHP-SI-15B Plaza G Bu1	bone	**0.708253**	0.0003	104/110	0.708240	0.710237	13
UM32A	CHP-SI-16B Plaza H Tomb 1	bone	**0.708565**	0.0003	104/110	0.708552	0.710237	13
UM33A	CHP-SI-17B Str B4 Bu 1	bone	**0.708600**	0.0003	104/110	0.708587	0.710237	13
UM34A	CHP-SI-18B Str B4 Bu 1	bone	**0.708368**	0.0003	106/110	0.708355	0.710237	13

Table C.4: Bone apatite and tooth enamel δ^{13}C and δ^{18}O raw stable isotope data.

Tooth - C. Freiwald	**SAMPLE ID**	**δ^{13}C VPDB**	**C measurement**	**δ^{18}O VPDB**	**O measurement**	**Voltage**
	UM1-B/FREIWALD/K909	-3.24	0.034	-3.72	0.057	1.48
	UM3-B/FREIWALD/K909	-2.91	0.022	-4.06	0.070	2.09
	UM4-B/FREIWALD/K909	-3.56	0.007	-4.02	0.034	2.26
	UM6-B/FREIWALD/K909	-2.66	0.015	-3.27	0.026	2.70
	UM7-B/FREIWALD/K909	-6.03	0.017	-3.87	0.019	1.69
	UM8-B/FREIWALD/K909	-3.03	0.033	-3.50	0.027	1.86
	UM10-B/FREIWALD/K909	-3.68	0.030	-3.16	0.075	1.59
	UM11-B/FREIWALD/K909	-5.56	0.007	-2.56	0.044	2.43
	UM12-B/FREIWALD/K909	-4.30	0.003	-3.19	0.031	2.47
	UM13-B/FREIWALD/K909	-3.35	0.055	-3.42	0.055	1.40
	UM14-B/FREIWALD/K909	-6.20	0.036	-3.46	0.020	1.75
	UM15-B/FREIWALD/K909	-1.69	0.043	-2.11	0.038	1.99
	UM16-B/FREIWALD/K909	-3.62	0.081	-3.78	0.039	1.40
Bone - E. Thornton						C%
KGR-0187	CHP-SI-01B	-4.03	0.44	-5.48	0.14	0.383
KGR-0188	CHP-SI-02B	-3.7	0.4	-5.99	0.07	0.403
KGR-0189	CHP-SI-03B	-3.98	0.4	-5	0.09	0.255
KGR-0190	CHP-SI-04B	-4.3	0.1	-6.3	0.11	0.351
KGR-0191	CHP-SI-05B	-5.28	0.14	-6.03	0.09	0.362
KGR-0192	CHP-SI-06B	-4.47	0.28	-5.63	0.2	0.263
KGR-0193	CHP-SI-07B	-5.97	0.1	-6.44	0.1	0.478
KGR-0194	CHP-SI-08B	-3.47	0.16	-5.39	0.18	0.309
KGR-0195	CHP-SI-09B	-3.54	0.67	-5.46	0.1	0.970
KGR-0196	CHP-SI-10B	-4.78	0.22	-5.77	0.1	0.477
KGR-0197	CHP-SI-11B	-5.8	0.32	-6.54	0.11	0.945
KGR-0198	CHP-SI-12B	-6.01	0.08	-4.75	0.1	0.796
KGR-0199	CHP-SI-13B	-6.25	0.24	-5.59	0.13	0.940
KGR-0200	CHP-SI-14B	-5.75	0.4	-5.72	0.14	0.498

KGR-0201	CHP-SI-15B	-8.55	0.02	-6.4	0.05	1.033
KGR-0202	CHP-SI-16B	-5.86	0.11	-6.48	0.17	0.533
KGR-0203	CHP-SI-17B	-6.5	0.15	-4.79	0.05	0.247
KGR-0204	CHP-SI-18B	-5.16	0.39	-5.23	0.08	1.118