MAYA MIGRATION NETWORKS: RECONSTRUCTING POPULATION MOVEMENT IN THE BELIZE RIVER VALLEY DURING THE LATE AND TERMINAL CLASSIC

by

Carolyn Freiwald

A dissertation presented in partial fulfillment

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Carolyn Freiwald

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The dissertation is approved by the following members of the Final Oral Committee:

Jason Yaeger, Professor of Anthropology, Department of Anthropology
T. Douglas Price, Weinstein Professor of European Archaeology and Director, Laboratory for Archaeological Chemistry, Department of Anthropology
James H. Burton, Senior Scientist and Associate Director, Laboratory for Archaeological Chemistry Department of Anthropology
Sissel Schroeder, Professor of Anthropology, Department of Anthropology
Sarah Clayton, Assistant Professor of Anthropology, Department of Anthropology
Eve Emshwiller, Assistant Professor of Botany, Department of Botany

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Carolyn Freiwald

Under the supervision of Jason Yaeger and T. Douglas Price

At the University of Wisconsin – Madison

abstract

Population movement was widespread in the Belize River valley during the Late and Terminal Classic periods (AD 600-900). Although long distance migration was rare, migration within the region was common, and more than 23% of the individuals sampled relocated at least once during life. These included men, women, and children residing in major centers, minor centers, and rural settlements. Strontium isotope ratios in tooth enamel of 178 individuals buried at 19 sites in the Belize River valley and neighboring regions are used to identify migration by comparing them against a detailed baseline of $^{87}Sr/^{86}Sr$ values from the across the Maya area. The study presents new isotope baseline values for the geologically heterogeneous Belize Valley region, where distinct strontium values characterize zones less than 20 km apart. New isotope values also are presented for other regions, including the Maya Mountains and Chiapas. Modern migration studies provide the framework for interpreting the resulting data, leading to a broader definition of migration that can be used to model population movement in other parts of Mesoamerica, as other parts of the world.

Carbon and oxygen isotope values in tooth enamel are used as another proxy to identify migration. These values also provide basic information about childhood diet, while carbon, oxygen, and nitrogen assays in bone collagen and apatite reflect adult dietary choices. Childhood diet resembled adult diet, and there were no patterned dietary differences between migrants and the locally born population.

A broader examination of diet, burial treatment, and body modification permits interpretations about the meaning of migration and social position of immigrants. Burial orientation proves to be an extremely strong indicator of origin. While non-local individuals were found in every type of burial context, they are more likely to be represented by partial remains, and less likely to be found in royal and noble burials. There are no notable differences in health indicators, but a re-analysis of linear enamel hypoplasia data by place of origin instead of burial location produces different results, reinforcing that ignoring population movement can confound other types of archaeological studies.

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This project has been – and will continue to be - a highly collaborative effort. It includes samples from more than 22 sites excavated by multiple projects over a period of fifty years. The samples were processed in labs and museums in five states with collaborators from at least five countries. Several researchers in particular were willing to share ideas and unpublished research and deserve special recognition, as do the members of my committee willing to read and critique this dissertation, the lab directors who taught me how to glean information from the fragile remains, and friends and colleagues in Belize who put up with me and made this research so much fun.

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I did not plan to include a formal dedication. I thought it was better to just send thanks directly to my advisors, dissertation committee, friends, colleagues, and family for all the support they have given me on this project. My friends and family, especially Matt, Alice, and Ray, participated in more conversations about chemistry, history, and dead animals than they may have liked. And that may not change, so I thank them also for their future support and patience. And thanks to Bill and Lynn Whitford for helping to produce another UW-Madison archaeology dissertation, possibly setting a new city record. But I write this after completing my final chapter in the rotunda and hallways of the Wisconsin State Capitol Building this final week of February, 2011, in the company of thousands of people who came to stand for something they believe in. They came from all over the state – some from tiny towns I have never heard of – with the support of people across the country and the world, as far away as Nicaragua, Egypt, and Antarctica. This book is dedicated to them.

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Chapter 1 Introduction

People move. Migration forms a part of the history of every country, every continent, and every culture. Some societies are more mobile than others, but population movement occurs to some extent even in the most closed and isolated communities. One could even say that human history has been the history of people's movement (Koji 2000:11).

Migration is a complex term that encompasses myriad types of population movement, from residential mobility within a city or state, to long distance relocation, to involuntary movement, like the slave trade or captive taking during times of war. Each type of movement potentially has an enormous impact on both the communities the individuals join and the ones they leave behind. The population size of a community affects the accessibility of resources like land, food, and water, and its demographic composition has an impact on the availability of marriage partners, caregivers, and the labor force. Archaeologists may use different terms to discuss population movement, such as residential mobility and migration, but have spent decades trying to identify and understand it in ancient societies around the world (Anderson and Gillam 2000; Anthony 1990; Beekman and Christiansen 2003; Bentley et al. 2003a, 2003b, 2007; Blitz 1999; Buikstra et al. 2004; Cameron 1995; Cameron and Duff 2008; Cohen 2000; Coombs 1979; Ezzo et al. 1997; Grupe et al. 1997; Hanson 2006; Haury 1958; Hoerder 1996, 2002, 2004; Jackson and Moch 1996; Killgrove 2010; Knudson et al. 2004; Krueger 1985; Marsden and West 1992; McKechnie 1989; Moch 1996; Nelson and Schachner 2002; Pauketat 2003; Price et al. 1998, 2000, 2001, 2004, 2007; Rouse 1986; Scheidel 2004; Snow 1995, 1996; Spence 1996; Spence et al. 2004; Varien 1999; White et al. 2002, 2004b; Wright 2005a, 2005b; Wright and Bachand 2009).

One of the key questions about the Maya during the Classic period (AD 250 – 900) hinges on understanding population movement. The collapse of social and political institutions during the Terminal Classic (~AD 800-900) is one of the most perplexing and well-studied phenomena in the Americas (Demarest 2006). While causes and contributing factors are still debated, the massive demographic shifts that define the collapse remain poorly understood after decades of research. However, population movement occurred on a large scale throughout the Classic period. Cities and small farmsteads were constructed, occupied, and then abandoned across the Maya lowlands. Changes in settlement patterns were at times accompanied by changes in material culture, but how does the presence of non-local goods relate to that of non-local people? Archaeologists traditionally have struggled to understand whether changes in architectural and ceramic styles signal an influx of people, or new trends developed by the same people.

Scholars now use archaeological geochemistry to refine interpretations about migration made using architectural, iconographic, and artifactual evidence. For example, Tikal and Copán rulers associated with the material culture of Teotihuacan were considered potential migrants from the Valley of Mexico. Isotope ratios in their bones and teeth suggest that they were, in fact, born in the Maya region (Price et al. 2010; Wright 2005a). In these examples, population movement has far-reaching implications for the influence of internal processes v. external interventions in development of sociopolitical power and kingship in the Maya region (see summary in Braswell 2003).

This study addresses the topic of migration directly, with the goal of reconstructing the most basic elements of migration among the Maya. What was the demographic profile of the migrant population? And how common was migration? Identifying who moved, how far, and in what direction, is the first step in reconstructing migration patterns. Strontium isotope ratios in the tooth enamel of 178 individuals buried at 19 sites in the Belize River Valley and neighboring regions are used to identify patterns of population movement in the Maya lowlands.

Migration patterns relate to larger questions about social and political organization. Many aspects of migration are tied directly to kinship, suggesting deep ties within and between regions where people have moved. Incorporating new individuals from distant locations, and even neighboring communities, also requires a flexible social structure, and the extent to which individuals assimilate or maintain their traditions is a reflection of social organization.

Migration can be identified at the individual level by measuring isotope ratios in human tooth and bone, which reflect different the sources and types of food and water in the diet. The ratio of isotope 87-strontium to 86-strontium varies according to the geologic age and elemental composition of bedrock in a region, so tooth enamel reflects where in individual obtained most foods. In Belize, geologic changes occur over such short distances that there are distinct strontium zones within the Belize Valley. Moreover, these have $^{87}Sr/^{86}Sr$ isotope ratios that differ from other parts of Mesoamerica (Hodell et al. 2004; Price et al. 2010), allowing both regional and long distance migration to be identified.

Individuals with $^{87}Sr/^{86}Sr$ values that differ from those of their burial location are considered migrants, and an individual's potential origin can be determined because strontium isotope values are known for most of the Maya region. Dietary differences, like water sources, the proportions of plants, and the types of animals consumed, also have been identified in different parts of the Maya lowlands (Gerry 1993; Piehl 2006; Price et al. 2010). Oxygen and carbon isotope ratios in tooth enamel reflect these differences and provide an additional means of identifying migration, especially when interpreted in conjunction with burial context and other archaeological evidence.

And what did it mean to be a migrant? There are many aspects of identify that are not visible in the archaeological record, like an individual's hairstyle, dress, or accent. Archaeologists have examined the role of sex, age, and status in behaviors that relate to identity, like burial treatment, diet, and body modification. Carbon and nitrogen isotope assays are used to determine whether a migrant maintain distinct dietary practices. Burial treatment and osteological data provide the additional data needed for an in-depth examination of the relationship between origin and identity in the Belize Valley.

This study focuses on reconstructing migration patterns during the Late and Terminal Classic (AD 600-900) in the Belize River Valley (Figure 1.1). The goals are twofold: first, to understand the importance of population movement during this critical time period, one that encompasses the time just before the collapse and as demographic shifts were occurring; second, to create a model of migration useful for understanding similarities and differences in population movement and its impacts in other ancient societies.

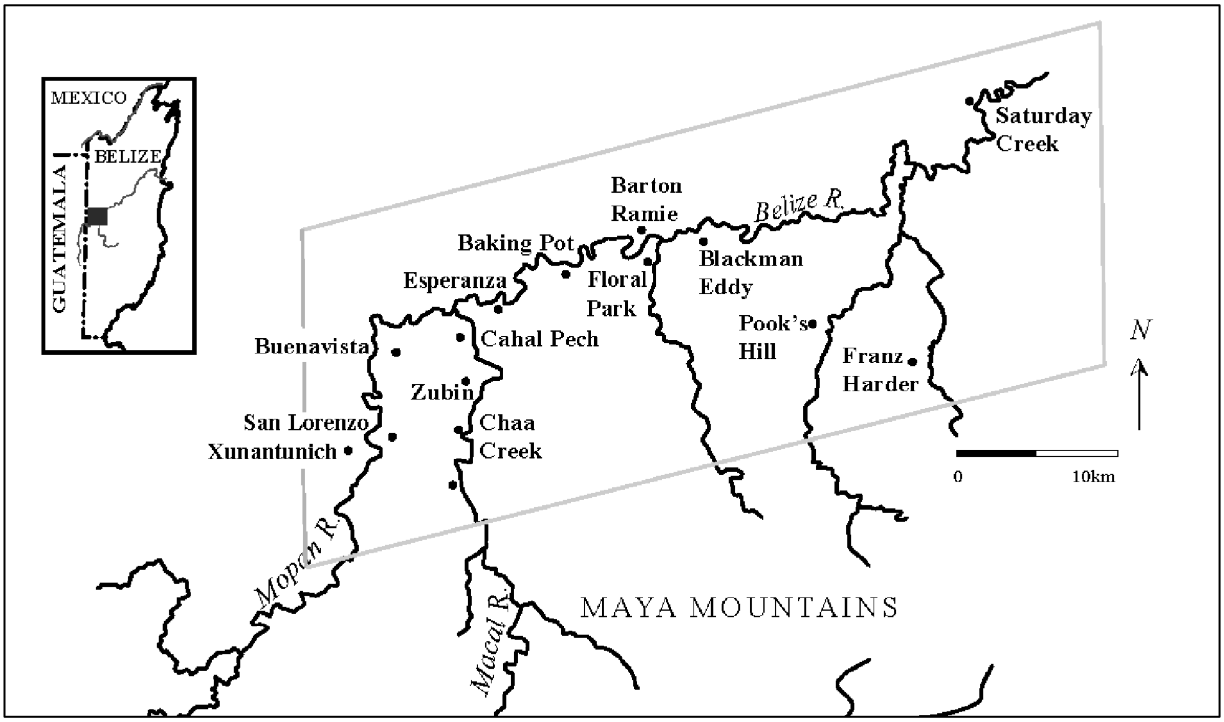

Figure 1.1 Map of Belize Rover Valley study area.

Migration has been a focus of anthropological research for more than a century. Chapter 2 provides a history of scholarship on migration by archaeologists, as well as researchers in other disciplines. An overview of research that ranges from Neolithic Europe, to complex civilizations in South America, to Mississippian and historic groups in North America presents the many approaches researchers use to reconstruct patterns of population movement. This includes traditional methods, like analyzing settlement patterns and research using historic documents, to use of bone chemistry methods to identify migration directly in the humans themselves.

Theoretical development lags behind advances in methods used to identify population movement. This may stem from the narrow definition of migration most commonly employed by archaeologists, which interprets migration as long distance, one-time movement, and excludes the myriad types of population movement considered by researchers in other fields (e.g., Cadwallader 1992; Koji 2000; Hoerder 2004). In fact, the studies that do model population movement implicitly reference modern studies rather than anthropological interpretive frameworks (e.g., Blitz 1999; Ezzo et al. 1997; Varien 1999).

Modern migration studies provide the framework for this project. Classic Maya texts make only limited references to migration (Martin and Grube 2000), and the applicability of Colonial era analogy to earlier periods is frequently questioned (see Farriss 1984). Therefore it is necessary to turn to more general analogy. Modern observations have proved useful in understanding population movement in historic studies, and can be used to model patterns of population movement in ancient societies (e.g., Coombs 1979).

Observations on modern population movement describe migration as a kin-based phenomenon with great time depth, one that occurs primarily for social reasons, though myriad other factors influence an individual's decision to move. Three questions are drawn from Ravenstein's (1885, 1889) descriptions of population movement more than a century ago to frame a model: these are not used to predict migration patterns among the Classic Maya, but to provide a baseline against which differences can be measured. The first proposes that most migration occurs within a polity or region, while the second suggests that patterns may vary by site or polity within a region, depending on each one's distinct historical trajectory. Third, migration should not occur evenly throughout the population.

These basic questions are important in the Belize River Valley, which forms a cultural and geographic subregion of the Maya lowlands. Population movement into the region may have contributed to the rapid population growth during the early Late Classic, but from where, and was it ongoing, or a temporary phenomenon? Will the different historic trajectories of polities in the region be reflected in patterns of population movement, and in what segments of the population?

Migration can be identified in the Belize Valley because key aspects of geology, diet, burial treatment, and body modification differed from those identified elsewhere in the Maya lowlands (Gerry 1993, 1997; Schwake 2008; Tiesler in press; Welsh 1988; Willey et al.1965; Yaeger 2003). Chapter 3 describes the diverse population sampled in this study. Individuals were selected from major and minor centers, as well as rural settlements, and from burial contexts in both residential and public architecture. While the demographic composition of the burial population does not mirror the age, sex, or status distribution of the living one (e.g., Wright 2006), the sample size is large enough to address demographic question using subsets of the total sample population.

The background on strontium isotope analysis and the geology of the Maya region presented in Chapter 4 shows how isotopic analysis is used to identify population movement, including a discussion of its limitations and how it cannot be used. This includes a description of the inputs of strontium sources into the local environment, and the manner by which the element is incorporated into human tissues. There is no measureable fractionation of $^{87}Sr/^{86}Sr$ ratios, so modern fauna sampled from the catchment(s) of sites in the study are used to establish a baseline of biologically available strontium isotope values expected in the human population. Although non-local foods are identified at nearly every Maya site, including marine foods, cacao, and salt, the main source of dietary elemental strontium should come from locally acquired foods.

Four zones with distinct average strontium isotope values are present in the Belize Valley and adjacent regions, and two of these have not been reported. $^{87}Sr/^{86}Sr$ average .7086 along the

Belize River, .7095 along the Macal River, and exceed >.711 in the Maya Mountains and Mountain Pine Ridge. Average values of .7077 are identified in the Vaca Plateau, which are similar to those reported by Hodell and colleagues (2004) for the Central Lowlands.

Strontium isotope values expected in two other regions in Mesoamerica are now documented in biological samples, including includes values from the Western Lowlands and the Central Depression and Pacific Coast of Chiapas. There are areas in Mesoamerica with unknown strontium isotope diversity, like eastern Honduras, that are culturally relevant to some Maya lowland sites. However, in this study, the closest potential homeland for non-local individuals is considered the most likely. Identification of non-local values is based on a modified version of Price et al. (2002) that uses both the range and mean of modern fauna as the baseline for expected values in the human population.

The results of the strontium isotope analysis (Chapter 5) show that more than 20% of the individuals in the study relocated at least once during life. This includes men, women, and children interred at major and minor centers and rural settlements. Migrants were buried in house mounds and residential shrines, as well as in public architecture. The diversity in the burial context and location of non-local individuals suggests that population movement was common, and that this estimate is probably still too low because relocation within a strontium zone cannot be measured using this method.

Information is presented for each individual and each burial in a detailed site-by-site format that includes age, sex, body position, strontium isotope value, and specific time period (additional information is provided in Appendix B). The rate of population movement ranged from 0 – 100% at different sites, but overall occurred mainly within the Belize Valley, with very few instances of either long distance or interregional in-migration.

Chapter 6 ties dietary analysis into the discussion of migration in two ways. First, oxygen and carbon isotope analysis of tooth enamel provide additional evidence for migration that complements information derived from the strontium isotope values. Second, these values compare aspects of childhood diet among sites in the Belize Valley, Vaca Plateau (Caracol), the Mountain Pine Ridge, and Chiapas. New data are presented that are valuable for identifying population movement over broad geographic regions in Mesoamerica.

The results of carbon, nitrogen, and oxygen isotope assays in bone apatite and collagen are consistent with those identified by Piehl (2006) and Gerry (1993) that show a regionally-distinct diet with no marked differences between individuals of different age, sex, status, and now, geographic origin. Migrants did not have diets distinct from those were who locally born. The combined results of the isotopic analyses prove useful in reconstructing life histories for a number of individuals in the study, which provide insight into what it meant to be a migrant in the Belize Valley.

All the lines of evidence come together in Chapter 7, which summarizes the main findings. Migrants were more likely to be buried with other individuals, and to be represented only by partial remains (e.g., crania or skulls), while rulers and royals were more likely to be locally born. However, the extent to which population movement was present in each burial location and context sampled shows that Maya social structure was set up to accommodate frequent movement.

There was no relationship between observations of pathology or trauma and migration. Nor was the absence of grave goods a key indicator of non-local origin. However, other aspects of burial treatment, like the orientation and position of the body, are strongly patterned. Dental decoration also may relate to an individual's origin, a finding that merits additional research. The greatest implications stem from a re-analysis of the distribution of linear enamel hypoplasias at two sites: the findings change significantly when the data are compared by place of origin (isotope values) instead of burial location. An understanding of migration is a critical consideration for analyses of skeletal populations.

The implications of these patterns of population movement are wide ranging (Chapter 8). The first finding relates to migration itself. Most movement occurred in the Belize River Valley, but in-migration from each neighboring region also occurred on a more limited basis. Migration networks were not the same in each community, but they were interconnected, and tied every polity, site, and community together within the region, and drew the region into broader social networks in the Maya lowlands. A comparison of findings in other published studies suggests similar patterns, which draws a picture of how migration was structured during the Late and Terminal Classic.

Widespread population movement also has implications for the political and economic structure, both of which are structured, at least in part, by social connections. To the extent that kin-based migration networks form the basis for ongoing social relationships, most interaction occurred over fairly short distances. The ability of individuals to migrate also reflects the level of political control of rulers in the region, either in their power to attract residents to areas they controlled, or in a lack of control over land tenure and movement in the valley.

Patterns of population movement provide more direct information on Maya social organization. Women were not more likely to relocate, which shows that postmarital residence patterns – and/or the reasons people moved – were fairly complex. The framework used in this study can be applied to other parts of the Maya lowlands to model population movement and to understand the variability of population movement over time and space in Mesoamerica. The model also provides a means to compare migration patterns in ancient societies in other parts of the world to understand how they affected people in the past, and how they differ from migration and the enormous impact it has on societies today.

Chapter 2 Migration and Archaeology

Chapter Summary

Archaeologists interested in studying migration have to contend with both methodological and theoretical difficulties. Scholars traditionally have relied on complex patterns of changing material culture to infer movement of people, a problem compounded by the use of an overly narrow definition of migration that limits construction of models needed to interpret this demographic process.

An overview of migration among the Maya over time shows that while substantial population movement occurred, insufficient evidence exists to construct a model of how it was structured. Models proposed for other parts of the ancient world also fail to provide a theoretical framework for movement within and between populated areas. Studies that attempt to understand migration at the microlevel, like those in the US Southwest, draw from modern migration studies, both for a broader definition of migration, and to frame the basic questions needed to effectively model ancient migration.

It is essential to understand migration, for it impacts nearly every aspect of society, from availability of land, to choice of marriage partners. A community's social fabric must be structured to accommodate migration, both to incorporate newcomers and to adjust to the loss of those who move away. Ongoing movement forms the basis for extended social networks with different levels of complexity. This study addresses basic questions about migration: Were there differences in mobility between Maya elites and commoners, men and women, or between rural and urban communities? And how did this affect social organization and relations within and among Belize Valley communities?

It is especially important to understand migration and its role in sociopolitical organization during the Terminal Classic, as the demographic shifts that define the Maya collapse occurred. Population movement was intertwined with the social, political, and economic changes, and understanding how it was structured may provide insight into why these changes occurred.

A. The history of migration in archaeological research

Migration was one of the earliest concerns of ethnologists, who considered material goods to be a direct representation of different cultures, which in some cases were interpreted as distinct ethnic groups. European scholars like Childe attributed the diffusion of material culture, especially technological advances, to the migration of people across broad regions. This scholarship was used to justify claims to territory and cultural superiority by Kossina and others

(Anthony 1990; Childe 1951; Trigger 2000:165). In North America and Africa, this related to the assumption that external forces, like migration, drove changes in otherwise static and unchanging native cultures (Chami 2007; Snow 1995:60).

Recognition of the limitations of migration as an explanation for culture change led to attempts by Haury (1958) and Rouse (1958) to refine trait lists used to identify which changes in material culture actually signal the actual movement of people. However, methodological difficulties in differentiating the movement of people from that of goods were compounded by several factors, including a preference for developing new methods to identify population movement, without also creating theoretical models to guide the interpretations. A rejection of studies from other disciplines and an over-emphasis on causality led to what Anthony (1990, 1992) describes as archaeologists throwing the proverbial baby out with the bathwater. Archaeologists still often assume a stable and stationary population that ignores migration entirely (Dewar 2000; Montgomery 2002). Demographic models that include migration as a variable often rely on estimates based on theoretical models or assume movement that ranges from 0-20% (Curet 2005; Snow 1995; Storey 1992).

Migration can affect the most basic aspects of life, from the availability of land, food, and marriage partners, to the way an individual’s identity is perceived by the community. Migration in ancient societies has not been ignored (e.g., Cheetham 2006; Curet 2005; Dumont 1998; Santley et al. 1987; Spence 1996; Smyth and Rogart 2004; Snow 1995, 1996). However, it is still understudied in many parts of the world despite efforts since the 1950s to reignite research (Anthony 1990, 1992; Cameron 1995; Haury 1958; Snow 1995; Rouse 1986).

Understanding migration as a demographic process poses both theoretical and methodological complexities. Migration is most commonly identified using artifacts, but when does a transformation in material culture reflect changing tastes and technologies, and when does it signal different people? Despite attempts to better define archaeological correlates for migration (Haury 1958; Rouse 1986; Spence 1996), artifacts, which can be traded and copied, serve only as indirect evidence for population movement.

Recently archaeologists have applied methods in bone chemistry to directly identify migration in individual people. These methods have been used to identify migration across the globe in diverse time periods and populations, from Neanderthals, to Neolithic farmers in Europe, and Native Americans (Bentley et al. 2003a, 2003b, 2007; Buikstra et al. 2004; Buzon et al. 2007; Ezzo et al. 1997; Grupe et al. 1997; Killgrove 2010; Knudson 2004, Knudson et al. 2004; Price et al. 1994, 1998, 2000, 2001; Richards et al. 2008; Shaw et al. 2009; White et al. 2002, 2004b, 2007). In fact, migration may be a nearly universal characteristic of human society. Instead of asking why people move, perhaps we should ask: why not? Archaeologists often regard migration as unusual or transitional, but population movement is a constant (Koji 2000:11).

B. Defining and theorizing migration: broadening the archaeological view

Theoretical development, however, lags behind methodological advancements. Models generally focus on colonization events or a single aspect of migration, like residential mobility. This reflects the traditional archaeological definition of migration solely as a long distance, unidirectional movement involving large numbers of people. This narrow definition is unique to archaeology as a discipline and excludes most types of population movement.

Migration is flexible term, used in a variety of ways by demographers, sociologists, economists, and anthropologists. It generally describes movement that crosses a political boundary (Finnegan 1976). This can include international and transoceanic movement (Geisen 2004:54), or relocation between cities, both of which occur over long and short distances (Hoerder 2004). Within political boundaries, residential mobility is the most common type of population movement. This distinction is echoed by Cameron (1995) and Anthony (1990), as well as Cadwallader (1992), who separates migration between cities, with no specific distance implied, from residential mobility, which represents a change of residence within them.

Other subcategories of migration describe types of long term or permanent movement. Step-wise migration occurs as an individual moves between two points gradually, from a village to town, and then to a city. Chain migration occurs as new immigrants follow the same path. The movement of individuals move back to their villages is referred to as return migration. This can create a series of movements by one or more generations of migrants between specific locations, which is called channelized migration. In some cases, temporary movement also is included in the definition of migration. Internal migration in China is referred to as floating migration, and includes tourism and other short-term mobility (Kiyoshi 2000). Temporary movement is an important aspect of migration, and can occur seasonally, or in a circular pattern between two regions, like villages and urban centers.

These categories describe the type of movement, but the reason for the move also is reflected in some of the terms. For example, migration is generally interpreted as a permanent move. In reality, temporary mobility can become permanent, and individuals may “permanently” relocate multiple times. Understanding push and pull factors presents a challenge in living populations; in most cases, the archaeological record lacks sufficient detail to make these distinctions. A definition of migration must be broad enough to accommodate this uncertainty.

The definition of migration in this project is not limited to long distance movement, but includes local and regional moves over short distances as well. More specifically, it is a move between an individual's childhood home and final residence, inferred by the place of burial. (Postmortem movement of remains also is considered where supporting osteological evidence exists.) This includes all permanent types of relocation described in modern studies, including long distance migration, residential mobility, and involuntary migration. While migration occurred between places – cities, communities, and polities – it is measured in this study by relocation between isotope zones (described in Chapter 4).

In some cases it may be possible to infer residential mobility by examining burial locations in house mounds and residential groups. The intent of the migrant to eventually return home is not known. Burial locations in the Maya area have meaning, and whether the individual intended to be permanent resident or not, those who were buried in residential groups had a connection to the community (e.g., Ek 2006; Krejci 1995; Kuznar 2003; McAnany 1995, 1998; Weiss-Krejci 2006a). Involuntary mobility may be visible in anomalous burial contexts, but it is extremely difficult without detailed burial records to identify involuntary migrants, even in cases where circumstantial evidence suggests sacrifice, slavery, or war. This is a critical point, because it does not assume that ancient migration can be placed into discrete categories (Nelson and Schachner 2002).

In addition, the borders of ancient political entities are sometimes unclear. What constitutes a meaningful boundary, a move between regions, cities, or villages? Hoerder (2004) notes that the distance involved may be long or short, as a move to a neighboring community for marriage may involve as great a social transition as one hundreds or even thousands of miles away. A review of archaeological research on migration shows how research might benefit from a broader definition of migration in order to effectively model population movement. The next section presents archaeological and modern models for migration, followed by an overview of available evidence for migration among the Maya.

1. Modeling population movement from North America to the Roman Empire

Studies of migration have resulted in a number of models of population movement that address diverse topics, such as residential mobility in Neolithic Europe, the colonization of the Pacific Islands by Lapita populations, or the nature of Tiwanaku imperialism. These analyses have allowed researchers to 1) identify who moved, 2) suggest possible homelands for the individuals, and 3) address the topic of identity and assimilation (Bentley et al. 2003a, 2003b, 2007; Knudson 2004, Knudson et al. 2004; Price et al. 1994, 1998; Shaw et al. 2009). However, a gap remains in our understanding of how population movement was structured in ancient urban areas. The conspicuous lack of broadly applicable models is due, in part, to a focus on migration *events* rather than the ongoing demographic process. Residential mobility is the term most frequently employed to describe migration, though involuntary or forced migration is sometimes addressed. The following discussion explores the type(s) of migration identified, the model presented, and how studies from different parts of the world can inform research in the Maya area.

Research on population movement in Mesoamerica initially focused on investigating foreign enclaves, such as those identified at Teotihuacan (Cowgill 2003; Spence 1996). The multi-ethnic nature of Teotihuacan's population is widely accepted, and immigration is perceived as an ongoing and dynamic demographic process. In-migration from multiple regions may have included recruitment of soldiers, as well as ongoing movement between immigrant communities at Teotihuacan and their homelands over generations (Clayton 2010; Millon 1973; Spence et al. 2004; White et al. 1998, 2000, 2002, 2004a, 2004b, 2007).

Price and colleagues (2000) used strontium isotope assays to identify non-local individuals in three compounds. Eight of ten individuals sampled from the Merchant's and Oaxaca Barrios, compounds with material connections to the Gulf Coast and Oaxaca, were not born in the Valley of Mexico. Strontium measures for two individuals were similar to those identified near Oaxaca. Stable oxygen isotopes show similar patterns: nearly 80% of the individuals in the Oaxaca Barrio have isotopic signatures that evince one or more migration episodes, and are even suggestive of 'ethnic networks' between Oaxaca and other locales inhabited by immigrants of similar ethnicity (White et al. 2002, 2004b).

Six individuals at Oztoyahualco, described by Manzanilla (1996) as a typical Teotihuacan residence, also were included in the sample. Two of these individuals have non-local strontium isotope values. Similar findings were reported at Tlajinga 33 by White and colleagues (2004a), where 20% of the population has non-local isotope values. These findings offer a model for how population movement was incorporated into the social and political structure of a contemporaneous polity. There also is a significant body of research on how immigrants maintained traditions for centuries and how they continually recreated individual and community identities (e.g., Clayton 2010; White et al. 2004b).

However, Maya cities typically lack evidence for foreign enclaves, and likely had very different social and political structures than Teotihuacan. In addition, concepts used to interpret migration at Teotihuacan draw indirectly from modern migration studies (White et al. 2004b), suggesting that examples from other ancient and modern societies should also be incorporated into a model for Maya population movement.

The question of migration has played a central role in research on the transition to farming in Europe. Application of bone chemistry methods to bones and teeth of individuals interred at LBK *(Linearbandkeramik)* early and middle Neolithic cemeteries show direct evidence for migration. Price and colleagues (2001, 2004) interpreted this to mean that population movement did play an important role in the spread of agriculture and associated ideas, though by no means the only one. They (Price et al. 2001, 2004) identified both male and female migrants and considered potential explanations for some population movement, including female exogamy, and attempted to locate the potential homelands of the migrants. Studies of later Neolithic populations at Bell Beaker sites also identified a significant number of migrants, but in this case, more migrants were female (Price et al. 1998).

Other research on the same broad time period, however, shows migration by both sexes (Price et al. 2004). No single pattern of population movement emerges; rather, patterns vary over both time and space. Yet in each case a large percentage of sample population had changed residence at least once during life (Bentley et al. 2003a, 2003b, 2007; Grupe et al. 1997; Price et al. 1998, 2001, 2004). The focus in each of these studies was on identifying migration rather than distinguishing one type of population movement from another. Most migration models still rely on circumstantial evidence, like the spread of ceramic styles or dispersion of language, rather than on direct indicators of migration like bone chemistry assays (but see Cavalli-Sforza 2002).

Migration patterns of Neolithic societies are discussed on a larger scale in ancient China. Analyses of settlement patterns show repeated movement of villages in low-lying coastal areas near the deltas of the Yangtze and Yellow Rivers. While the effect of climate change was strong, and included shifting river courses and changes in sea level, migration patterns were mitigated by cultural choices in subsistence strategies (Chen et al. 2008). Population movement in two large regions is inferred by shifting settlement distribution, with a focus on large-scale settlement formation and abandonment rather than a model of how the movement may have been structured.

In South America, some studies of population movement are associated with a different set of questions that focus on the nature of Tiwanaku imperialism (Knudson et al. 2004; Knudson and Price 2007). Artifactual, architectural, and biogeochemical evidence suggest that diaspora communities and colonies might have formed part of state integration strategies, based in part on analogy from later Spanish accounts of the Inka sociopolitical landscape. These documents describe a number of migration types, including forced resettlement, colonizing communities, migrants, diaspora, sacrifice, and even sojourning, or temporary relocation (Tung 2008). When measured directly using isotopic and elemental assays and biodistance measures, the focus narrows to residential mobility (used to mean a change in residence) and the involuntary movement of sacrificial victims (e.g., Knudson et al. 2004; Knudson and Price 2007). This allows for discussion of marriage practices and social identity, as well as the growth of urban centers. However, these interpretations rely heavily on historic analogy that may not provide an appropriate model for the process of population movement in other parts of the ancient world.

In Africa, scholars have used the diffusion of people and ideas to explain societal change (Chami 2007; Childe 1951). Chami (2007) considered migration to be a form of diffusion, suggesting that people transport objects and ideas that influence ongoing cultural evolution. This provides a contrast to diffusion theories that posit replacement of one group by another and results in a discussion of population interaction along the east coast of Neolithic Africa that includes myriad types of population movement, including temporary mobility, trade, and visits. This model provides a dynamic picture of ancient movement, but focuses more on the results of the interactions than reconstructing the actual movement of people.

Colonization also figures prominently in scholarship on migration in North America. The migration of humans across the Bering Strait provides the archetype for the archaeological concept of migration. Long distance unidirectional movement by groups or people is conceptualized by models such as those proposed by Anderson and Gillam (2000). These could provide useful descriptions of the long distance conquests, colonizations, and migrations described in Mesoamerican Colonial-era texts, such as the peregrination of the Mexica from Aztlan to the Valley of Mexico (Townsend 2000). Colonial texts like the *Anales de los Cakchiqueles* and the *Popol Vuh* also recount long distance migrations (Edmonson 1982; Gubler 1992). However, these events differ in spatial and social scale from the structured and ongoing process of population movement in ancient cities like those of the Maya (Inomata 2004).

Even colonization is better described as a patterned, demographic process where population movement occurs repeatedly over long periods, rather than in a single event. Nelson and Schachner (2002) described linguistic, biological, archaeological, and historic evidence that suggests that the initial movement of Nahuatl speaking groups into the Valley of Mexico was followed by multiple movements during the Epiclassic and Postclassic. Multi-ethnic groups contributed to ongoing gene flow between multiple regions in Mexico, which likely occurred through repeated interaction and marriage exchange. The Epiclassic was a period in which substantial population movement may have resulted from warfare or promotion of attractive ideologies by elites in competing centers (Beekman and Christiansen 2003).

Shifting population densities in Mississippian polities also are the focus of models of population movement on a smaller, regional scale. Pauketat (2003) posited localized resettlement of groups into previously unoccupied zones. Relocation of family groups and/or households may have occurred every 1-3 generations in order to optimize resources, as well as when group members shifted their alliance to another political entity. Pauketat envisioned this occurring within a region rather than over great distances. Neither environmental reasons nor purely political ones *caused* migration; rather, a dynamic landscape was a key element of Mississippian culture. Blitz (1999) also described a fluid landscape in his fission-fusion model. He envisioned kin-based movement at the family and household level as the basis for the formation and decline of centers over multiple generations. While both of these paradigms are useful for studies of the growth and decline of polities (e.g., Marcus 1992), they do not provide a model for movement between heavily populated areas like the Maya lowlands during the Late Classic period.

Population movement in the US Southwest has been the focus of multiple research projects during the past three decades. Population aggregation and resettlement at Mesa Verde, Grasshopper Pueblo, and the Four Corners and Rio Grande regions presented questions similar to those in Mississippian polities. However, in these cases, historic sources were available and models more explicitly incorporated concepts from modern migration studies. Varien (1999) explained the migration processes that eventually led to long term depopulation at Mesa Verde using the concept of supra-annual household mobility. Rather than the movement of entire family groups or households, he suggested after some individuals relocated, others slowly joined them, setting up migration streams that structured the final depopulation of the region.

Cameron's discussion of late 13th century movement of ancestral Puebloans from the Four Corners region to Rio Grande described the movement of small groups into frontier areas as community fissioning (Cameron 1995; Cameron and Duff 2008). Her discussion drew heavily from Anthony's (1990) call to explore migration in a structured manner. Like Pauketat, she suggested that most movement occurs within a familiar area, and that people relocate within the context of what they know. These ideas stem from modern migration theory, which can be used to understand the casual mechanisms, or the potential push and pull factors, that explain why people choose to move (Cameron 1995). However, she relied more on oral traditions and historic sources than general migration theory. She also focused on the movement of large groups because the movement of individuals and small family units can be difficult to detect archaeologically using traditional means.

Ezzo and colleagues' study in the same region moved the question of population movement from a macro scale to a micro one (Price et al. 1994, 2002; Ezzo et al. 1997). Strontium isotopes were used to identify first generation migrants interred at Grasshopper Pueblo, and show ongoing in-migration from both within the region and more distant locations. They cited a model of Hopi population movement that provides a direct historic analogy for the reasons population movement occurred, resulting in the patterns of population aggregation and resettlement seen in the archaeological and isotopic record. This includes environmental conditions, like the presence of an open, unoccupied landscape, and availability of resources as a draw for loosely structured semi-sedentary groups. However, the proposed structure of the movement comes directly from modern discussion of migration: kin-based residential mobility that occurs in bidirectional streams as an ongoing process. This allows historically specific conditions to translate into a useful model for migration in other reasons.

It is also important to mention Snow's (1995) contribution to scholarship on migration, which stems from demographic studies of the Iroquois. He attributed key cultural changes to multiple types of migration, including societal fissioning and long-distance movement. While he offered no specific model, his study showed that is it critical to evaluate migration processes rather than assuming a stagnant and isolated population. Most archaeological examples lack the rich historic linguistic and cultural histories that allow for his detailed interpretations. However, even rich historic records leave questions about key aspects of population movement. Classical Greece and Rome are two of the most well documented populations in the ancient world and have extensive census and military records that provide substantial information about population movement.

Much of the scholarship on the extensive records available to Greek and Roman historians focuses on authenticating population size and census data (e.g., Hansen 2006). However, despite the large quantity of information available, the demographic composition of Classical cities remains only vaguely understood. Recordkeeping often focused mainly on male activities like the military (Cohen 2000). Still, it is clear that population movement was common and that Greek and Roman cities included a substantial number of foreign residents.

Greek cities were demographically very complex places, with mercenaries, destitute wanderers, and others considered non-local outsiders all documented in the historic record. Other mobile individuals included temporary workers, like builders or traders (McKechnie 1989). Census records also document the presence of resident foreigners, whose influence on Greek cities was significant. These individuals, known as *metics*, were present in every level of society and, at times, comprised nearly half of the registered population (Cohen 2000).

Population movement in ancient Rome included both state-sponsored resettlement on a massive scale and private population movement. This also is supported by isotopic assays (Killgrove 2010). Many of these large-scale movements resulted from military defeat and conquest, resulting in colonies and diaspora across the Roman Empire (McKechnie 1989). It sometimes had a substantial impact on family composition, causing nuclear family units to move away from households occupied by extended families. Non-local individuals, however, often were assimilated into the population as citizens under Roman integration policies, sometimes in large numbers (Scheidel 2004). These events are better understood than other types of population movement, even though records may include women, children, and both free and slave individuals, because population movement is generally characterized in terms of empire building.

While these records document different types of population movement, which can even include the names and migration histories of specific individuals, large gaps remain in the historic record (Killgrove 2010). Archaeological research on changing population levels in

Londinium shifts the focus from authenticating the historic record to reconstructing demographic trends. Marsden and West (1992) wrote that long term population changes more frequently resulted from economic causes rather than variables like epidemics. They identified more migration by males – both landless and educated – and suggest that migrants tended follow the paths of their neighbors or family members, creating larger networks. While many scholars do not interpret migration in preindustrial societies as economically driven, Marsden and West (1992) suggested that this creates false assumptions about social conditions in the past. Like scholars studying migration in the US Southwest and at Teotihuacan, they suggest that findings from modern migration studies might prove useful in evaluating pre-industrial societies.

Similar conclusions are evident in studies of later epochs in Europe. Moch's (1996) research shows that European societies were not sedentary before the industrial era. Mobility and migration in peasant life in Europe is documented since at least the 18th century - that is as far back as records go (Nugent 1996). Both temporary and permanent relocations were linked to family formation at the most basic level, first shaped by neo and patrilocal residence patterns and then by subsistence needs. Access to land and the basic needs of household economies, as well as life cycle and gender, all were important factors in determining migration patterns. Both male and female mobility was linked to specific work, like farmhands, sawyers or maids.

Hoerder (2004, 1996) also noted the importance of economic motivation in the decision-making processes of individual migrants; however, the movement is structured by kin-based networks. He relied on written documents in medieval Europe to identify different types of population movement, asserting that pre-modern agricultural populations were not stationary. Preindustrial population movement included planned settlements, the slave trade or involuntary movement, relocation within and between rural and urban areas, and patrilocal residence practices (Hoerder 2002).

Modern terms and definitions also are employed in an historic study of prehistoric population movement in southern California. Coombs (1979) analysis shows that Chumash migrants moved incrementally, initially over short distances within the region. These streams of movement generated counter streams, or return migration, and grew into broader networks. Like modern studies show, the decision to migrate was based on perceived opportunities (Coombs 1979). While there is no single model of population movement that is referenced by historians or archaeologists, these and other observations are noted repeatedly, providing a useful reference point for building an archaeological model.

2. Migration among the Maya

2a: The Classic period

It is clear that substantial population movement occurred in the Maya Lowlands during the Classic period. Shifting population densities from one area of the lowlands to another mark the changes between major archaeological time periods (i.e., Early and Late Classic), and occur within them as well. The most detailed evidence for population movement comes from bone chemistry assays and epigraphic texts that document movement within the Maya region.

Archaeological evidence for migration from foreign regions to the Maya area is limited. Non-local architecture and similarities in material culture have prompted suggestions that individuals from Teotihuacan resided at the Chac site in the Yucatan Peninsula (Smyth and Rogart 2004). Multi-ethnic populations have been proposed at Quirigua and Copán, and elsewhere in the Motagua Valley (Canuto and Fash 2004). At Seibal, changes in architecture and material culture suggest in-migration of peoples with ties to the northern Yucatan (see discussion in Demarest 2006). Yucatecan influence also has been identified in eastern Belize (McAnany et al. 2004), but the relationship between use of foreign symbols and the presence of foreign individuals is not clear.

Archaeometric assays show that non-local material culture in graves or associated architecture may be a poor indicator of an individual's origin. Two notable examples include Classic Maya rulers K'inich Yaax K'uk' Mo' of Copán and Yax Nuun Ayiin at Tikal. Architectural, iconographic, and material evidence support a Central Mexican origin, but strontium isotope values do not (Buikstra et al. 2004; Price et al. 2008; Wright 2005a). Both individuals have $^{87}Sr/^{86}Sr$ ratios that indicate an origin in the Central Lowlands. This is also the case with individual PC103 at Punto de Chimino, whose burial had some traits suggestive of a Central Mexican origin. Although isotope values show a non-local origin, they match values identified in the Central Lowlands rather than in Central Mexico (Wright and Bachand 2009). Based on these examples, the presence of foreign material culture appears to relate more closely to political affiliations, real or claimed, than an individual's place of birth.

These studies instead document movement within the Maya region. In fact, non-local strontium isotope values comprise 10-15% or more of the sample populations in most published studies (Krueger 1985; Mitchell 2006; Price et al. 2007, 2008, 2010; Wright 2005b; Wright and Bachand 2009). Nearly all studies with small sample sizes (~10 individuals) have at least one individual with a non-local value. In larger samples, non-local individuals from multiple locations are consistently identified. However, many Maya sites and regions share similar ranges of strontium values, limiting detailed analysis of broader patterns of movement. Genetic affinity between most lowland regions as demonstrated in dental morphology, with some exception for the centers Tikal and Calakmul, provides additional support for substantial, patterned population movement (Scherer 2004, 2007).

Information on the type of mobility and the demographic profile of the migrant population is more limited. Classic Period hieroglyphic texts describe several instances of long-term and/or permanent change of residence. Post-marital relocation by elite women is suggested by names, titles, and statements of parentage and shows family ties between both distant and neighboring polities. For example, texts note that Yaxchilan's Bird Jaguar had non-local wives from Motul de San José and Hix Witz. Royal women from other polities, including Lady Wac Chanil Ahau from Dos Pilas and the Lady of Palenque, lived at Naranjo and Copán (Josserand 2002). However, these texts document only thirteen family linkages among polities, and parentage statements exist for approximately 20% of known rulers (Mathews in Culbert 1991).

Other instances of elite mobility are documented as well. The exodus of Tikal's king B'alaj Chan K'awiil to Dos Pilas implies that relocation, potentially long-term in nature, occurred by entire households (Houston and Inomata 2001; Martin and Grube 2000). However, most noble visits documented in texts were short-term events for trade, tribute, or diplomacy. The Deletaille Panel and Panel 2b from La Corona show a 19-year-old prince residing in a foreign court near Calakmul for 3½ years. Scholars believe these texts refer to La Corona, and that in AD 667 the prince returned to inherit the throne (Houston and Inomata 2001; Martin 2001). Likewise, Piedras Negras Panel 2 shows young men from Lacanja, Bonampak, and Yaxchilan possibly residing in a foreign royal compound, though there are alternative interpretations (Martin 2001; *cf* Schele and Mathews 1991). The presence of a non-local artist from Sak Ook is documented at Yaxchilan (Culbert 1991; Martin and Grube 2000), but this is not necessarily a permanent or long-term relocation.

Maya inscriptions also document elite visits to oversee and participate in rituals (Houston 2001; Culbert 1991; Schele and Mathews 1991). More prevalent are war-related inscriptions, which form a large part of the corpus of Maya texts. Warfare surely had a large impact on population movement, but the only specific evidence in the texts comes from iconographic depictions of captive-taking, or the involuntary mobility of young males who are frequently also elites (Webster 2000). The fate of a captured noble, including both junior elites and royals, likely varied (Nahm 2006). While some individuals shown as captives appear in later scenes, iconography and epigraphy suggest that sacrifice awaited others (Martin and Grube 2000). The extent to which factors like military conflict or famine affected the non-elite population is unknown. Fortified farmsteads in the Petexbatun region suggest that warfare and raiding did in some instances affect the whole polity (Demarest et al. 1997; Inomata 2004).

Despite the richness of Classic period inscriptions and art, they have several key limitations. These include a lack of information about many regions and a focus on larger centers in regions with rich epigraphic records. For example, few texts exist for the Northern Lowlands during the Classic period. More important, they provide almost no information about the commoner population. It is possible that the shared material culture found in elite contexts represents a social network that extended over longer distances than the networks in which commoners participated. However, non-elite mobility is an important consideration given that gaining and securing subjects in the Maya Lowlands must have been a key concern for competing elites (Inomata 2004:190; Tourtellot 1993). Likewise, the ability to relocate and take advantage of better opportunities probably was crucial for farmers. There is not enough information from the Classic period to model population movement, so it is necessary to turn to other sources.

Records from the Colonial period provide information about both the commoner and elite populations, not only on the rate of population movement, but on its direction, frequency and even demographic make-up. Scholars like Farriss and Restall see continuity from the Classic period in many aspects of Postclassic and Colonial Maya culture; however, continuity is the key question. To what extent did population movement during the Colonial period resemble that of the Late Classic? Spanish rule - and the Terminal Classic collapse - wrought significant changes in many aspects of Maya life. However, as the closest temporal and spatial comparison, the Colonial period offers valuable insight into cultural practices of population movement.

2b. The Colonial Period

Colonial records show multiple patterns, some of which resemble practices described in Classic texts. For example, patrilocal postmarital patterns are well-documented in Colonial Yucatan. Parish registers from the 17th and 18th centuries show that exogamous marriage practices led as many as two thirds of all women to relocate from their natal villages (Robinson 1981). Other research shows more variable postmarital residence patterns. Although most new wives eventually joined the husband's extended family, married couples often resided with the bride's parents first (Farriss 1984; Haviland 1968). Individuals who relocated were sometimes accompanied by other household members, frustrating Spanish officials who lamented the Maya ability to move expediently and frequently (Farriss 1984). New communities also were formed by the dispersal of young household members, a pattern of growth of residential groups that Haviland (1968, 1988) believed he could identify in architectural patterns at Tikal.

Colonial baptismal and marriage records also show the direction and rate of movement. Most movement occurred within the region, and each village had distinct migration fields that were similar for migrants of both sexes. This shows the deeply-rooted ties between kinship and population movement (Robinson 1981). Migrants' connections to kin in their birthplaces resulted in regional networks of population movement with persistent, multi-generational streams (Restall 1997). These networks create social fields through which information on marriage and work opportunities is exchanged.

Non-local individuals formed a large part of the population in cities: figures in marriage and baptismal documents show rates as high as 35%, and in some cases approach half the population (Robinson 1981). Marginal members of society moved more frequently, even multiple times, while less than 10% of elites had non-local origins. Farris (1984) notes a decline in elite mobility as Spanish control increased. Despite a greater economic ability to relocate, elite individuals may always have exhibited generally lower rates of population movement. This may relate to land tenure – individuals with no material ties to a region can more easily leave for better opportunities. Control of trade routes or resources cannot be easily transferred to residence in a new region, providing greater impetus to stay than to leave. Wealthier households often were the longest occupied and the last to be abandoned at sites in the Maya lowlands (e.g., McAnany 1995; Yaeger 2000).

Spanish rule affected other types of mobility as well: captive taking and the slave trade documented by early chroniclers did not persist (Farriss 1984). In fact, it may have affected all types of movement, including marriage practices. High tribute and tax burdens may have played a greater role in shaping the high frequency of extensive regional mobility than did exogamous marriage practices (Robinson 1981). Farriss (1984) defines this as ‘drift,’ and notes that it mainly occurred within and between regions. Longer distance movement may reflect ‘flight’ from Spanish control to avoid famine and forced resettlement. This often led migrants to frontier zones beyond Colonial authority.

Despite this, Farriss (1984) makes a good case that these data represent a tradition of mobility with deep time depth that relates to landscape, material culture, and agricultural organization more than Spanish rule. Maya commoners may have reacted in a similar manner to repressive Classic era rulers. Hostile takeovers of large centers are well-documented in Maya texts and must have affected the trade, tribute, or taxation systems to some extent. Unfortunately these are little understood for the Classic era, but the Postclassic annals the Books of the Chilam Balam also document the relationship between migration and marriage, and link them to commercial expansion for the Itza or *mactunes* (Peniche Rivero 1994; Roys 1967). Itza men reportedly married local noblewomen and used the family pedigree to attain political and economic power.

The crucial question is the extent to which migration during later periods resembled that of the Late and Terminal Classic. Do the high rates of Colonial period population movement reflect a tradition of mobility with great time depth (Farriss 1984; Restall 1997), or are they largely a reaction to Spanish rule and its forced resettlements, the disruption caused by population loss and epidemics, and high taxes? This is not a simple dichotomy between viewing migration as a culture trait or a temporary reaction to economic or political conditions. Migration is neither: it is a social practice mediated by factors that include economic and political conditions, but also changing climate, religious views, and popular culture.

While the historic record lacks the detail needed to effectively model migration, research in other regions show that modern studies offer both the framework and information that can fill in the gaps left by Classic era evidence. The next section discusses modern scholarship on migration and offers a model for Classic Maya migration.

3. Modern migration: providing the framework for study of ancient societies

Many basic tenets of modern migration theory originated at the end of the nineteenth century with Ravenstein (1885, 1889), whose observations on population movement were meant to explain mobility in the rapidly industrializing world. He described migration as a series of sequential moves over short distances, in step-by-step movement from rural to urban areas. He described the tendency of young males to move greater distances, while females exhibited more movement locally, with mobility declining with age for both sexes. Multiple individuals moving to the same location created migration streams, which in turn, generated a counter current referred to as return migration. After more than a century, Ravenstein's observations still serve as a reference point for modern studies and provide a common set of terms used in studies across disciplines (see discussion in Arango 1985; Cadwallader 1992; Koji 2000).

Ravenstein (1885, 1889) also noted that most migration had an economic cause (Cadwallader 1992). This is one of two reasons that archaeologists avoid explicitly citing modern studies in their research. In fact, most macro-level models of migration do privilege economics above other factors, whether in reference to Neoclassic supply and demand mechanisms, the institutions and individuals that drive them, or Marxian class-based analyses that focus on conflict over economic control (Cadwallader 1992). However, analyses of migration at the micro-level focus on individual choice and behavior. These incorporate social concerns, like kinship and communication, which are relevant for ancient societies as well as modern ones.

Studies during the past several decades also show that modern migration is a kin-based phenomenon, and that real and fictive kin-based relationships serve as social capital for new immigrants (Denich 1970; Wilson 1998). The decision to move – whether based on an economic, religious, social or other cause – is based on access to information, whether accurate or not. Even in the modern era of telecommunication, information about conditions and opportunities are relayed person-to-person and are paramount in a migrant's decision-making process. These networks can be maintained for generations, regardless of the original cause for migration. This creates networks of population movement - migration networks - with potentially great time depth (Jedlicka 1979).

Another reason archaeologists avoid modern scholarship on migration is the assumption that modern global population movement represents a sharp break from migration in preindustrial societies. However, most patterns of migration have deep roots. For example, Finnegan's (1976) anthropological assessment of Mossi culture in Burkina Faso shows that all documented patterns of population movement predate colonization, with the exception of relocation for wage labor. Migration, in fact, was embedded within Mossi culture and formed an integral part of the social structure. The social field of each small village might encompass hundreds of miles, defining a spatial network of kinship.

A different kind of continuity is documented for wet rice farmers in Yogyakarta, Indonesia (Mantra 1981). In the modern era, individuals still migrated more commonly for social reasons, primarily marriage, than economic ones. Perhaps for this reason, relocation outside the ethnic group was rare. Other patterns mirror those documented for western European societies, with most movement occurring during an individual's late teens and early twenties, and men generally traveling longer distances than women. Individuals in Yogyakarta were less inclined to permanently relocate than the Mossi, and hoped to return home before they died. Differences between two cultures like these could be identified archaeologically using the same set of questions asked in modern studies.

Without assuming a connection between modern and ancient Maya who lived more than 1000 years earlier (e.g., Haviland 1968), studies of the modern Maya show substantial variability in patterns of population movement. Ethnographies of modern era Maya at Chan Kom, Yucatan, and Zinacantan, Chiapas, identified patrilocal residence patterns in which newly married women relocated to neighboring communities (Redfield and Villa Rojas 1934; Vogt 1969). Genetic studies provide general support for more frequent relocation of women than men (Seielstad et al. 1998).

Local movement also was reported when lineages expanded into neighboring areas as families grew (Redfield and Villa Rojas 1934; Vogt 1969). More recent studies in Guatemala show that movement is now multi-directional, from rural to rural areas, as well as rural to urban ones (Roberts 1970). Expropriation of land and changing economic pressures are linked to relocation of both individuals and groups of modern Kekchi and other Maya (Ordóñez M. 1982; Pedroni Donnet 1990; Velasquez C. 1990). Some of this can be explained by the introduction of wage labor and global economics, but complex economic forces were at play in ancient societies as well. Classic Maya rulers likely imposed tribute demands on local and regional farmers, and artisans traveled to some extent to work in other polities.

In the US, low income families are more likely to relocate than wealthy ones. Income levels currently play a strong role in the United States: while an average of 16% of the population relocated in 1999, nearly 30% of low income individuals did (Schafft 2004). Other modern phenomena, like government sponsored relocations, also existed in the past and are documented in ancient Rome. Conversely, governments also enact programs to inhibit migration, such as China's *Hukou* policy, which attempts to limit internal migration. Barriers to migration also can be physical, like walls, or archaeologically invisible, like laws and regulations.

C. Using modern observations to model migration among the Classic Maya

1. Modeling migration

A model of Classic Maya migration can be constructed using modern observations on the structure of population movement that are framed as questions. The purpose is not to suggest that migration patterns 1300 years ago in the Maya lowlands resembled those of 19th century New York. Like any model, these questions provide a useful way to measure variability in ancient societies and serve as a baseline to show how Maya population movement resembled – and differed – from generalized, modern patterns. Concentrating on the micro-level, or that of the individual and the household, provides a kin-based focus appropriate for both modern and ancient migration societies. Three questions will form a model that predicts where migration occurred, how it was structured, and who migrated. Material correlates, and how they identify aspects of migration posed in each question, are described in the next section.

Question 1: Most migration occurs within a polity or within a region

Most movement documented in modern studies initially occurs incrementally, over short distances. This is supported for the Maya region by Colonial era documentation in the Yucatan Peninsula, as well as by isotopic analyses showing movement occurring mainly within the Maya region (e.g., Farriss 1984; Price et al. 2008; Restall 1997). While long-distance movement is documented in a few instances for the Classic Period, and biodistance studies support genetic exchange among the Maya across the Lowlands, this likely occurred as a result of substantial movement over short distances in multiple interconnecting social networks.

Question 2: Migration patterns in polities correspond to distinct sociopolitical relationships

Migration is a kin-based phenomenon in modern societies. This suggests that regardless of the cause, individuals relocate within existing networks. Some goods and services also should move within the same networks, resulting in archaeologically visible patterns that show the connection between different sociopolitical entities. Migration patterns may be more identifiable between entities with more intense relationships and/or those with great time depth. Reconstruction of the history of the Belize Valley suggests that distinct relationships between polities and communities may be reflected in migration patterns at each site.

Question 3: Migration does not occur evenly throughout the population

Historic and modern studies document more frequent movement by women, mainly due to patrilocal residence patterns (e.g., Hoerder 2004; Seielstad et al. 1998; Vogt 1969). This is a strong possibility for the Classic Maya, though Colonial evidence suggests more complex residence patterns (Farriss 1984; Haviland 1968). Migration is repeatedly described as a youthful phenomenon. Although the age at which an individual migrated cannot be determined in most cases, a relationship between migration and marriage suggests that it should be identified in remains of individuals who died during adolescence or later. Migration may also occur more frequently in poor families who had fewer ties to local resources, both material and social, than wealthy families.

2. Identifying migration

The goal of identifying non-local individuals is to build a demographic profile of migration in one region of the Maya Lowlands that will create a useful migration model for ancient societies. How common was population movement, and who were migrants? How far did people move, and in what direction? Strontium isotope values serve as the main - but not the only - archaeological correlate for migration. Geologic differences between the Belize River Valley and neighboring regions, including the Maya Mountains and Central Petén, result in distinct isotope values that are reflected in the individuals living in regions as close as 25 km apart (Cornec 2008; Freiwald and Price 2008; Yaeger and Freiwald 2009; Hodell et al. 2004).

Isotope values in tooth enamel provide a comparison between two periods in an individual's life: infancy and early childhood, when the enamel forms, and the place of burial, which is used to infer residence at the time of death. It is possible that an individual may have relocated multiple times, or had many travels in the intervening years, but this would not be captured without isotope assays of multiple bones or teeth that formed at different times.

Dietary variability provides another means of differentiating residents living in different lowland regions. Belize Valley residents consumed less maize than other Maya populations, so dietary signals of non-locally born individuals may differ from those who spent their childhoods in the Belize Valley (Gerry 1993; Piehl 2006). Variability in oxygen isotopes stems from different water sources, which also occurs both locally and on a regional scale. Variability in metabolism between individuals may complicate these results, so population movement can only be identified between some regions in Mesoamerica (Lachniet and Patterson 2009; Longinelli 1984; Marfia et al. 2004).

Body modification also may signal an individual's origin. An individual's cranium was modified during infancy and is a conservative, multigenerational tradition that is identified in both males and females that can be used to identify origin (Knudson 2004; McCafferty and McCafferty 1994; Tiesler 1998; Torres-Rouff 2002). Tiesler suggests that the type of deformation, which results from the technique used to shape the cranium, varies within and between regions. Belize Valley residents practiced cranial modification to a lesser degree than other residents of the Maya Lowlands. While 88% of 1515 crania in Mesoamerica studied by Tiesler showed some measure of cranial modification, this is documented on less than 50% of the Belize Valley burial sample (Tiesler 1998, 1999, 2009, in press).

Dental decoration also shows some geographical patterning and is identified in nearly 60% of Tiesler's (1999) sample population. However, there also are differences by sex and status, perhaps reflecting a complex set of meanings. It is more difficult to relate dental modification to an individual's origin, since filing of teeth was practiced through an individual's life and inlays are normally documented in individuals older than 15 years of age (Tiesler 1999). Dental modification in children is rarely reported (Braswell and Pitcavage 2009).

What did it mean to be a migrant among the ancient Maya? Immigrants in many societies maintain the culinary traditions of their childhood homes, and regional dietary differences are documented in the Maya lowlands (Gerry 1993). The cause of this variability is not clear: it has been attributed to environmental heterogeneity, social organization, and agricultural intensification (Chase et al. 2001; Gerry 1993; Gerry and Krueger 1997; Reed 1999; White et al. 1993; Wright 1997). Nitrogen and carbon isotope ratios in bone collagen reflect the foods an individual consumed as an adult, which provides an opportunity to compare general dietary practices of individuals born in different region with those born in the Belize Valley.

Some aspects of burial treatment, like body position and orientation, also were different in the Belize Valley than in neighboring regions (Schwake 2008). A prone, extended body position is common (Welsh 1988; Willey et al. 1965:533), and burials were oriented to the south in more than 75% of Schwake's study population, which includes seven of the sites sampled in this study. This contrasts with a northern or eastern orientation that seems to prevail at sites elsewhere in the Maya lowlands (Schwake 2008; Welsh 1988).

In sum, there are multiple differences between burial, dietary, and body modification customs practiced in the Belize Valley and other parts of the Maya lowlands that are visible archaeologically. Modern migration observations provide a framework for interpreting broader patterns. The next section describes the study region and sites, how the samples were selected and used to reconstruct a profile of the migrant population and migration networks, and to explore the extent to which migration was a part of Maya social structure.

D. The importance of population movement: why migration matters

Migration is not a novelty: it is an ongoing process that has occurred at some level in every society throughout history. It has enormous cultural implications for the migrants, the communities they join, and the ones they leave behind (Koji 2000). Where people move, they create social networks, and bring with them ideas, goods, and even conflict. Reconstructing population movement among the Maya is a critical part of interpreting other aspects of the archaeological record, like social, political and even economic organization.

Migration is an especially important topic for scholars of the ancient Maya. Throughout the Terminal Classic, cities that thrived for centuries were abandoned as the sociopolitical system collapsed, a process that remains poorly understood. Evidence for warfare and increasing conflict are present in some regions, while drought or an increasingly unstable social system is noted in others (Yaeger and Hodell 2008). The key defining factor in all regions is population movement that resulted in the abandonment of the majority of lowland cities. In order to understand these massive demographic changes, it is necessary to understand preexisting demographic processes. It is likely that migration also was an important part of life throughout the Classic period. Reconstructing the demographic profile of the migrant population, and comparing patterns of population movement within the Belize Valley and neighboring regions, will show the extent to which migration was accepted in Late and Terminal Classic Maya society, and its potential impacts on other aspects of economic, political, and social organization.

Chapter 3 The Belize River Valley: the study region and sample population

Chapter Summary

The Belize River Valley provides an ideal location for a study of population movement for multiple reasons. First, a substantial amount of well-documented archaeological research during the last two decades offers insight into sociopolitical organization and other aspects of Late and Terminal Classic Maya civilization that are intimately intertwined with migration. These excavations also have resulted in a burial population that includes individuals from major centers as well as small, hinterland settlements across the valley in diverse in burial contexts.

Second, the region also is considered to represent a broad cultural area with shared burial and dietary patterns that contrast with those of other parts of the Maya lowlands. Most important, the geology in and around the Belize Valley is heterogeneous, with distinct strontium isotope zones within the Belize Valley, in the adjacent Maya Mountains, and in the Vaca Plateau and Central Lowlands. This allows identification of both long and short distance population movement.

The sample burial population is drawn from 15 sites and includes 148 individuals (149 samples) representative of the Belize Valley burial population. In addition, individuals from four sites in neighboring regions result in a total of 170 individuals (171 samples) discussed in the study. This is not a direct reflection of the living population, and more likely is the result of selective burial practices, which is critical to interpretation of the findings. The demographic make-up of the individuals in this study is described by age, sex, and multiple aspects of status. These data are used to identify the demographic profile of the migrant population. Then, an understanding of what it meant to be a migrant is discussed in the context of childhood and adult diet, burial context, and health and body modification, with descriptions of each provided in this chapter.

A. Belize River Valley sites

1. The study region

The Belize River Valley is a well-studied part of the Maya Lowlands with a substantial burial population and a heterogeneous geology suitable for study of movement both between and within distinct cultural areas. Research on ceramic assemblages, and burial and dietary practices (Aimers et al. 2000:311; Gerry 1993; Schwake 2008; Willey et al. 1965), shows that the Belize Valley forms a distinct subregion of the Maya Lowlands. Moreover, these cultural differences correspond well to isotopic variability. Strontium, oxygen, carbon, and nitrogen isotope ratios in the Belize Valley should differ from those identified elsewhere in the Maya lowlands (Gerry

1993; Hodell et al. 2004; Lachniet and Patterson 2009; Marfia et al. 2004; Piehl 2006), which makes this an ideal region for a study of population movement.

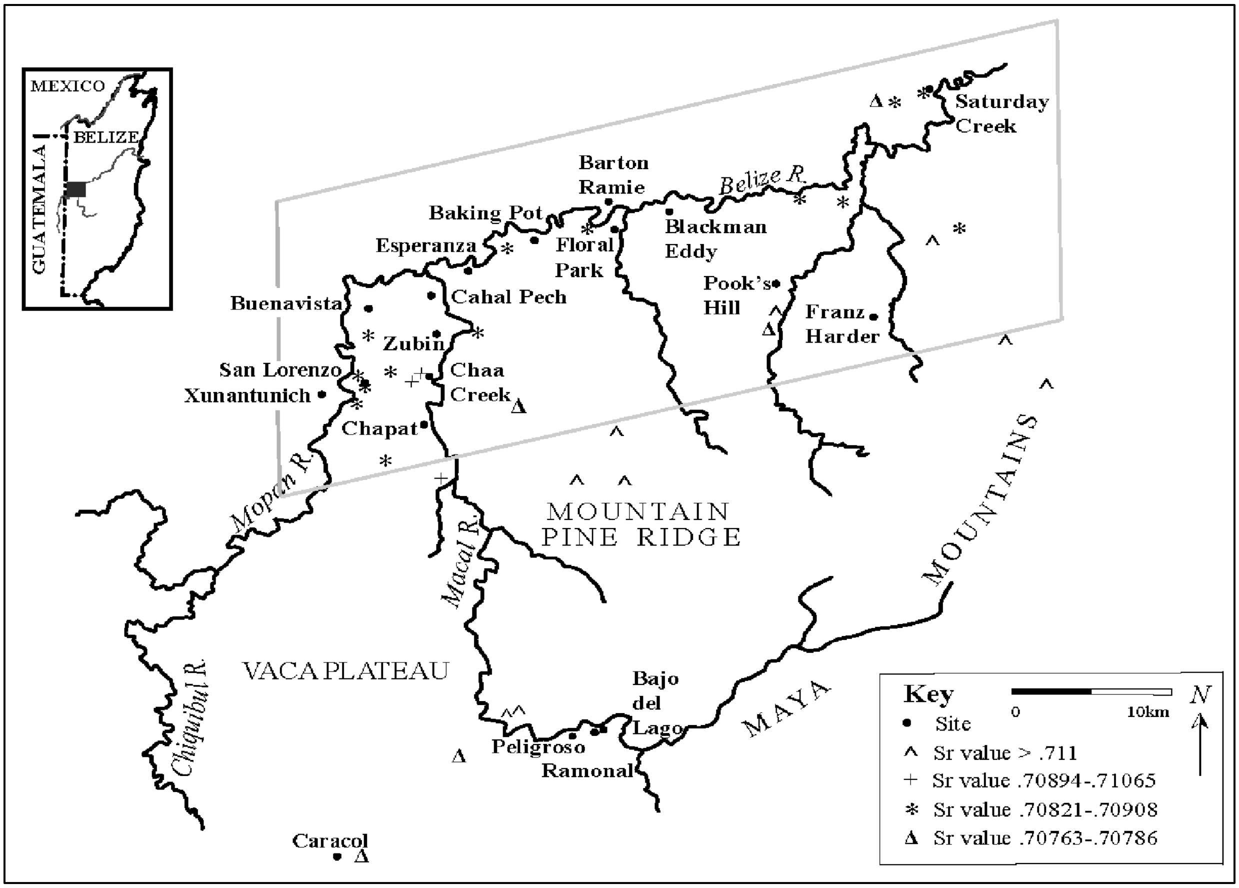

Figure 3.1. The Belize River Valley and the sites included in the study.

The upper portion of the Belize River Valley is located between the confluence of the Mopan and Chiquibul Rivers near Guatemala's eastern border and the confluence of the Mopan and Macal Rivers near the modern town of San Ignacio. The central portion of the valley extends east from Baking Pot to Saturday Creek (Driver and Garber 2004). Fewer sites are located along the eastern half of the Belize River, and instead are situated along valleys formed by tributaries like the Sibun River. The Maya Mountains delineate valley's southern border, and the Yalbac

Hills (not shown on map) line its border to the north (Helmke and Awe in press). The study area is outlined in Figure 3.1.

Shared ceramic styles show a close relationship among sites in the region, with strong ties to the Central Petén (Aimers et al. 2004:311; LeCount 2010). The region also likely was affected by the shifting relationships among Caracol, Calakmul, and Naranjo (Ashmore 2010; Ball and Taschek 2004; Helmke and Awe in press; Leventhal and Ashmore 2004; LeCount and Yaeger 2010). It is reasonable to posit that population movement also occurred, but recent studies show that shared material culture may not always signal migration (Buikstra et al. 2004; Price et al. 2008; Wright 2005a).

Inscribed and/or painted non-local vessels document a relationship between elites at Naranjo and those at Buenavista, Baking Pot, and Xunantunich during Late Classic (Helmke and Awe in press). For example, a vase in Burial 1 in Baking Pot Str. B (re-named as A1) is in the style of Naranjo-area workshops. Helmke and Awe (in press) describe the glyphic text as a name consistent with that of a Naranjo monarch. In fact, the Belize Valley may have been part of the greater Naranjo area during part of the Late Classic (Ball and Taschek 2004; Helmke et al. 2010).

The most extensive interaction is visible at Xunantunich. The site's architectural layout mimicked that of Naranjo (Ashmore 2010), and the combination of architectural, epigraphic, and ceramic evidence is sufficiently strong to suggest Petén influence that may even have included foreign rulers installed by Naranjo (see detailed discussion in Helmke et al. 2010; LeCount and Yaeger 2010; Yaeger 2010). Immigration also may have contributed to a rapid increase in population density in the countryside in the Xunantunich polity, as well as elsewhere in the region (LeCount and Yaeger 2010).

In contrast, there is a lack of non-local goods that show interaction with elites at other centers: non-local ceramics form only 2% of the assemblage (LeCount et al. 2002). This may result from infrequent interaction with elites elsewhere within the valley, but also could reflect a subordinate status to Naranjo that resulted in disproportionate tribute and trade patterns (Jamison 2010; LeCount 2010:216). In contrast, ceramic exchange at Buenavista documents interaction Naranjo, Holmul, La Rejolla, and Calakmul (Ball and Taschek 2004). This includes the Jauncy, or Buenavista vase, a polychrome cacao drinking vessel probably given by the ruler of Naranjo to the Buenavista ruling family (Ashmore 2010; Mitchell 2006). Likewise, the presence of chemically and stylistically non-local ceramics shows that Baking Pot elites interacted with those from multiple locations, including Holmul, Pusilhá and the Motagua Valley (Reents-Budet et al. 2005).

Within the Belize Valley region, Ball and Taschek (2004; Taschek and Ball 2004) see a close-knit relationship between Xunantunich, Cahal Pech, and Buenavista, with a shared lineage governing the three centers. However, they view Xunantunich only as a short-term residence for visitors. Ceramics at Buenavista and Baking Pot, however, may have been produced in the same workshop (Reents-Budet et al. 2000). Interactions were not always friendly, as shown by the destruction and desecration of structures in the Xunantunich polity (Connell 2010; Yaeger 2010), but movement between sites located along the Belize River is not visible isotopically.

Influence from centers to the south, like Caracol, also was important, and is visible in deeply-rooted as caching and burial practices at Cahal Pech and Baking Pot, as well as other sites in the valley (Helmke and Awe in press; LeCount and Yaeger 2010). For example, human phalanges placed as offerings, or 'finger bowls', are reported in the Belize Valley (Piehl and Awe 2009). Caracol's influence was more prevalent earlier during the Late Classic at these sites, but it is noted later at Buenavista only after Naranjo's influence in the valley waned (Chase 2004). Use of resources, like slate and pine, from the sparsely populated Maya Mountains was widespread (Graham 1987), but the nature of interaction with its residents is not known. In-migration from the an unknown in Maya Mountains is documented: at least one individual with a Maya Mountain zone isotopic signature is reported at Tikal (Wright 2005b).

The relationship between Belize Valley residents and other parts of the Maya lowlands may have taken on a different form during the Terminal Classic (LeCount and Yaeger 2010). Erection of stelae at both major and minor centers, along with identification of a number of emblem glyphs, suggests increased independence and a lesser role for former patron states like Naranjo in the Central Petén (Helmke and Awe in press). Aimers (2004) notes the presence of different ceramic styles, like grater bowls at Barton Ramie and Xunantunich, that shows participation in spheres to the north and west. Northern Yucatan influence during the Terminal Classic also is noted in the Sibun River Valley (McAnany et al. 2004). Did the movement of people who accompanied these goods include migration? The time-depth of these interactions must have formed deep relationships that should be reflected in regional migration networks.

2. Sample selection

2a. Demography

This study draws from a cross-section of the burial population in order to reconstruct a demographic profile of the migrant population, including individuals of different age, sex, and status. The main focus of the study is on 134 individuals (135 samples) buried at 15 sites in the Belize River Valley. Biogeochemical data from two other studies of Belize Valley sites also are included in the analysis, including eight individuals from Buenavista, six from Cahal Pech (Mitchell 2006) and eight from Barton Ramie (Krueger 1985). Krueger's data are presented but not included in the analysis because it is not clear which individuals he sampled. In addition, four sites in two neighboring regions include 11 individuals from the site of Caracol in the Vaca Plateau, and 11 individuals from three sites located in the Mountain Pine Ridge section of the Maya Mountains. These are included for two reasons: 1) to show that human strontium isotope values reflect those identified in the faunal baseline, and 2) to provide comparative information on migration patterns in adjacent regions. This results in a total of 149 Belize Valley samples (148 individuals) and a total of 171 samples (170 individuals) overall.

While this study focuses on the Late and Terminal Classic, burials from earlier periods in the same context or location are included (Table 3.1 next page). Not only does this provide a larger sample size, but it allows limited comparison of migration patterns between the Late and Terminal Classic and earlier periods. It is possible that some of the eight individuals in the Not known category were buried during the Late Classic. For example, four additional individuals in Ricketson's (1931) Baking Pot burial sample may date to the late Early Classic – Late Classic

(Christophe Helmke personal communication 2010). It also is likely that the two cave burials date to the Late Classic, the period of the greatest cave use in the Belize Valley region.

Table 3.1. Distribution of Belize River Valley values by date

Time Period		#	%
Late/Terminal Classic	(AD 600 - 900)	123	82.5%
Early Classic	(AD 250 - 600)	9	6.0%
Protoclassic	(AD ~100 - 250)	4	2.7%
Preclassic	(BC 2000 - AD 100)	5	3.4%
Not known		8	5.4%

Maya burial practices show incredible variability in nearly every aspect of their treatment of the dead. Individuals were interred in house mounds, temples, shrines, ballcourts, and plazas, inside and outside of buildings, and even in caves. They were buried in elaborate tombs with ornate goods, or in simple pits with nothing, either interred alone or with other individuals. Some are missing skeletal elements, like skulls or femora, while others were buried with the bones of other people. Using burial populations to understand living ones is difficult enough in populations using cemeteries, and relying on the complex burial practices of the Classic Maya to address demographic questions poses an even larger challenge (i.e., Wood et al. 1992; Wright and Yoder 2003). The burial population does not directly reflect the living one, in part due to selective burial practices that bias preservation of males and elite individuals.

2b. Age and sex

The most critical of these challenges is understanding the uneven distribution of age and sex in the Maya burial population. Adult males are overrepresented in the burial population of the Belize Valley, as elsewhere in the Maya Lowlands (Table 3.2). This is a real bias, not one created by misidentification of skeletal materials, which may stem from both preservation and selective burial practices (e.g., Adams 1998; Wright 2006). Buildings with higher architectural investment, like plastered surfaces, preserve bone better than perishable dwellings in the tropical environment. It seems that males were more likely to be selected for burial in well-made structures that favored their preservation. Likewise, children, whose mortality is proportionately the highest, are underrepresented. Poor preservation of juvenile skeletal remains accounts for some, but not all, of the disproportionate age representation.

Table 3.2. Distribution of Belize River Valley samples by sex

Identified sex	#	%
M = Male (includes probable male (M?) identifications)	54	36.2%
F = Female (includes probable female (F?) identifications)	24	16.1%
Not known (juveniles <18 years)	18	12.1%
Not known (adults > 18 years)	35	23.5%
Not known	18	12.1%

The problem of selective burial practices is compounded by methodological difficulties. Nearly 48% of the 135 samples (134 individuals) were in sufficiently poor or incomplete condition that no sex estimate was possible (Figure 3.2). Of the individuals for which sex was estimated, 32% were probable designations (Adams 1998; Piehl 2002, 2006, 2008, personal communication 2010; Vera Tiesler personal communication 2009).

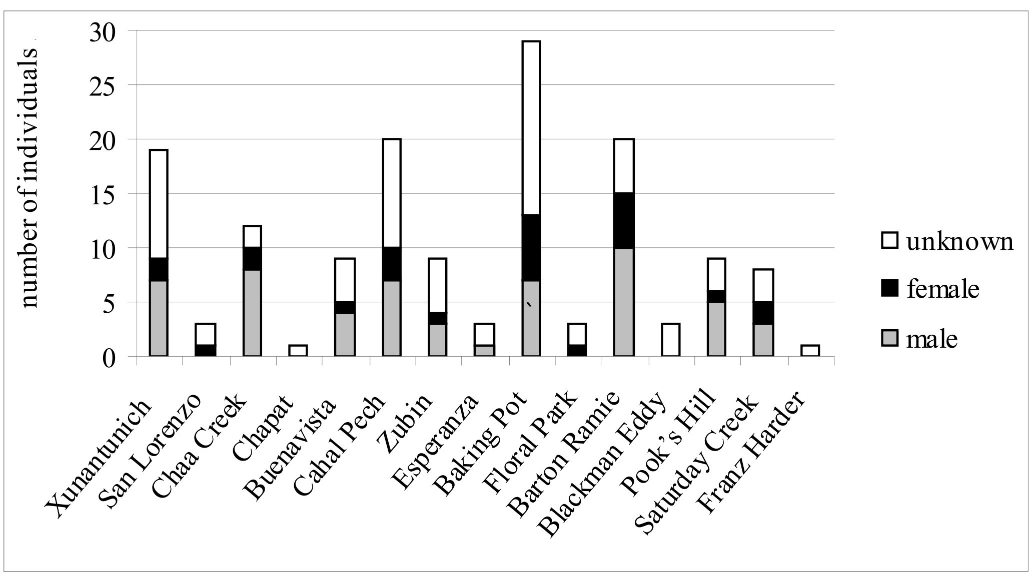

Figure 3.2. Sex distribution of the study sample by site.

Likewise, age was not estimated for 13% of the individuals. One clarification of the discussion of age is necessary. The age of the individual is the age at death, which relates to the age of migration only in cases where non-local juveniles show that movement occurred during a more limited time period, like infancy, children, or adolescence. Age estimates are derived from Ubelaker and Buikstra (1994) as shown in Table 3.3. Therefore, only a subset of the remains can be used to profile the age and sex of the migrant population (Figures 3.3 and 3.4).

Table 3.3. Age classes used in study: following Ubelaker and Buikstra (1994).

Abbreviation	Age estimate	Age range
I	infant	birth to 3 years
C	child	3-12 years
Ao	adolescent	12-20 years
A	adult	>20 years
Yad	Young adult	20-35 years
Y-Mad	young to mid-age adult	20-50 years
Mad	mid-age adult	35-50 years
M-Oad	mid- to old-age adult	35 years or older
Oad	old adult	50 years or older
I	Not determined/not analyzed	Unknown

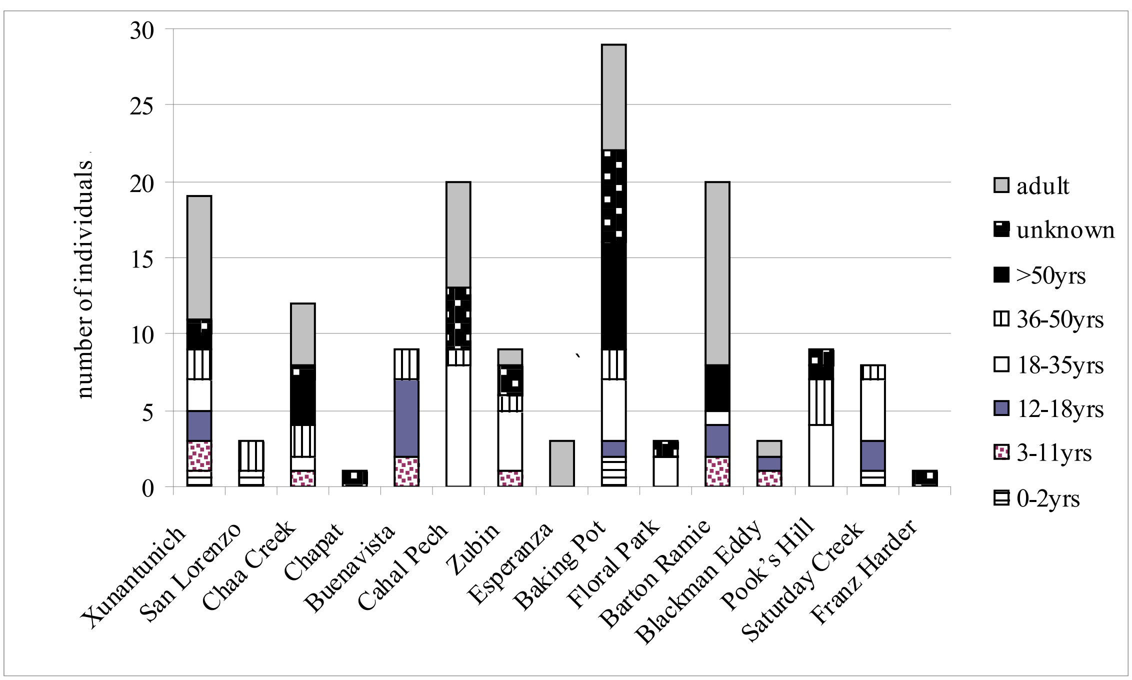

Figure 3.3. Distribution of the sample population by site and age.

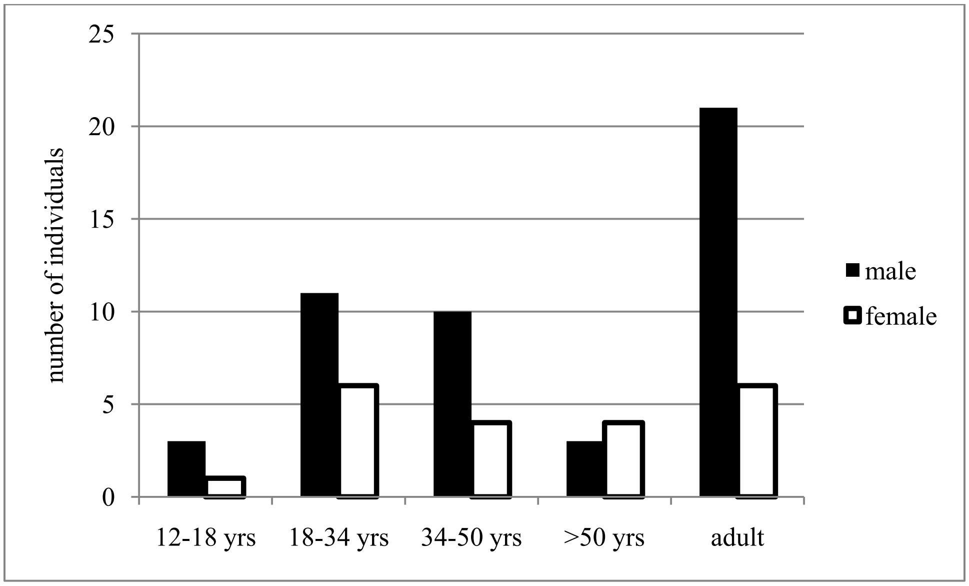

Figure 3.4. Distribution of the sample population by sex and age.

Efforts were made to minimize inter-observer error since the burials were analyzed by multiple individuals with varying levels of training, applying different osteological standards over a 50-year period. First, analysis of the remains from three sites were conducted as part of this project (Blackman Eddy, Esperanza, and Floral Park in Appendix A), and observation of remains from five additional sites, Barton Ramie, Baking Pot, Xunantunich, San Lorenzo, and Chaa Creek, resulted in agreement with most osteological analyses referenced as part of this project (see references in Appendix C). This includes a comparison of observations made for this study with those by Tiesler for Baking Pot and Barton Ramie (personal communication 2009) and for Baking Pot and Xunantunich by Piehl (personal communication 2010).

2c. Status and its reflection in burial treatment

The concept of status poses a more complex set of questions. Mayanists, for the most part, use a material interpretation that relies heavily on architectural investment to separate households of high and low status (Gerry 1997; Hendon 1991; Wright 1997, 2005b, 2006).

Hendon (1991) describes decreasing investment in architecture moving from the site core of Copán to its periphery. Other researchers create complex categories using wealth objects, architectural investment, and burial treatment to compare different levels of elites and commoners, while acknowledging that these divisions do not represent a simplistic class divide (Gerry 1997).

Other key factors used to identify status include differences in grave preparation, burial goods, and other aspects of burial treatment like body position and orientation, as defined by Welsh (1988). Gerry (1997) created four categories of social status as the basis for his dietary analysis: high elites, junior elites, petty elites, and commoners, while Wright (2006) analyzed patterns in 54 traits within these four categories to parse out different levels of social status.

A connection between an individual's treatment in death and status during life stems from observations made by Binford (1971) and Saxe (1970). Complicating factors include the role of the individual's family or community, as well as the opportunity that death presents to rewrite the social role of the deceased (Wright 2006:107). Taphonomy also influences what is left of the process for archaeologists to find; however, one may still assume that variability in burial treatment relates in some way to an individual's position in life (Clayton 2010; Morris 1991; Parker Pearson 1999). However, an individual's status is derived from more than material wealth, and can include traits like age, birth order, genealogy, and achievement, which are difficult to neatly separate into simple categories. Status also is situational and may shift according the situation and individuals present (Clayton 2010; Hendon 1991).

Moreover, what are archaeologists trying to recreate? Mayanists still lack a clear understanding of many aspects of social organization during the Classic era. There are clearly different levels within Maya society, but was there an actual middle class, or a hierarchy within elite and commoner populations (Chase and Chase 1992)? An analysis of tomb distribution at Caracol shows that elites were present in both urban and rural areas, and that even status defined only by wealth has a complex archaeological signature. Burial practices also changed between the Late and Terminal Classic periods, which further complicates interpretations because this may reflect changes in social organization (Chase and Chase 1992; Schwake 2008).

The Xunantunich polity presents a good example of ambiguities inherent in using grave goods to interpret status. Glyphic titles suggest that royal individuals resided at the site's epicenter, but elite residential compounds nearby had differential access to wealth items (Braswell 1998; Helmke and Awe in press). Burials at Xunantunich contained fewer wealth items than other major centers in the valley (Audet 2006), and more jade is present at the nearby minor center of Chaa Creek (Connell 2010). This may reflect decisions by Xunantunich elite to emphasize local goods as political alliances shifted rather than a lack of status for its inhabitants (Jamison 2010). In some cases, burial goods placed with multiple individuals cannot be associated with an individual. Likewise, goods placed near a grave, but not in it, present a similar interpretive problem (Braswell 1998; Connell 2000).

To avoid overemphasizing on a single line of evidence, like grave goods, or introducing false specificity in Maya social organization, systematic comparisons are drawn from multiple aspects of burial location, context, and treatment. Descriptions of grave preparation and burials still provide useful information on how material wealth was used in each burial context. For example, the richly adorned burial of a Baking Pot individual considered the site's Terminal Classic ruler can be compared with interments of individuals in a small house mound with few wealth objects at Saturday Creek. However, other aspects of burial treatment include patterns of skeletal representation, body position and orientation, and body modification that may relate to aspects of status like age, sex, or other non-material social categories.

A multi-level comparison of these factors will provide insight into aspects of status and its potential relationship to migration. The goal is to address an aspect of the third question that frames the model of migration: Did migration occur evenly across the Maya population? This is not simply a question of poor v. wealthy individuals, or commoners v. elites. The question will be address spatially, between large and small centers, and between burial locations like temples v. small house mounds. Burial treatment also is a critical consideration and is interpreted in conjunction with other demographic variables like age and sex.

The first comparison is between individuals interred at major centers, minor centers, and hinterland settlement. Settlement in the valley is often classified into three basic levels (Driver and Garber 2004; Iannone 2004). This study uses the categories of major and minor centers, and house mound groups, as described by Willey and colleagues (1965:561; also see Conlon and Powis 2004; Healy et al. 2004a), although the largest sites are referred to as upper level centers (Iannone 2004), medium centers (Audet 2006), and urban centers (Ball and Taschek 2004). Major centers were located every 10 km along the Belize River and had approximately 2000 residents in and around the site centers (Audet 2006; Driver and Garber 2004). While not as large or densely populated as the supercenters of Tikal to the west and Caracol to the south, Belize Valley major centers had most of the characteristics of their larger counterparts, such as ballcourts and temple pyramids, and some likely had royal courts (Martin and Grube 2000 in Helmke and Awe in press).

The second level is comprised of minor centers (Driver and Garber 2004; also called middle level centers by Iannone 2004 and Connell 2003), which were nodal compounds surrounded by residential house mounds interspersed between major centers at 3-5 km intervals. Minor centers may have one or more plazas and may include public architecture, such as ballcourts and burial shrines. The size of the monumental architecture, and its integration with nearby settlement and distance from the site core, also figure into site classification (Driver and Garber 2004; Iannone 1996, 2004; Lucero et al. 2004).

At the smallest level is dense, but evenly dispersed, residential settlement that formed a densely settled landscape. Yaeger (2003) estimates a population of 35,000 individuals living within 5 km of Xunantunich. Inhabitants likely had political affiliations with the nearest major center, though these may have shifted over time (Connell 2003; Yaeger and Robin 2004). The integration and function of these sites within the larger political entities in the region have been the subject of numerous dissertations (e.g., Braswell 1998; Connell 2000; Iannone 1996; Robin 2000; Yaeger 2000) and multi-year projects (Audet and Awe 2005, Healy et al. 2004a; Garber et al. 2004; Leventhal et al. 2010). Discovery of new sites continues (Andres et al. 2010; Guerra et al. in press).

The burial population comes mainly from major centers, or the larger settlements in the Belize Valley, but includes individuals buried in each of the types of settlement and activity (i.e., caves) where burials are found (Tables 3.4 and 3.5).

Table 3.4. Distribution of Belize River Valley samples by site size.

Site type	#	%
Major Center	88	59.1%
Minor Center	27	18.1%
Other settlement	32	21.5%
Cave	2	1.3%

Table 3.5. Distribution of Belize River Valley samples by site: The table shows the site size and the number of samples from each site. Sites are placed in the same row if they are considered to be part of the same polity. Cahal Pech also includes Zotz, Zopilote, and Tolok groups, and Baking Pot includes one individual from the Atalaya Group.

Major centers	Minor centers	Hinterland settlements	Caves
Xunantunich (n=19)	Chaa Creek (n=12)	San Lorenzo (n=3)	
Buenavista (n=1)			
Cahal Pech (n=14)	Zubin (n=9)		
Baking Pot (n=29)			
	Esperanza (n=3)		
	Floral Park (n=3)		
		Pook's Hill (n=9)	
Blackman Eddy (n=3)		Barton Ramie (n=20)	
	Saturday Creek (n=8)		
			Chapat (n=1)
			Franz Harder (n=1)

Burial context provides a second comparison of patterns of population movement in funerary monuments, eastern shrine structures, residential groups, house mounds and in various types of public architecture. These analyses are combined by comparing burial contexts at major centers, which include monumental architecture like temples, ballcourts, and palaces, terminus structures, and residential groups of various levels of wealth, with contexts at minor centers, which include mainly ancestor shrines, and hinterland settlement, which includes both interments in household and public architecture. Finally, two individuals interred in caves that are not associated with sites in the study are incorporated into the discussion.

The burial contexts are diverse, but can be placed in broad categories that are used to compare 1) the relationship between burial treatment and individual origin, and 2) migration patterns in different parts of Maya society (Table 3.6). These categories are not discrete; for example, veneration of ancestors is not limited to individuals interred in residential shrines but also includes burials in house mounds and temple structures. It is the combination of the type of burial and type of structure that allows a comparison of burial context. Detailed information is presented site by site for each individual's burial context and location.

Table 3.6. Distribution of Belize River Valley samples by burial context.

Burial Context	**Public architecture: royals and rulers**	**House mounds and residential groups**	**Residential burial shrines**	**Public architecture: other**	**Unknown**
Xunantunich	1	7	2	9	-
San Lorenzo	-	1	-	2	-
Chaa Creek	-	1	10	-	1
Buenavista	4	1	4	-	-
Cahal Pech	8	-	6	4	2
Zubin	-	-	9	-	-
Esperanza	-	-	3	-	-
Baking Pot	3	9	9	7	1
Floral Park	-	-	3	-	-
Barton Ramie	-	20	-	-	-
Blackman Eddy	1	-	-	2	-
Pook's Hill	-	-	9	-	-
Saturday Creek	-	8	-	-	-
Caves	-	-	-	2	-
Total	**16**	**47**	**55**	**26**	**5**

The first category has fairly limited membership, and is meant to include the upper sociopolitical echelon of Maya society. This includes interments interpreted by excavators as those of royal individuals who were buried in temple structures – some of which are E-Group complexes – situated around the main plazas of major centers. This only includes burials in tombs or cists with trappings of rulership, like the K'awil pendant identified in one Baking Pot tomb (Audet 2006) or stelae (Cheetham 2004; Garber et al. 2004). This category does not include individuals placed in the fill or in front of structures, without burial goods or prepared graves. These are included in the public architecture: other category. This category is relevant to each question used to frame the model, but specifically to #3, that migration does not occur evenly throughout the population.

Burials in house mounds and residential groups include interments in single mounds and in residential group structures not interpreted as burial shrines. This includes house mounds at the major centers Xunantunich, Buenavista, and Baking Pot, at the minor center Saturday Creek, and in the San Lorenzo and Barton Ramie settlements. Most of these are interments of single individuals, though the Group D chultun burial at Xunantunich includes multiple individuals. Evaluation of migration patterns in this category specifically addresses question #1, that residential mobility occurs over short distances, and also form the backbone of constructing a demographic profile of the migrant population.

Other burials in residential groups are not located in houses or patios, but were placed in special shrine structures that are usually located in the eastern structure of a plazuela group. Residential shrines contain both single interments and burials with multiple individuals. This includes all burials from Pook's Hill, Zubin, and Chaa Creek, one structure at Group D, Xunantunich, and the principal interments in the Buenavista royal residence in Mitchell's (2006) study. At both Zubin and Chaa Creek, burials come from shrine structures used during (or before) initial occupation of the site and those used during the Late and/or Terminal Classic. This category also includes burials excavated by Ricketson (1931) in a structure interpreted as a burial shrine. This will be considered in discussions of ancestral shrines, but not in comparison of residential v. other burial contexts.

Shrine structures often functioned as the cemetery for key members of the household (Helmke et al. 2006; McAnany 1995). The burial locus served as a connection between the family and the local landscape, and even access to resources, a relationship renewed and displayed by ritual veneration of ancestors (Iannone 2003; Kuznar 2003; McAnany 1995, 1998). Not all community members were interred in these structures (Aimers et al. 2000). Initially, burials in ancestral shrine structures at Chaa Creek and the Chan site in the Xunantunich polity were of adult males. However, additional members of the household were later included in family shrine contexts during the Late and Terminal Classic (Connell 1995, 2000; Novotny and Kosakowsky 2009).

The fourth category includes other burials in public locations, like the child interred in the center of Xunantunich ballcourt and individuals in terminus structures at Cahal Pech (Zopilote) and Baking Pot. Burials with more ambiguous contexts are described in detail in the following section and may provide insight into question #2, where migration patterns reflect each site's unique history, but also present some interpretive challenges. The final category includes individuals for whom insufficient information is available to determine a burial context (unknown).

3. Interpreting burial categories: the relationship between sacrifice and non-local origin

The association between individuals in non-residential burials and their burial location is not always clear. Did they actually live in the site or polity? This question relates specifically to two types of burial contexts: those that archaeologists associate with sacrifice, and secondary or partial interments that could indicate postmortem movement of bones. Isotopic analysis has demonstrated an association between non-local individuals and atypical burials suspected to be sacrificial victims (Price et al. 2007; Tiesler et al. 2010; White et al 2007; Wright 2007). However, isotopic analysis does not offer proof of either the type of migration or the cause of death. A substantial body of research centers on differentiating evidence for sacrifice from that of ancestor worship; that is, from the individuals most and least likely to have local origins (e.g., Berryman 2007; Jacobi 2007; Krejci-Weiss 2003, 2004, 2006b; Tiesler 2007; Tiesler and Cucina 2006b; Welsh 1988). An overview of this debate suggests that it is reasonable to assume an association between the burial location and residence during life in the case of typical burial contexts.

Mayanists frequently use Welsh's (1988) burial categories, and as a result often rely on the broad definition of sacrificial burial contexts in the same publication. Lack of a prepared grave or burial goods and a public burial location is often considered key evidence for sacrifice (Berryman 2007). However, Welsh also interprets the presence of multiple individuals as evidence for sacrifice, and classifies remains that are disarticulated, displaced, or disturbed as skeletal mutilation. Using these criteria, a high number of burials - 11% - are defined as one of four types of sacrifice.

Recent studies offer alternative explanations for key aspects of Welsh's (1988) interpretations. Burials may contain multiple individuals who died at different times and were buried sequentially. New burials disturbed older ones and resulted in the disarticulation of remains that originally were interred as articulated, complete skeletons (Novotny and Kosakowsky 2009; Weiss-Krejci 2003, 2004, 2006b; but see Tiesler and Cucina 2006b).

They also offer more explicit criteria to identify sacrificial burial contexts. Berryman (2007) suggests that a specific demographic profile should be visible, like an overrepresentation of young males (also see Cucina and Tiesler 2007). In addition, dismemberment or decapitation must not be the result of other taphonomic processes (Barrett and Scherer 2005; Duncan 2005). Each of these patterns should be atypical for the burial population (Berryman 2007; also see Mendoza 2007).

A substantial body of work on taphonomy focuses on natural processes and their effects on archaeological contexts (Duday 2006; Duday and Sellier 1990; Nilsson-Stutz 2005). Human remains that disintegrate in filled and unfilled spaces will look different to excavators. In unfilled spaces, unwrapped skeletal elements move from anatomical position and become disarticulated as the body decays. Roots, rodents, and re-use of space also disturb remains and are more relevant to the interpretation of the burial context than ethnohistoric and iconographic evidence (Jacobi 2007).

Identification of actual skeletal mutilation is aided by application of forensic methods to identify perimortem damage to bones. This even includes actualistic studies of heart extraction (Tiesler and Cucina 2006a). While evidence for skeletal modification is uncommon (Jacobi 2007; Tiesler and Cucina 2006a; Serafin 2010), it often is highly patterned. For example, trophy heads may have a patina caused by handling, or bilateral holes drilled for display (Mendoza 2007; Tung 2007; Tiesler et al. 2010). Perimortem damage also includes injury-related trauma or cut marks related to dismemberment and defleshing. Serafin (2010) provides a thorough review of trauma identified in Maya skeletal populations (also see Weiss-Krecji 2006b; Tiesler 2007).

The presence or absence of skeletal elements also is used as evidence for sacrifice (Berryman 2007; Jacobi 2007; Mendoza 2007). Some common examples are skull-only interments or deposits of phalanges, or ‘finger bowls,’ each described by de Landa (Berryman 2007). The latter have been interpreted as auto-sacrifice by living individuals (Piehl and Awe 2009), and both are reported in the Belize Valley. The postmortem movement and re- or disinterment of the remains also is reported epigraphically as part of ancestor veneration rites (Harrison 1997; Helmke et al. 2010; Tiesler et al. 2010). This includes skeletonized remains that were broken and scattered long after death, perhaps as an act of desecration (McAnany et al. 2004).

Only a limited number of individuals in this study fall into one or more of these categories mainly because most samples came from burials, rather than problematic deposits or caches. A number of burials with missing or extra bone elements are reported. However, several burials described in field observations as secondary interments of only the skull and long bones are found to be the poorly preserved remains of a complete skeleton (see Appendix A). Postmortem movement of bones also is described. In the Zotz residential group at Cahal Pech, an extra femur was included in Burial Zotz 2-B/3, while the lower leg was missing from Burial 2-B/2. Tombs that were emptied or re-used are reported at multiple sites.

Missing or extra skulls are more easily identified during excavation and field analysis. At Xunantunich, the cranium was missing from Burial Op. 21E in the Group D residential compound, though the mandible was present. Skulls with no postcranial remains were present in Xunantunich burials in Structures A-15 and A-4 (Audet 2006; MacKie 1985): the latter were sampled, along with those in similar interments at Zopilote group at Cahal Pech and Baking Pot. All were found in non-residential architecture.

These ix individuals represent interments of a more ambiguous nature. One of the skulls in Str. A-4 may be associated with one cervical vertebra, but it is not clear whether it was still articulated – or even in close proximity – to the cranium (e.g., Berryman 2007). Trauma-induced periosteal reaction is noted on the two crania-only interments at Baking Pot (Piehl and Awe 2009). However, there is no evidence for use of the skulls as trophies and other supporting war iconography (e.g., Tiesler et al. 2010). These observations are intriguing, and results discussed in Chapter 7 show that individuals represented only by crania or skulls are more likely to have non-local $^{87}Sr/^{86}Sr$ values.

Four other Xunantunich individuals were buried without grave goods or prepared graves. They were buried in atypical burial positions in public locations; however, there is no perimortem alteration of the remains. However, even if these contexts are interpreted as sacrificial, it is more conservative to assume a connection to the site. There is no contextual evidence to support transport of the remains from another site or region, and to suppose that a capture event occurred would be based on generalized analogy alone. These individuals are considered part of the burial population at each site for the purposes of this analysis.

B. The sample population and other aspects of migration

A subset of the sample population is used to understand what migration might have meant 1300 years ago. Individuals from some sites in the study were selected 1) based on availability of relevant information, and 2) to address specific questions. For example, osteological research on Xunantunich skeletal materials includes two studies of linear enamel hypoplasias. These remains and data were available for re-analysis, so form the basis for the discussion of the relationship between childhood health and migration. Similar information is not yet available for the human remains at other sites in this study. Ideally, all information would be collected for all individuals; however, this was not possible due to both money and time constraints.

Two sets of samples were used to address dietary questions and are described in detail in Chapter 6. Tooth enamel from individuals buried at Xunantunich, Chaa Creek, and San Lorenzo provide a baseline for childhood diet in the Belize River Valley, at the same time providing additional evidence for population movement based on patterned differences in oxygen and carbon isotope values. Potential long distance migrants from Barton Ramie, Baking Pot, and Floral Park also were sampled, along with the individuals from Caracol and Mountain Pine Ridge sites to add to comparative information on Maya lowland diet.

Bone collagen and apatite assays for a 24 individuals from Pook's Hill, Barton Ramie, and Xunantunich were selected to identify potential dietary differences in adults, potentially long after relocation occurred. Individuals from Xunantunich and Pook's Hill were selected because imported foods were identified at these sites. This could result in elevated local strontium isotope values (e.g., Wright 2005b), allowing exploration of the relationship between strontium isotope values and non-local foods. The Barton Ramie individuals were included to further expand on published dietary studies in the region by Gerry (1994) and Piehl (2006).

Information on health, pathology, and body modification is discussed for individuals buried at Xunantunich, Chaa Creek, San Lorenzo, Pook's Hill, Saturday Creek, and most individuals from Baking Pot (Adams 1998; Piehl 2002, personal communication 2010; Scopa

Kelso 2005, 2006). Sample selection is based on the extent to which osteological analyses were completed: there is limited published information on the Belize River Valley burial population.

C. Conclusion

The Belize Valley burial population is representative of assemblages of human remains in the Maya lowlands, where poor preservation and selective burial and excavation practices result in a demographic profile that is not a direct reflection of the living population. Availability of samples for any study is affected by myriad taphonomic factors, as well as challenging storage conditions that may affect the condition - or the presence - of tooth or bone (see Appendix A).

Using a regional burial population allows greater flexibility in addressing these issues. The individuals included in this study are drawn from centers of all sizes and nearly every type of burial context known in the region (caches are intentionally excluded). This provides an opportunity to understand the general rate and direction of movement into the region. Additional questions about who moved, and sometimes when migration occurred, are addressed using subsets of the sample population. This includes understanding differences in migration patterns between men and women, or between that of royals and nobles and rural farmers in the region.

Selecting specific sites and individuals for more in-depth analysis of diet and health and body modification allows further insight into the meaning of migration. This required consideration about availability of information, as well as which subpopulations would best answer the questions. The most promising findings can be expanded upon in the future when additional osteological and contextual analyses are complete.

Chapter 4: Identifying Locals and Migrants in the Belize River Valley: Methods and Assumptions

Chapter Summary

Bone chemistry methods are used to identify population movement, and strontium isotope ratios in human tooth enamel serve as the principal correlates of human migration. The ratio of $^{87}Sr/^{86}Sr$ changes over millions of years as the radioactive isotope of rubidium-87 decays into strontium-87. Ratios vary according to the composition and age of rock formations, resulting in variable $\delta^{87}Sr$ ratios across Mesoamerica. In Belize, measureable differences occur over distances of 20-25 km or less, allowing identification of local and regional movement, as well as long distance migration.

For humans to reflect the strontium measures of the region, they need to eat a largely local diet. This assumption is valid in the Maya lowlands. Although imported foods like salt are documented, nearly every study shows that the average strontium isotope values in the human populations reflect those identified in baseline values near the sites. A detailed map of $^{87}Sr/^{86}Sr$ isotope values in the Belize Valley and neighboring regions forms the baseline for identifying local and migrant individuals in the population. The baseline information is combined with statistical analyses to identify individuals who were not born in the same strontium zone where they were buried, as well as to explore the isotopic variability present in the locally-born population.

The method for preparing the samples and a description of the processing techniques and facilities is presented for the strontium isotope samples. A description of additional processing required for carbon, oxygen, and nitrogen isotope samples, which serve as correlates for migration and to reconstruct diet, is presented in Chapter 6. Methodological choices are discussed that could introduce additional variability into the results; however, none should significantly impact the overall outcome.

A. Strontium isotope values as correlates for human migration

An understanding of migration at the regional, polity, community, and even household level begins with identifying individual migrants. Isotopic values in body tissues like tooth and-bone contain the history of an individual's residence and diet. Strontium isotopes in tooth enamel, expressed as the ratio of $^{87}Sr/^{86}Sr$, reflect an individual's place of birth and early childhood residence. Carbon and oxygen isotopes in the same tissue reflect an individual's eating and drinking habits, which are shown in some studies to vary regionally (Gerry 1997; Price et al.

2010; White et al. 2004a, 2004b) and can serve as an additional indicator of an individual's origin.

Elemental strontium in body tissues has been intensively studied in order to understand the potential effects of nuclear testing, which generates the radioactive isotope ^{90}Sr (e.g., Wright and Anderson 1957). Strontium, which has four naturally-occurring stable isotopes, is incorporated into human tissues in the same manner as calcium. Each isotope is relatively stable in these approximate proportions: 0.56% ^{84}Sr, 9.87% ^{86}Sr, 7.04% ^{87}Sr, and 82.53% ^{88}Sr. However, the proportion of ^{87}Sr increases over time due to the decay of 87-rubidium (Dickin 2005). Because the time scale is geologic rather than human - its half-life is 48.8 billion years – strontium values for modern samples (e.g., fauna or flora) will show the same values as archaeological ones taken from the same region.

Differences in ^{87}Sr/^{86}Sr values are due to the age of the rock and its mineral and elemental composition (Faure and Powell 1972). Rubidium isotope 87 decays at a constant rate to form 87-strontium, so rocks comprised of minerals rich in rubidium, such as plagioclases, biotites, potassium feldspars, and micas, become enriched in ^{87}Sr over time (Ericson 1985). The decay of 87-rubidium into 87-strontium is used to date geologic processes, like the crystallization of metamorphic and igneous rock formations with minerals rich in potassium. Older rocks will have higher ^{87}Sr/^{86}Sr ratios that generally exceed .710, while those formed recently, especially if Rb/Sr ratios are low, will have values lower than .704 (Bentley 2006). Marine limestone will reflect the value of water at the time it was formed, ranging from the .7092 value of modern seawater to .707 during the Cretaceous period approximately 140 million years ago (Dickin 2005; Hodell et al. 2004, 2007; Palmer and Elderfield 1985).

The isotopic composition of a region also is affected by atmospheric conditions and soil or fluvial inputs. At the most basic level, differential weathering rates of minerals in bedrock affect the isotopic composition of δ^{87}Sr values in soils (Stewart et al. 1998). Fluvial transport and deposition is another important factor. Floodplains formed by sediments carried downstream derived from rock formations with distinct strontium values may shift the isotopic average away from that of the parent bedrock material. Strontium values of large river systems are reported to have high average values, .711, that represent a mixing of diverse inputs (Graustein 1989). However, fluvial strontium values generally reflect values expected for the local geology, rather than the suspended load of sediments moving downstream (Bentley 2006).

Rainfall, sea spray, and dust also can affect the isotope values in a region, depending on the concentration of strontium. Coastal environments may show strontium isotope values more elevated than the bedrock due to sea spray or rainfall. Elemental and isotopic strontium concentrations in precipitation samples differ across the United States. δ^{87}Sr and δ^{18}O covary as water evaporates (Bullen and Kendall 1998), and decreasing strontium concentrations result from precipitation, which will be especially pronounced near mountain ranges due to the orographic effect (Gosz and Moore 1989).

Body tissues reflect the average ^{87}Sr/^{86}Sr ratio of the local ecosystem because strontium, along with barium and lead, substitutes for calcium in teeth and bones. Biological processes do not fractionate these elements. As a result, plants, the animals that consume them, and the humans who eat both plants and animals, all share a similar isotopic value (Price et al. 2002). Strontium isotope ratios in animals at higher trophic levels, those who consume other plants and animals, will better reflect the average value for the region (Bentley 2006; Burton et al. 1999).

There is fractionation by trophic level in the ratio of 88-strontium to 86-strontium that reflects differences in diet (Knudson et al. 2010). However, $^{87}Sr/^{86}Sr$ values reflect the average of local geologic and atmospheric processes. To determine this average value, a detailed map of strontium values is needed that includes not only plant, soil, and water values, but how these are reflected in living creatures: that is, the biologically available strontium average (Price et al. 2002).

Several studies illustrate how biological strontium values reflect average values for a region. Forty-five water, rock, and plant samples near Mayapán and Chichén Itzá have values ranging from .70780 - .70908, with an average value of .70905 in rock outcrops (Gilli et al. 2009). The average value for deer sampled at Mayapán is lower, .70886, as is the range of human values interpreted to be local, .7086 -.7089 (Wright 2007). More complex processes are at play in Iceland, where biologically available strontium values average .706, higher that those expected for the basaltic volcanic geologic formations (~.704) and lower than sea spray and coastal rainwater (~.709) (Price and Gestsdóttir 2006).

Defining the area considered local is a critical aspect of provenance studies (Frei et al. 2009). The term local in this case refers to food procurement, not aspects of identity or political affiliation. What is the dietary catchment area for the site? Of equal importance is the assumption that most food comes from that catchment area and that imported foods make up only a small portion of the diet. During the Classic era, the Maya likely acquired most food from the immediate vicinity of the site (Pohl 1985), though there is evidence that foods like cacao, salt, deer, and marine fish were traded. Could these imported foods shift biologically-available strontium values away from local ones? It depends on the concentration of strontium and calcium elements different food sources and how these are incorporated into tooth and bone tissues.

Carbon isotope ratios identified in dietary analyses using suggest that maize may have contributed 50-75% of the diet (Gerry 1993, 1997; Piehl 2006; Wright 2006). Maize is low in calcium, so its elemental contribution to bone and tooth formation is minimal. However, modern food preparation techniques that use lime to soften the pericarp add calcium to the diet (Rosado et al. 2005). Ancient food treatment also may have resulted in increased calcium absorption, and therefore strontium, but depends on the variety of maize eaten and the additive used. Treatment with lime, shell, and ash all are documented, depending on the region and the type of food being prepared (Burton and Wright 1995; Wright 2006). Cooking techniques also can affect the concentration of elements in food sources. Charred grains have a higher concentration of strontium than uncharred ones (Heier et al. 2009).

Farming formed the basis for the subsistence economy in most Classic era Maya cities. Even in densely populated centers like Caracol, agricultural terraces were interspersed with residential groups and agricultural fields were present within the city (Chase and Chase 1998). The house garden concept forms a popular model for the household economy, which also presents a localized view of food acquisition in residential groups (Killion 1992). Overall, major crops may have moved within the polity, probably over fairly short distances.

Wild game presents a more complex problem. Isotopic studies show that terrestrial protein was a common dietary component in the Maya lowlands, though in varying quantities (Gerry 1993; Piehl 2006). Some movement of wild game, like whitetail deer and peccary, has been identified in the Belize Valley (Yaeger and Freiwald 2009) as well as elsewhere in the

Maya lowlands (Hamblin 1984; Kennedy Thornton 2008). Some of these animals have strontium isotope values that differ from values near the sites where they were found. Animal proteins also may contribute relatively little calcium to the diet as compared to plants (Burton and Wright 1995), though protein can increase the absorption of calcium in other foods.

Consumption of marine fish, which are identified at Maya inland sites in minimal quantities, might also shift strontium isotope values away from local ones. Marine resources have higher strontium isotope values than all but one area of the Maya Lowlands, the Maya Mountains and Macal River Valley. Many of these goods may have moved along the Belize River to sites in the Central Petén (Audet 2006). However, fish and other imported foods, like cacao, generally formed a small portion of the diet for most people so would have a negligible impact on human strontium isotope values.

However, salt acquired from coastal areas could affect strontium values (Wright 2005b). In Belize, saltworks identified along the coast probably were the salt source for Belize Valley residents (McKillop 2005). At Tikal, high salt intake is inferred from a range of human $^{87}Sr/^{86}Sr$ values that is higher than the local baseline identified in the vicinity of the site. However, with the exception of Tikal, studies in the Maya area still show a close correspondence between local human and baseline values.

Differences between humans and local isotope values also can be explained by variability in water sources. Roman aqueducts moved water over great distances, which potentially can shift isotope values away from local ones (Killgrove 2010). Most Maya water sources likely were local ones, but rivers flow into the Belize Valley from at least two distinct strontium zones. Imported tools, like manos and metates, also have the potential to impact $^{87}Sr/^{86}Sr$ values as tiny fragments of grit are inadvertently mixed in with food. However, the most parsimonious assumption for food sources among the Maya in the Belize Valley is that most foods for most people were acquired locally. This topic is explored in greater detail in Chapter 6.

Heterogeneous geology in a site's catchment also can result in multiple local values that are reflected in the human population. The site of Palenque is located on a limestone bluff overlooking an alluvial floodplain, a younger geological formation with higher strontium isotope values than those identified near the site center. Individuals residing at Palenque show both the values identified on the bluff and on the floodplain, reflecting different food sources for residents of the same polity (Price et al. 2008). Complex geology in the Upper Midwest at Aztalan also results in multiple local strontium isotope signatures, which are predicted for the broader region as well, including Cahokia (Hedman et al. 2002; Price et al. 2007).

The Belize Valley is a well-studied, geologically heterogeneous region that is described in the next section, followed by a presentation of baseline strontium values for the Belize Valley and neighboring regions and a discussion of sample preparation and selection.

B. The Geology of the Maya Region

The Maya lowlands are situated on the Yucatan Peninsula, an ancient seabed of marine limestone formed during the Cretaceous Period. Variability in strontium isotope values stems from changes in the value of seawater as the limestone gradually formed. As a result, $^{87}Sr/^{86}Sr$ ratios decrease from .7092 in the northern Yucatan to .707 in central Guatemala (Palmer and Elderfield 1985). Values also decrease from coastal areas over a short distance to inland areas.

Hodell and colleagues (2004) divide the Maya area into five broad regions where isotopic differences correspond well to broadly-defined cultural areas, including the Northern Lowlands, Southern Lowlands, Metamorphic Region (including the Motagua Valley), the Southern Highlands and Pacific Coast, and the Maya Mountains. While Hodell and colleagues (2004) separated the northern and southern lowlands, it is possible to further divide the Maya lowlands into northern, central, and southern strontium isotope zones (Figure 4.1).

A map of strontium isotope value ranges for each region shows broad differences that can be used to identify long-distance population movement. For example, the metamorphic formations near Copán have an average value of .706, while the volcanic-derived soils of the Southern Highlands and Pacific Coast are markedly lower (.704) (Hodell et al. 2004; Price et al. 2008). The Maya Mountains, the oldest geologic formation in the region, have high values that exceed .711.

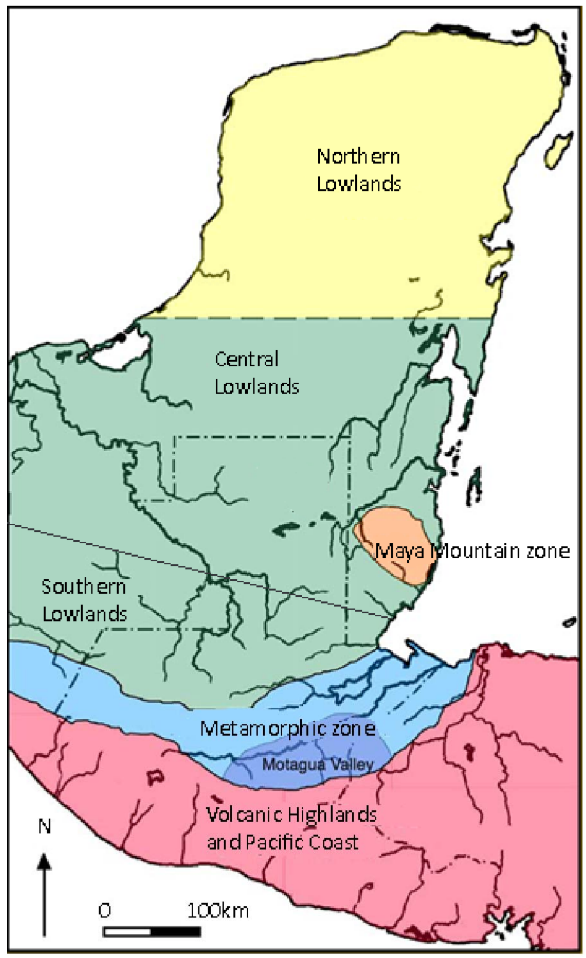

Figure 4.1. Maya lowland regions: Each region has distinct strontium isotope values. Map modified after Wright (2005b). Reprinted from *Journal of Archaeological Sciences*, 32(4), Lori E. Wright, Identifying immigrants to Tikal, Guatemala: Defining local variability in strontium isotope ratios of human tooth enamel, 555-566. Copyright (2005), with permission from Elsevier.

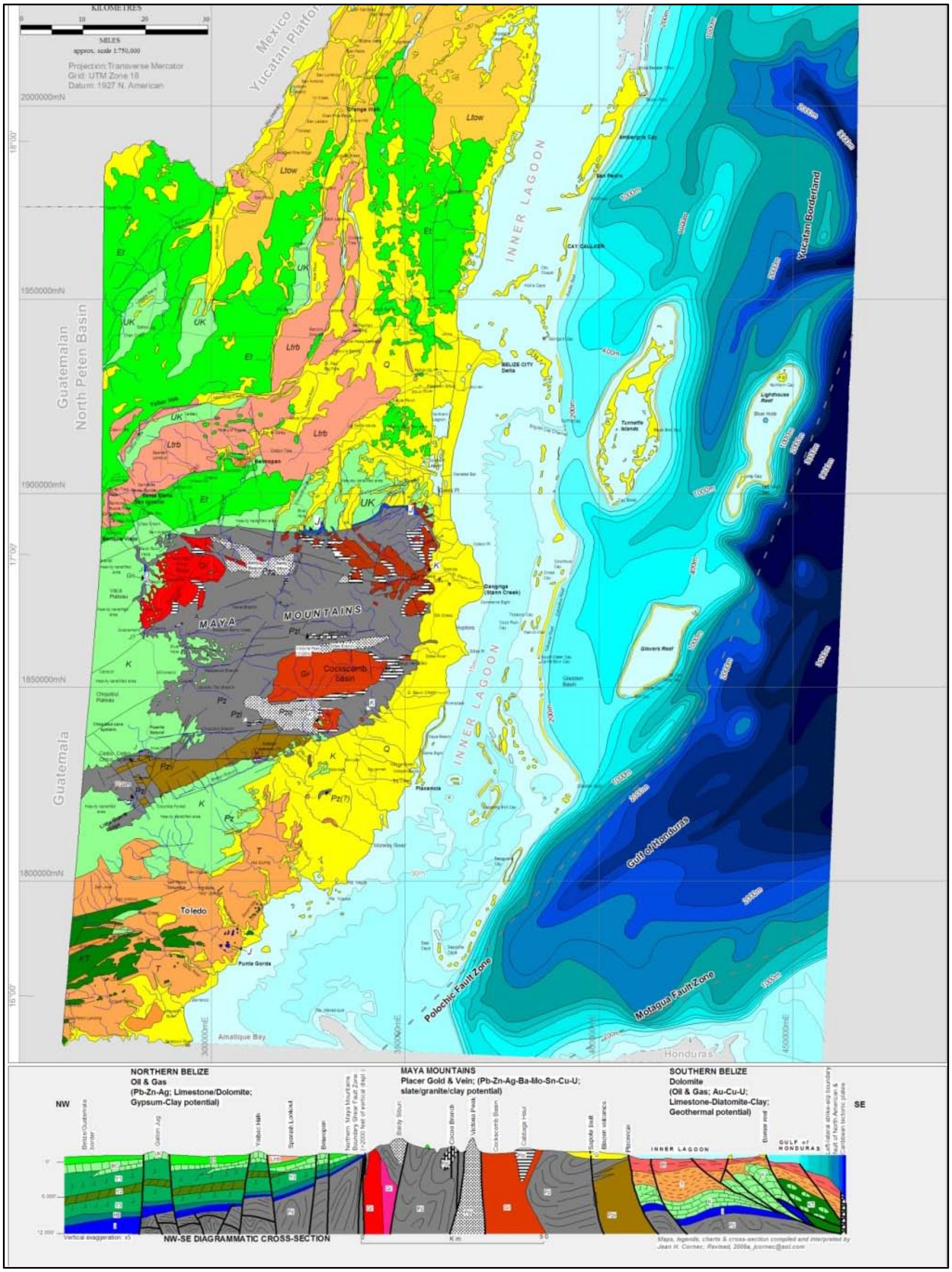

Figure 4.2. Geology map of Belize (Cornec 2008).

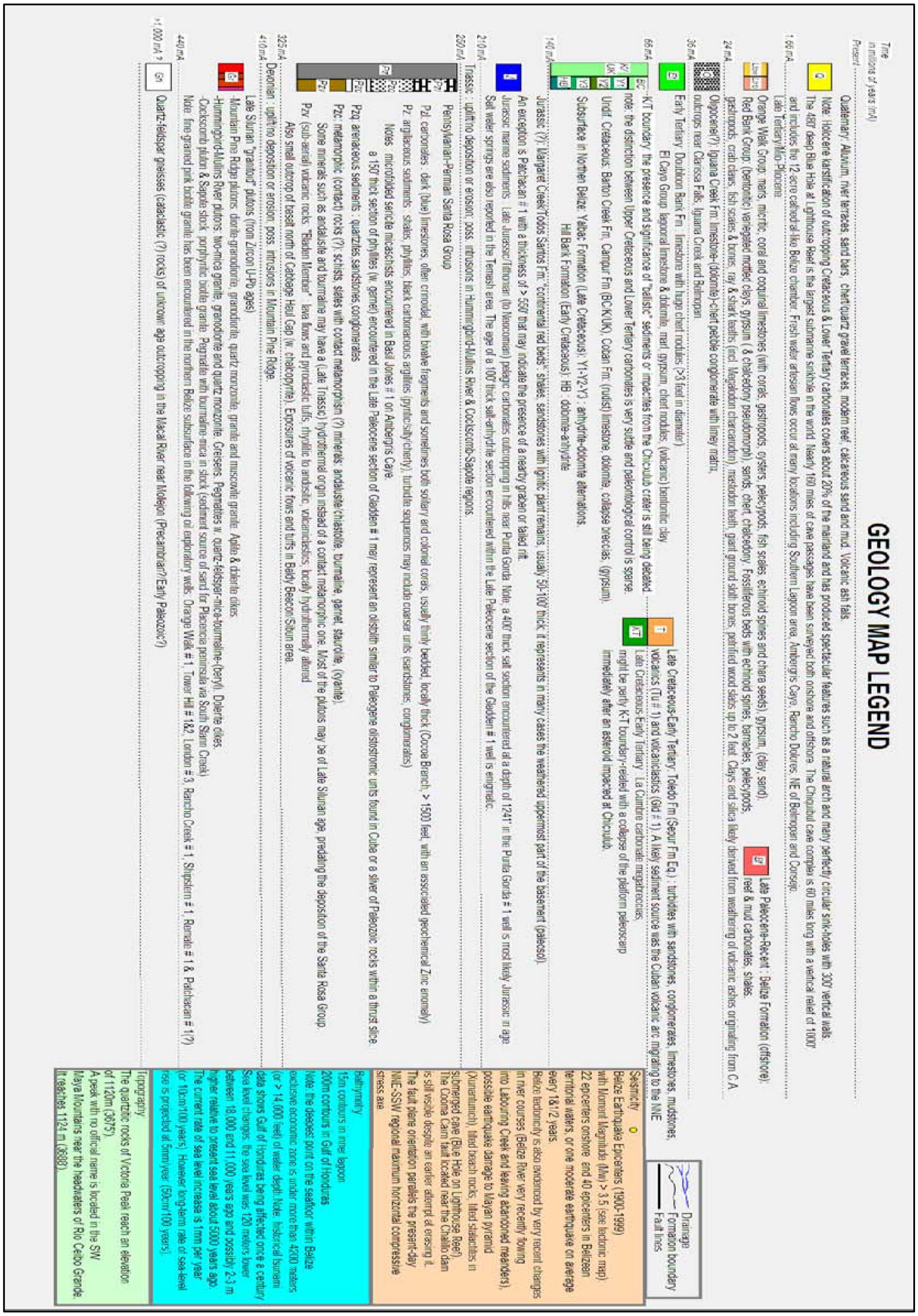

Figure 4.3. Legend for geology map of Belize by Cornec (2008).

However, geologic differences in Belize change over distances <20 km apart (Figures 4.2 and 4.3), creating four zones with distinct $^{87}Sr/^{86}Sr$ values. The concept of zones is more specific than areas with different geologic formations as other aerial, fluvial, and soil formation process may result in distinct strontium isotope within a geologic region (*sensu* Evans et al. 2009). Strontium zones along the Macal River and in the Maya Mountains have values not identified elsewhere in the Maya region. Most sites in the study are located in the Belize River Valley, which is located in the southern portion of the Yucatan Peninsula on Paleocene and Eocene limestone. Its average strontium isotope value, .7086, is similar to Northern Lowland coastal values rather than those of the Central Lowlands. This area forms the easternmost section of the Maya lowlands, a region of mixed broadleaf deciduous semi-tropical forest (Wright et al. 1959). Sedimentary deposition also comes from the Macal River, the main branch of the Belize River, which drains the Mountain Pine Ridge.

A second zone of low strontium isotope values is the Vaca Plateau, directly to the south, which is a late Cretaceous limestone formation. As part of the Central Lowlands, this region has lower values, ~.7078, than the Belize Valley (Hodell et al. 2004). The limestone supports mixed deciduous broadleaf forest with canopy height and precipitation increasing to the south. Broken forest canopy allows growth of grasses and pine stands normally found at higher elevations, with an average elevation of ~450 - 610 meters (Wright et al. 1959).

The Maya Mountains are late Carboniferous and Permian land forms with argillites, shales, slates, schists, gneiss and phyllites that rise to an elevation of 1066 meters (Ower 1921). Granites in the Maya Mountains have variable signatures that exceed .711 (Ericson 1985; Hodell et al. 2004). Parent rock depleted in nutrients produce poor soils that become leached and eroded over time. The broadleaf forests of the lowlands give way to xerophytic species on upper slopes, the canopy becomes light and broken, and grasses grow on the forest floor (Wright et al. 1959).

The closest part of the Maya Mountains to most sites in the study is the Mountain Pine Ridge. The area covers 482 square kilometers, and the lowest elevation of the region is 533 meters. The principal soil-forming materials are Triassic granites, shale and sandstone conglomerates, banded quartz sands and gravels, and limestone remnants. Most of the post-Eocene limestone cap on the Mountain Pine Ridge has been stripped away by a combination of winds, solution, and erosion by fast-moving mountain streams that drain into the Macal branch of the Belize River. The ridge lies within a rain shadow of the Maya Mountains and evaporation exceeds precipitation for most of the year.

The vegetation of Mountain Pine Ridge is characterized in recent times as a pine forest savannah. The borders of the forests and savannahs have changed over the centuries, most likely relating to human activity. Annual fires caused by *milpa* farming in the valley below, lightning strikes, and actions of loggers and hunters maintain savannahs with groves of oak and pine, along with palms, grasses and other species tolerant of low soil fertility (Wright et al. 1959). A similar environment may have existed during the late Classic, though the extent of anthropogenic influence is unclear. Neither highland area shows sign of significant levels of permanent human occupation (Wright et al. 1959), though well-worn trails cross the mountains to the coast and highland resources such as pine, slate, and granite abound in lowland archaeological sites (e.g., Helmke et al. 2006, Lentz et al. 2005).

C. Establishing the Range of Strontium Isotope Baseline Values

Samples of modern fauna were used to establish a detailed map of strontium isotope values near the sites in the study and in neighboring regions. The goal was two-fold: 1) to obtain the $^{87}Sr/^{86}Sr$ signatures of the Belize River Valley and Maya Mountains and validate expected isotopic differences between regions, and 2) to thoroughly map the full range of strontium values in the study area in order to understand the variability *within* each region. Geologic maps provide estimates of isotopic variability, but aerial and fluvial inputs, as well as differential weathering of rock formations and other soil formation processes, can create unexpected isotopic complexity (Bentley 2006).

Thirty-five $^{87}Sr/^{86}Sr$ values from the Belize Valley, Vaca Plateau, and Maya Mountains characterize the Belize study area (Figure 4.4). Most of the values are derived from modern fauna, which provide measures of biologically available strontium. This better represents the average $^{87}Sr/^{86}Sr$ measure for a region than rocks and water, which can be highly variable (e.g., Price et al. 2002). In addition, use of modern samples assures a known collection location, while archaeological fauna may not have been acquired locally.

Sample collection along the Belize River and its main tributaries, the Mopan and Macal Rivers, targeted probable catchment areas of sites in the study. Samples were obtained along the Belize River, which extends approximately 100 km from the Guatemalan border near Xunantunich to Ladyville near the coast. The intent was to measure the variability along the river to determine whether upper and coastal portions of the river are isotopically distinct.

It was possible to access two areas within the Maya Mountains: the Mountain Pine Ridge, the closest point in this region for many of the sites in the Belize Valley, and the eastern area near the Hummingbird Highway. Three samples published by Hodell and colleagues (2004) confirm geologic expectations for strontium isotope ratios, but do not fully characterize the variability within the region.

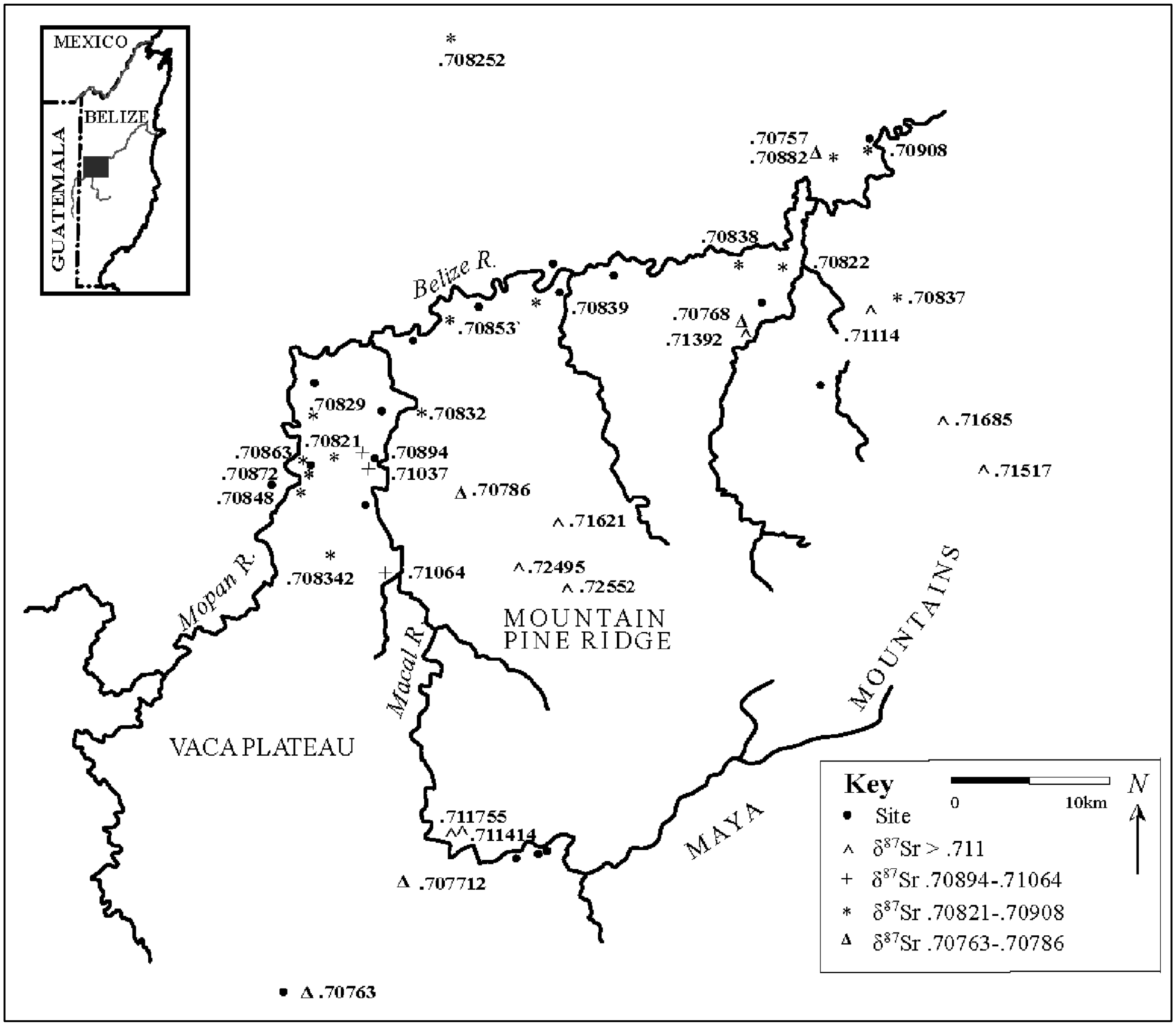

Figure 4.4. Strontium isotope samples in the Belize Valley and neighboring regions: Not shown are coastal samples from Spanish Creek (F4938) and Ladyville (F1750), and the southern Belize sample from Blue Creek (F4524). Locations are described in Appendix B.

Opportunistic sampling of modern fauna was conducted in parts of the Vaca Plateau, especially near the site of Caracol. These values show a geologically homogenous region over more than 40 km in a north-south direction. Average human values near Pusilhá have an isotopic signature similar to those at Caracol (Somerville 2010), as do samples collected by Hodell and colleagues (2004) in the Eastern Petén. The decrease in values from the Central to Southern Lowland regions appears to be gradual, as the single sample south of the Maya Mountains at Blue Creek matches those identified in humans at Seibal and Punto de Chimino (Krueger 1985; Wright and Bachand 2009). However, the range of values in whitetail deer sampled at Lubantuun, .7074-.7078, (Kennedy Thornton 2008) and recent work by Somerville (2010) and Trask and Wright at Uxbenká (2011) show that the area south of the Maya Mountains exhibits greater variability that is not yet well understood.

Fauna used in the study was salvage-collected near highways, riverbeds, or fields, with the exact location marked with GPS coordinates or estimated according to the nearest landmark. Jason Yaeger collected six samples in the Belize Valley and Vaca Plateau and Bernadette Cap provided the sample from Buenavista. The rest of the samples were collected by the author between 2008 and 2009. Land snail shells were most commonly found in fields, and freshwater *jute* shells (*Pachychilus* sp.) were collected from streams, and occasionally from the vicinity of archaeological sites. Information on the provenance of tooth or bone sampled from domestic animals, like cow, sheep, or dog, always was recorded so that the sample likely reflected the local strontium signature.

The range of each species varies, but generally reflects a small territory that represents one part of the catchment for any given site. For example, the gray four-eyed opossum *(Philander opossum)* generally inhabits an area of less than 300 m^2, with most movement occurring in a 30 m^2 area. The territory size of the Virginia opossum *(D. virginianus)* also ranges between .6 – 1.2 km^2. While this depends on availability of food and may shift over the course of an animal's lifetime, and should not exceed 5 km along a river or stream (Krause and Krause 2006). Green iguanas (*Iguana iguana)* also have a fairly small range. With the exception of for birthing females, they reside in trees located close to rivers or streams. Each of these species eats varied foods in its territory and represents a good average of the area's strontium values. Opossums are scavengers, so no samples were collected near garbage dumps or heavily populated areas to avoid sampling imported foods that the animals may have acquired by foraging through human refuse.

Snails generally represent a much smaller area, like a single field, or even a single outcropping of rocks in that field (or stream). However, the habits of the most common snails used in this study, the *mazamorra* (*Neocyclotus* sp.*)* and *jute (Pachychilus* sp,*)* are not well known (Thompson 1969). Even land snails are known to occasionally move long distances, and *jute* can be washed downstream in fast-moving water. It was not always possible to locate faunal samples in a desired area, so seed pods from trees, like pine cones, were used instead.

Selection of diverse fauna was intentional in order to represent multiple water and food available to residents of the Belize River Valley. Some are animals that people eat, like *jute,* which has been a Maya dietary component for millennia. Other samples include animals that eat like people. Opossums are omnivores and consume a mix of plants, insects, and animals, so provide an average of the strontium sources within their habitat. Finally, samples were collected where people grew their food. Terrestrial snails were collected in fields near house mounds at many sites, especially along the floodplain of the Belize River.

A preliminary comparison of tooth enamel from individuals buried in each of the three areas confirmed that archaeological human values would resemble those of the modern fauna.

This included 11 individuals from Caracol, 11 individuals from three sites in the Mountain Pine Ridge, and 10 individuals interred at Xunantunich, Cahal Pech, and Baking Pot in the Belize Valley (Freiwald and Price 2008). This demonstrated that the $^{87}Sr/^{86}Sr$ isotope values identified in the modern faunal baseline also are identified in individuals who resided in the regions. Average strontium isotope values that are reflected in human populations are referred to as strontium zones.

A fourth strontium zone with values intermediate to those in the Belize Valley and Maya Mountains later was identified along the Macal River. Terrestrial fauna sampled near Chaa Creek, a minor center on the Macal River, show an average value of .710. Similar values are identified at Tipu (Erin Kennedy Thornton personal communication 2009) and further upstream. This is just a few kilometers from Belize River zone values.

The next section summarizes information for isotope values elsewhere in the Maya lowlands and neighboring regions. This is used to identify potential origins for individuals buried in the Belize Valley who were not born there. Detailed information on the fauna sampled and the collection location is presented in Appendix B. This includes new strontium isotope values for the Western Lowlands and the Chiapas Central Depression and Pacific Coast. Averages of some of these values have been presented elsewhere (Price et al. 2008).

1. Strontium zones in the Maya region

The thirty-five fauna and plant samples collected in this study show four zones in Belize with distinct strontium isotope values that have very little overlap (Figures 4.5 and 4.6). Two of these, the Maya Mountains and Macal River zones, have values not identified elsewhere in the Maya lowlands. The other zones have values that also are found in other parts of the lowlands.

Values identified in the Belize River zone are found across the northern Yucatan Peninsula and in its coastal areas (Price et al. 2008). Values in the Vaca Plateau mirror those identified in the Central and Southern Lowlands (Hodell et al. 2004).

The map in Figure 4.5 shows the approximate locations of each zone, but must be interpreted cautiously. The borders are approximations drawn from the values of the baseline fauna sampled in this study, along with Hodell and colleagues (2004) three values for the Maya Mountains. They do not encompass the entire range of strontium isotope values in each geologic zone and may be adjusted if further values are identified. Results are summarized in Table 4.1 and then presented in detail for each strontium zone.

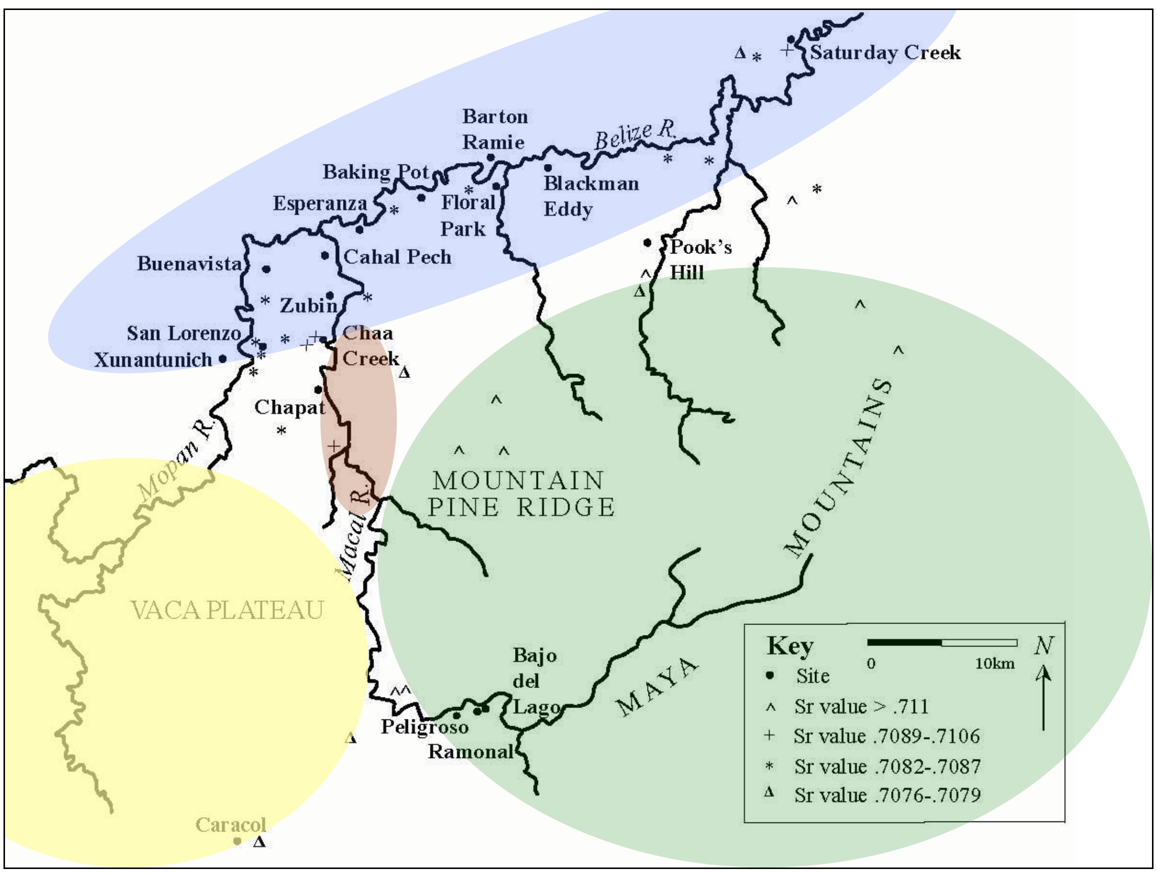

Figure 4.5. Strontium zones in and around the Belize Valley.

Table 4.1. Strontium isotope zone values in study area.

Strontium Isotope Zone	Mean value	Range of values	No. of samples
Vaca Plateau zone	.7077	.7076 - .7078	4
Belize River zone	.7086	.7082 - .7091	17
Macal River zone	.7010	.7089 - .7107	3
Maya Mountain zone (includes Mountain Pine Ridge)	.7179	.7114 - .7255	9

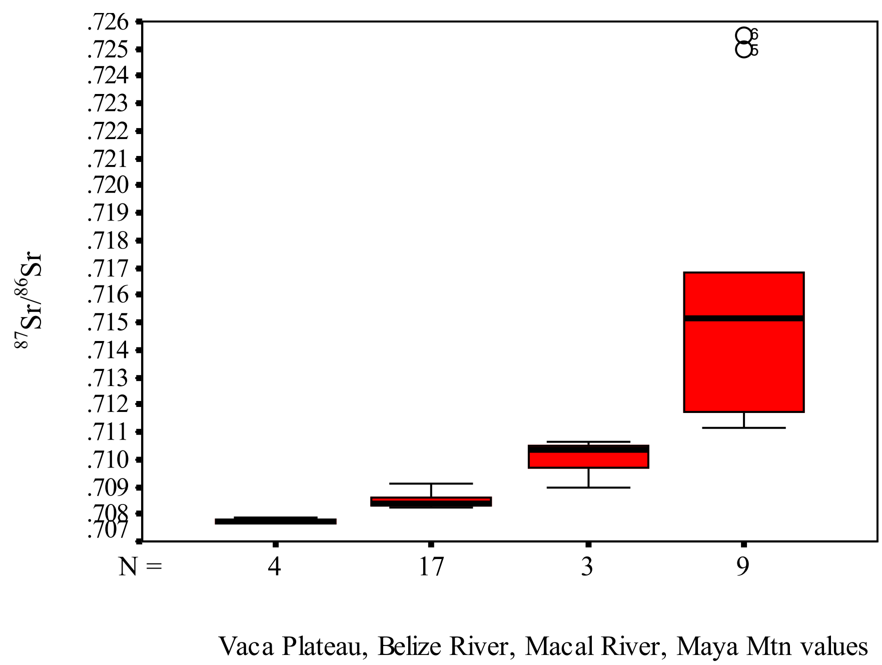

Figure 4.6. Strontium isotope zones in Belize Valley and adjacent regions: note the range of values in the Maya Mountains, including the two outlier values that exceed .724 $^{87}Sr/^{86}Sr$.

1a. The Belize River zone

The seventeen baseline values collected along the Belize River and one tributary, the Mopan River, have values that increase gradually toward the coast, from .70821 to 0.70908 (Table 4.2). The Belize Valley differs from other areas of the Maya Lowlands due to its proximity to the coast. Values decrease from those approximating seawater near the coast inland along the Yucatan Peninsula. The proximity to the coast, reflecting the period in which the land mass formed, likely has a greater effect on strontium isotope values than the region's proximity to the Maya Mountains.

Figure 4.7 shows the increase in $^{87}Sr/^{86}Sr$ values from the upper Belize River valley to its central and eastern portions. The three easternmost samples form a cluster of three samples with values exceeding .7088 separate from the lower values of the upper and central parts of the valley. This results in an average value for the region of .7085, which is slightly higher than the median value of .7084.

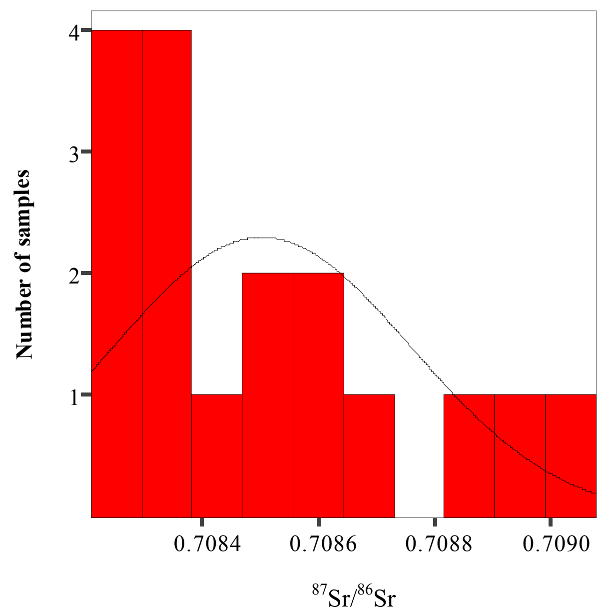

Figure 4.7. Belize River Valley baseline samples.

Table 4.2. Belize River zone strontium isotope values.

Belize River Valley $^{87}Sr/^{86}Sr$ values	Minimum	Maximum	Mean	Std. Deviation
17 samples (the outlier value is excluded)	.708208	.709077	.708503	.00026

The Belize River zone extends from the western edge of the Belize Valley near the Guatemala border to the coast at Ladyville. Values begin to increase in the central Belize River valley near Saturday Creek, where two values exceed .7088. However, multiple geologic zones converge in this area (Cornec 2008 in Figures 4.2 and 4.3), which may be the cause of the diverse values identified near the Saturday Creek site.

This includes one low value that is a statistical outlier (Figure 4.8), with two possible explanations. Either the rabbit bone collected from a field near a gravel road was transported there after its death (i.e., through hunting or with road construction material), or the value represent additional geological variability in the region. In either case, values lower than .708 are not reflected in the average value of humans buried at any site in the Belize River strontium zone.

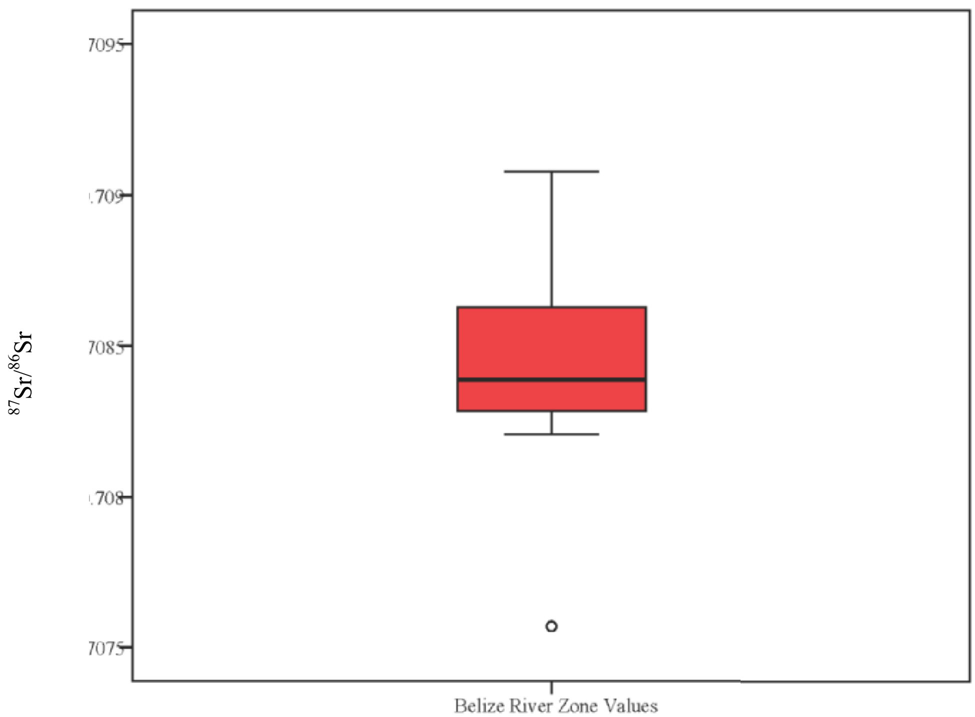

Figure 4.8. Belize River zone strontium isotope values.

The Belize River zone of strontium isotope values extends at least 15 km to the north, where average .7085 $^{87}Sr/^{86}Sr$ values are identified near the Yalbac Hills and Spanish Creek. However, values decrease markedly over the same distance to the west. Hodell and colleagues (2004) measured values ranging from .70766 to .70792 in rocks and water near El Pilar ~15 km to the northwest of Xunantunich in the upper Belize River valley. Four rock, soil, and plant samples from the near the Mopan River show similar values (.70791 to .70797) that reflect strontium isotope signatures of the Central Petén (Hodell et al. 2004).

The Belize River strontium zone includes Caves Branch in the central portion of the valley, and extends as far as Arenal and Zubin in the upper Belize River valley. A thin strip of Tertiary limestone extends into this area, resulting in a thin strip of Central Lowland values along the edges of the Maya Mountains. However, Central Lowland values have not been identified as the average human value for any site in the area. Individuals in the Pook's Hill sample reflect average Belize River zone values.

Table 4.3 shows the gradual increase in values toward the coast. The upper and central valley divide corresponds to divisions described by Driver and Garber (2004), who define the central region as the area between the sites of Baking Pot and Saturday Creek. Values from each section of the river valley have similar means and ranges, so population movement between sites located along the river cannot be discerned.

Table 4.3. Upper, Central, and Coastal Belize River zone strontium isotope values: An increase in values is visible along the Belize River, but is insufficient to distinguish movement within the region.

Belize River zone $^{87}Sr/^{86}Sr$ values	Minimum	Maximum	Mean	Median	Std. Deviation
Upper Belize River valley (n=7)	.708208	.708719	.708427	.708342	.00019
Central Belize River valley (n=7, without the outlier value)	.708219	.709077	.708525	.708390	.00032
Coastal Belize River valley (n=2)	.708615	.708912	.708764	.708764	.00021

1b. The Vaca Plateau zone

The Vaca Plateau forms the easternmost extent of the Maya lowlands adjacent to the Maya Mountains. The Cretaceous-era limestone uplands are isotopically homogenous and show very little variation (Table 4.4). A thin strip of this plateau extends into the Belize Valley between the Belize River and the Maya Mountains. Values of ~.7078 in riverine snail shell and carnivore tooth enamel are found both near Roaring Creek and the modern town of San Antonio, but terrestrial snail shell samples collected near Caves Branch have Belize River zone values.

The Vaca Plateau is actually part of the Central Lowlands strontium zone. There appears to be no gradual increase in values near the Mountain Pine Ridge. In fact, two *jute* snail shells sampled near Roaring Creek have distinct values, one with a Vaca Plateau value and the other with high Maya Mountain value. The latter sample likely washed downstream from a different location.

Table 4.4.Vaca Plateau strontium isotope values.

Vaca Plateau $^{87}Sr/^{86}Sr$ values	Minimum	Maximum	Mean	Std. Deviation
4 samples	.707630	.707863	.707743	.000098

Values in archaeological deer teeth recovered from the site of Caracol reflect these homogenous values. Eleven samples of tooth enamel from five whitetail deer (*O. virginianus)* and two brocket deer (*Mazama* sp.) have a mean value of .707747 ± .00007, nearly equal to the region average. One problematic sample is excluded because multiple samples from the same tooth resulted in different values and further analysis is needed to rule out sample contamination or lab error.

While the homogenous values extend ca. 20 km north from the site of Caracol and nearly the same distance toward the Mountain Pine Ridge, this zone forms a transition with gradually decreasing values between the Central and Southern Lowlands. Central Lowland values in plant and rock samples average .7079 near Tikal (Hodell et al. 2004). In contrast, .7076 average values are reported for humans living in the Southern Lowlands at Seibal and Punto de Chimino (Wright and Bachand 2009; Krueger 1985).

1c. The Macal River zone

$^{87}Sr/^{86}Sr$ values along the Macal River increase over a short distance between its confluence with the Mopan River and its origin in the Maya Mountain Pine Ridge. The river runs across the Vaca Plateau, and its fast-flowing waters cut deep gorges, leaving no floodplain for sediment to be deposited. Flooding instead occurs near the confluence of the Macal and Mopan Rivers north of Cahal Pech near the modern town of San Ignacio. However, values intermediate to the Belize River and Maya Mountain zones have been identified at four locations adjacent to the Macal River (Table 4.5 and Erin Thornton Kennedy personal communication 2009).

Table 4.5. Macal River zone strontium isotope values.

Macal River area $^{87}Sr/^{86}Sr$ values	Minimum	Maximum	Mean	Std. Deviation
3 samples	.708942	.710653	.709989	.00092

While none of these strontium zones have clearly defined borders, the extent of this zone is puzzling, especially in light of the results presented in Chapter 5. The sites Cahal Pech and Zubin are located on the lower Macal River and have strontium isotope values similar to those found along the Belize River floodplain. However, values in between those of the Belize River and Maya Mountain zones are identified less than five km upstream near the site of Chaa Creek. This may be the result of sedimentary deposition from an ancient Macal River floodplain (Smith 1998a, 1998b).

Values of .70894 and .71037 are found adjacent to two plazuela groups at the site of Chaa Creek that contained individuals sampled in the study. Additional values exceeding .710 are identified upstream near the site of Tipu in three samples processed by Kennedy Thornton (personal communication 2009). Unlike the Vaca Plateau/Central Lowland values identified in the Belize Valley, these intermediate values are found in the human burial population of Chaa

Creek. Chapter 5 describes twelve $^{87}Sr/^{86}Sr$ values with an average value (.7094) that is similar to the two identified at the site (.7097).

Chaa Creek is located just four km south of Zubin and seven km east of Xunantunich where human values reflect those of the Belize River zone. There is overlap between the two strontium zones: values of ~.709 are found along the coast of the Yucatan Peninsula. Values exceeding .7089 are identified in the central Belize Valley near Saturday Creek and near the coast by the modern town of Ladyville. However, these high values should not exceed .7092 and human values above ~.709 are not common at Yucatan Peninsula sites (Burton personal communication 2010; Price et al. 2008).

The overlap may result from the type of samples collected at Chaa Creek. Terrestrial snail shells represent a more localized strontium isotope value than fauna with larger territories, like the toads or carnivores collected along the Belize River floodplain. It is possible that intermediate values are present elsewhere in the foothills of the Maya Mountains: there are no published values for the southern Maya Mountains. However, five samples on the eastern, northern, and western borders have values exceeding .711. Intermediate values have not been identified elsewhere in the Maya lowlands.

1d. The Maya Mountain zone

Nine measures show the range of values in the Mountain Pine Ridge and Maya Mountains. Six samples were collected along a north-south road that bisects the Mountain Pine Ridge. These range from .71141 to .72552, with an average value of .71797 ± .0069 (Table 4.6). Three additional samples collected along the Hummingbird Highway have a slightly lower average value (.71439 ± .0029). The values fit well with the three published measures of Maya

Mountain strontium isotope values. Hodell and colleagues (2004) measured rivers and streams, including the Sibun River (.7119) to the north, Stann Creek (.7128) to the west, and Little Vaqueros (.7151) in the Mountain Pine Ridge.

Table 4.6. Maya Mountain zone strontium isotope values.

Maya Mountains $^{87}Sr/^{86}Sr$ values	Minimum	Maximum	Mean	Std. Deviation
9 samples	.711136	.725520	.716325	.0055

It may be possible to isotopically distinguish zones within the Maya Mountains, but this seems unlikely. Although samples in this study were collected in areas of granitic outcroppings, individuals sampled from sites in the broad geologic zone described for the rest of the mountain zone reflect the same range of values, though there may be additional variability in the southern portion of the mountain range. However, only a limited number of sites have been identified in the Maya Mountains, so this information might be more valuable for identifying origins of resources than people.

1e. Other Maya lowland strontium zones

Hodell and colleagues (2004) defined strontium zones across the Maya lowlands. Information on strontium values in other parts of Mesoamerica was published later, and includes biologically available strontium in faunal samples and average human values (Price et al. 2008). Table 4.7 incorporates this published information with the results of this study, which presents strontium zones not previously identified. It is equally important to consider values that duplicate those found in other regions when identifying potential origins for migrants in Mesoamerica.

Table 4.7. Strontium isotope zones in the Maya region: similar values for several zones also can be found in non-Maya regions in Mexico (Price et al 2008).

Region	**Location**	**Average value** **Sample type**	**Zones with similar values**	**Reference**
Northern Lowlands	Multiple locations	.7085 rock, water, plant	Belize River, Macal River, Western lowlands	Hodell et al. 2004 Price et al. 2008
Central Lowlands	Tikal[1] Calakmul[2]	.7079 rock, water, plant .7077 unknown	Western Lowlands	Hodell et al. 2004[1] Price et al. 2008[2]
Southern Lowlands	Seibal[1] and Punto de Chimino[2]; Chiapa de Corzo	.7076 (human) .7074 (fauna) .7075 (human)		Krueger 1985[1] Wright and Bachand 2009[2]
Western Lowlands	Palenque[1] Bonampak Yaxchilan	.7078 and .70874 modern fauna .7077 modern fauna .7082 modern fauna	Central and Northern lowlands, Belize River	Price et al. 2008[1]
Belize River zone	Multiple locations	.7085 modern fauna	Western lowlands, Yucatan Peninsula	
Macal River zone	Multiple locations	.7010 modern fauna		
Maya Mountain zone	Multiple locations	.7163 modern fauna and flora		
Metamorphic zone	Motagua Valley and Copán	.7060 rock, water, plant		Hodell et al. 2004
Volcanic Highlands	Multiple locations	.7042 rock, water, plant	Pacific Coast	Hodell et al. 2004
Pacific Coast	Multiple locations in Chiapas, Mexico	.7048 modern fauna	Volcanic Highlands	

The rest of the Maya lowlands can be subdivided into several strontium zones. Sites within each zone generally have distinct average human values (e.g., Krueger 1985, Wright and Bachand 2009), but the boundaries are not clear and there is some duplication in values. Figure 4.9 and Table 4.8 (page 95) show the approximate boundaries of the Northern, Central, Western, and Southern Lowland strontium zones. The Northern and Central Lowland zone boundary is near the juncture of the three modern Mexican states, Quintana Roo, Campeche, and Yucatan. Values exceed .708 in the north and along the coast, and below this boundary have lower values.

The central-southern divide occurs along the boundary between Tertiary and Cretaceous formations. These formed during different epochs, which results in different average strontium isotope values. These decrease gradually, but are reflected in distinct average human values at sites in each region. Both the Central and Southern Lowland zones are bounded to the west along the Usumacinta River, where the Sierra Madre de Chiapas-Petén foldbelt is located. This is the Western Lowland strontium zone. This zone has two average values, both of which are similar to those identified in other regions. Each zone is described in detail in the next section.

1f. The Northern Lowland zone

This strontium zone encompasses most of the coast of the northern Yucatan. Values in the north are highest, where several sites have average values that range from .7088 to .7089. These values decrease to the south, but remain consistently above $^{87}Sr/^{86}Sr$ .708. Values inland shift over a short distance to approximately .7077 mid-peninsula, marking the boundary with the Central Lowland zone (Price et al. 2008). Geologic values correspond well with those measured in humans and archaeological fauna (Gilli et al. 2009; Wright 2007). Average human values at sites in the Northern Lowlands are generally higher than those identified in the Belize River zone, but it is not possible to identify movement between the two zones using strontium isotope ratios alone.

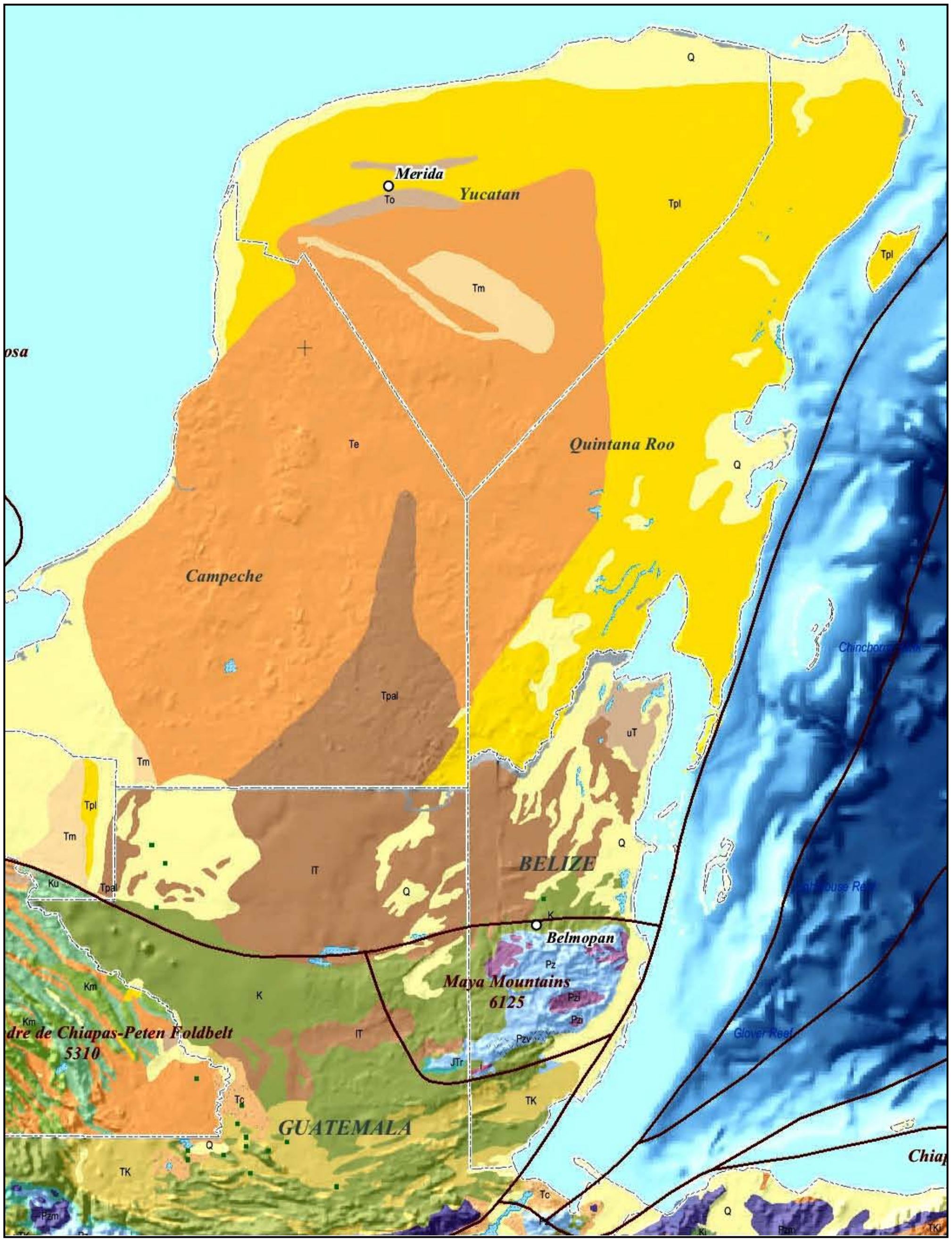

Figure 4.9. Geological map of the Maya lowlands: Map used courtesy of the U.S. Geological Survey.

Table 4.8. Geological map of the Maya lowlands legend: Legend adapted from Nagle et al. 1977.

Q	Quaternary alluvium	iT	Paleo-Eocene marine sediments
Tpl	Paleo-Eocene marine sediments	K	Cretaceous carbonates
To	Tertiary-Oligocene marine sediments	Ku	Upper Cretaceous limestone
Te	Tertiary-Eocene marine sediments	Km	Lower Cretaceous limestone
Tpal	Paleo-Eocene marine sediments	TK	Cretaceous-Tertiary clastic marine sediments
Tm	Tertiary Miocene marine sediments	JTr	Jurassic-Triassic granites
Tc	Upper Tertiary Oligocene-Pliocene continental	Pz	Paleozoic undivided metamorphic rock Phyllites, chlorites, schists and gneisses
uT	Upper Tertiary Mio-Pliocene marine sediments	Pzi	Paleozoic undivided plutonic rocks: granites and diorites

1g. The Central Lowland zone

The Central Lowland zone is large, extending from the central portion of the Yucatan Peninsula to the northern and central Petén in Guatemala. Its transition to the Southern Lowlands is a gradual one, but can also be seen in geographic distinctions (Sharer 1994). In addition, it extends from the Vaca Plateau in the east, into the Western Lowlands beyond the Usumacinta River, and beyond the Maya region in Chiapas. The Western Lowlands have additional variability which is described below, but share the same range of values as centrally-located sites. This region includes many prominent centers, like Caracol, Tikal, Calakmul, and Tonina.

The largest study of a site in this region is Wright's (2005b) at Tikal, which included 83 individuals. The human values have a wider range than the baseline samples, and the average value is elevated. However, this may be due to a combination of imported foods (Wright 2005b) and high levels of immigration into the site. Values of individuals at other centers in the region, like Calakmul, are more homogenous (T. Douglas Price personal communication 2010).

1h. The Western Lowland zone

The western portion of the lowlands has greater isotopic variability over short distances than the central area. Baseline values identified near Palenque, Bonampak, and Yaxchilan show the .7077 average values of the Central Petén, but also show higher values between .7082 and .7087 due to the presence of exposed limestone formed at different times. At Palenque, values in both of these ranges are present in the skeletal sample (Price et al. 2008) because the immediate catchment area of the site was geologically diverse.

A bimodal distribution of values at Pusilhá, on the other side of the lowlands, may also result from localized geologic diversity. When individuals interpreted as non-local are removed, two groups of five individuals have different average values ($^{87}Sr/Sr^{86}$ .7078 and .70823). However, there are no published faunal or geologic baseline samples from the vicinity of the site. Faunal samples collected by Kennedy Thornton (2008) and Freiwald from Lubantuun and Blue Creek, two other sites in southern Belize, also show greater heterogeneity in isotopic values than the northern portion of the Vaca Plateau, ranging from .7073 to .7078.

Chiapas

The transition from Central to Southern Lowland values also is visible at sites in Chiapas in both human populations and baseline faunal samples. The average value of modern fauna sampled at San Cristobal in the Central Highlands is .7076, decreasing to .7074 at Chiapa de Corzo in the Grijalva River Valley, and to .7072 moving west toward the coast at Mirador, Chiapas. The Chiapa de Corzo values also are reflected in the average of the human population (.7075 ± .0001), with one outlier value removed (this individual is interpreted as a migrant). These values show that the Central and Southern Lowland zones extend across a wide area, with values decreasing from the north to the south.

1i. The Southern Lowland zone

The southern lowlands extend from the southern Petén to the Guatemala Highlands, but include a broad area from the east to the west, extending from the Vaca Plateau into the Central Depression of Chiapas. There is no clear boundary between the Central and Southern Lowland strontium zones; rather, there is a gradual transition. However, average values at sites in the two zones appear to differ. Average human values of .7076 are identified at Punto de Chimino and Seibal (Krueger 1985; Wright and Bachand 2009). The average of human values at the Central Lowland site Calakmul is .7077 (Price et al. 2008) and .7078 at Caracol (Chapter 7).

1j. The Metamorphic zone

The values identified in Hodell and colleagues' (2004) Metamorphic Province are not duplicated elsewhere in the Maya Lowlands. Copán is the most well studied site in this strontium zone and human values reflect those of modern and archaeological fauna used as an isotopic baseline (Buikstra et al. 2004; Gerry 1993; Gerry and Krueger 1997; Krueger 1985; Price et al. 2008, 2010). The average of local fauna is .7068 (Price et al. 2008), slightly higher than the geologic mean (.70644 in Hodell et al. 2004). Published studies to date have not included samples east of Copán, so sites and regions in Honduras have not yet been characterized isotopically.

1k. The Volcanic Highland zone

This region includes the southern highlands of Guatemala, a region of volcanic deposits that are the parent material for the soils along the Pacific Coast (Hodell et al. 2004). The most well studied site in this region, Kaminaljuyú, also shows a correspondence between human and baseline isotope values. Wright and colleagues (2010:164) present a sample population of 26 values that, when two outliers from the interquartile range are excluded, have an average value of .70485 ± .00059. This is higher than the published average value, .70415, but fits neatly within the range of values (.7038 - .7053) identified for this isotope zone (Hodell et al. 2004).

1l.The Pacific Coast zone

The alluvial deposits along the Pacific Coast in Guatemala and Mexico are derived from eroded volcanic deposits in the adjacent mountains. Strontium isotope baseline values are consistent, with the exception of canid bone sampled at the town of Pijijiapan. While a brief interview with local residents (presumably the dog's former owners) suggested that its remains were of local origin, the strontium values are inconsistent with the geology of the coast. Either the dog was acquired from an inland location or there is additional isotopic variability in this part of the Chiapas coast.

1m. Other strontium zones

Strontium isotope values are well-known in several regions in Mesoamerica outside the Maya area, while other areas have not yet been studied. Multiple isotope values are published for Teotihuacan and the Valley of Mexico as a result of research on the polity's widespread influence (Price et al. 2000; White et al. 2004a, 2007). Out-migration - and even the establishment of colonies – has been proposed. However, oxygen and strontium assays show that similar values exist in different areas. For example, the average Valley of Mexico strontium isotope value (.7046) is similar to measures of the Pacific Coast and the Volcanic Highlands. Values also are known for the Veracruz region thanks to interest in Olmec influence and potential population movement (Price et al. 2008). These values (.7081 and .7085) are the same as those in the Northern and Western Lowlands, as well as in the Belize River zone.

It is not likely that outside of exceptional circumstances, long distance movement from more distant regions can be identified. Most studies consider the closest potential strontium zone to be the most likely origin, rather than more distant ones (Killgrove 2010). The full range of values present in most regions also is not well-understood. This includes most of Honduras and El Salvador, where multiple strontium zones also are visible in geologic maps (Figure 4.10 next page). Nor is isotopic variability well-understood between centers where population movement is well-studied, like Monte Alban and Teotihuacan.

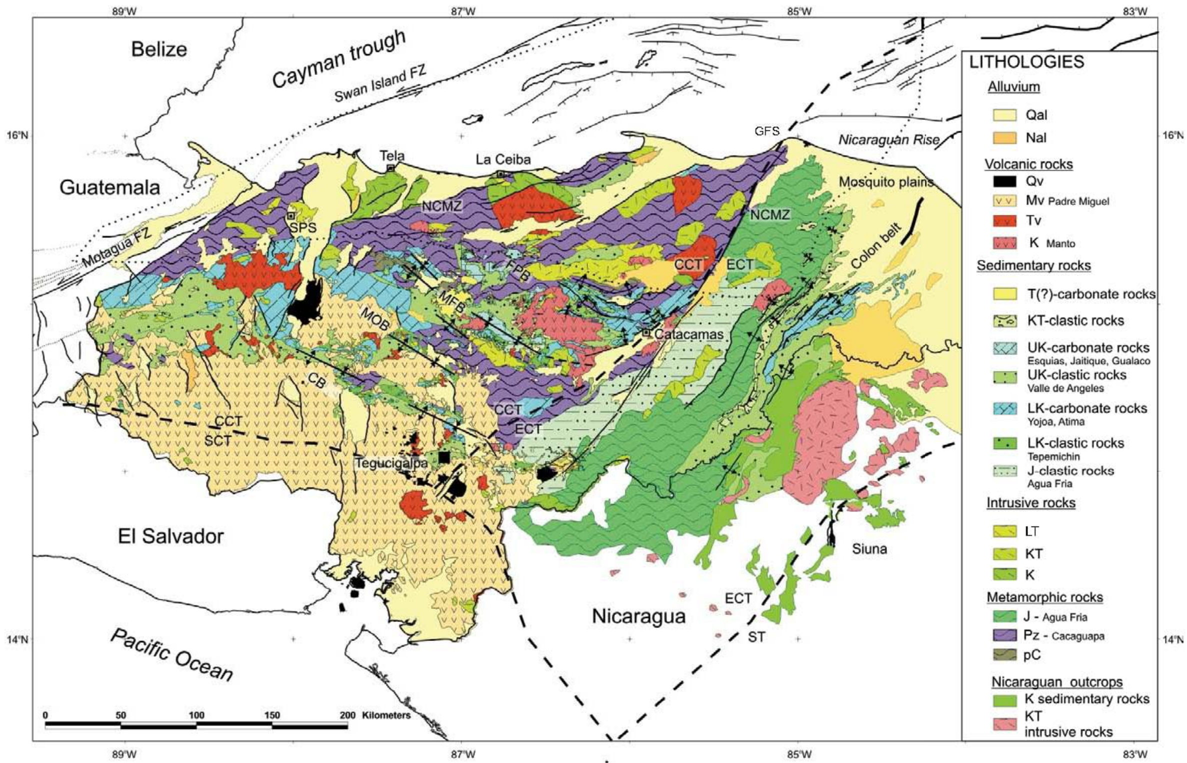

Figure 4.10. Map of the geology of Honduras: Reprinted from Tectonic terranes of the Chortis block based on integration of regional aeromagnetic and geologic data (Rogers et al. 2007:68 Figure 2).

Extensive mapping of strontium baseline values in the Belize Valley reveals isotopic variability that is not visible on geologic maps, obscuring the complexity of migration patterns within the region. In-depth background research, in this case, makes it possible to identify movement within the region, and possibly at the local level. This also identifies additional Maya lowland strontium zones with similar values, which emphasizes the need to avoid overly precise interpretations of origin. This is possible with a large number of samples in a small region; the picture is less clear when the same number of samples is spread out over hundreds of kilometers.

D. Establishing the range of local human values

There is no single manner of determining which part of a sample represents the local population and which individuals are migrants. Early studies relied on estimates of strontium isotope values in broadly-defined geologic regions to identify population movement (e.g., Sillen et al. 1995). While some studies continue to rely on these rough estimates (Evans et al. 2006), most researchers attempt to create more precise measures. This involves establishing isotopic baseline values and interpreting the results in conjunction with chemical or statistical analyses.

Sealy and colleagues (1991) used thirteen faunal samples to estimate the range of strontium isotope values for two regions in their study, and complemented this with an assessment of diagenesis in each of the human bones analyzed as part of the study. Bones of individuals who resided at the site represent the local value. Eventually those of migrants do as well, as they eventually remodel to the local isotopic average. Diagenetic exchange of strontium with the burial environment can also result in local values for bone tissues. The average value of bone and/or teeth in the study population also is used to identify non-local individuals as those beyond two standard deviations from the mean (Somerville 2010; Wright 2005b). Both methods have a critical flaw: the cut-off value used to identify non-local individuals is based on values of the migrants themselves.

Price and colleagues (2002) recommend using modern fauna to establish baseline values, which tend to show little variation within a population. For example, standard deviations are very low for mice ($n=10$, $\sigma=0.0003$), deer ($n=10$, $\sigma=0.00022$), rabbit ($n=8$, $\sigma=0.00005$) in Wisconsin and the Valley of Mexico. Even animals with large territories may have homogenous values: the standard deviation for six elephants was 0.00008 (Vogel et al. 1990). Bentley and Knipper advocate using archaeological fauna to avoid contamination with modern strontium sources (e.g. fertilizer), but in the Belize Valley, isotopic evidence already exists for movement of fauna between areas with different strontium isotope values (Yaeger and Freiwald 2009).

In this study, both statistical and geochemical techniques are employed to differentiate local from migrant populations, and to reconstruct patterns of population movement (e.g., Knudson 2004; Price et al. 2010). First, expected local values are derived from modern fauna, which represent biologically available strontium in the region (e.g., Price et al. 2002; Sillen et al. 1998). The faunal samples were collected where residents of Belize Valley sites grew their food, and include many animals with omnivorous diets that resemble those of humans. These same values should be reflected in the human population, except in exceptional circumstances (i.e., studies in coastal areas) that are not present in the Belize Valley. Most major food sources were locally available, so complex end member mixing models are not needed (e.g., Killgrove 2010).

A cut-off point is determined statistically; however, this is considered in the context of archaeological and geologic evidence. Most archaeological research considers isotope values within two standard deviations of the mean as part of the same population. However, using this statistical formula with data in this study conflicts with the known geology of the region in each strontium zone, and in some cases directly contradicts archaeological evidence, as shown by the following examples.

For example, of the 18 samples collected along the Belize River, more than 75% fall within one standard deviation of the mean (1 σ range=.708246 to .7087596, with 1 outlier value excluded). These values range from .70821 to .70908: a standard two σ cut-off, .707988 to .709165, includes values that conflict with the geology of the valley and (Cornec 2008; Hodell et al. 2004; Nagel et al. 1979). Values below .708 include the entire Central Lowland strontium zone, while those exceeding .7090 are not common in the Yucatan Peninsula and are instead identified along the Macal River.

This is better illustrated by differences between Macal and Maya Mountain zone geologic and archaeological evidence. If all values within two standard deviations of the mean are considered local to the Macal River zone (.708149 to .711829), values from three burials that *predate occupation* at Chaa Creek must be considered local (see detailed discussion in Chapter 5). This range of values also includes those identified in both adjacent strontium zones. Maya Mountain zone values present a more striking example: values within two standard deviations of the mean would include all values in Mesoamerica, including those from the Pacific Coast 500 km away (2 σ range .70535 to .72735.)

Two strontium zones are present in the Belize River Valley, and sites in each are compared to the zone in which they are located. Individuals buried at Chaa Creek are compared to Macal River zone values, while the other sites are compared Belize River zone values. All human values higher or lower than 2 standard deviations of the mean of the baseline fauna are considered non-local; however, values lower than the baseline fauna are discussed as marginal values. Marginal values could represent variability within the isotope zone that is not yet measured, or relocation from another area.

A conservative estimate of migration would exclude marginal values; however, a conservative estimate of the local population would also exclude them. Therefore, the rate of migration is presented as a range of strontium isotope values. They are re-interpreted in Chapter 7 in conjunction with archaeological evidence (Chapter 5) and additional isotopic assays (Chapter 6).

Additional statistical analysis is employed to understand variability *within* the local population at each site. The median value is employed, rather than the mean, because neither the sample population as a whole nor small and large site-specific samples are normally distributed. The interquartile range (IQR or midspread) is a robust measure of central tendency based on the median value that includes 50% of the data. This is useful in identifying both similarities in values as well as those that are outliers from the rest of the population. Outlier values are those more than 1.5 times higher or lower (~25%) than the IQR. The top of the box represents the 75^{th} percentile, and the bottom the 25th. The line in the middle is the median value. The whiskers represent the highest and lowest values that are not extreme or outlier values.

The determination of outlier values is based on the dispersion of the data. Evenly dispersed data (Figure 4.11) will have fewer outlier values, if any, than a set of values with distinct groups (Figure 4.12). For example, if the numbers in Examples 1 and 2 represent two different distributions of isotope values, outlier values are identified only in Example 2 (Figure 4.13). Both sets of numbers have the same median value, but Example 2 has clusters of values that may correspond to individuals procuring food from different locations, either within the strontium zone and elsewhere. While the statistical test identifies individuals with values that differ from others buried at the same site, it does not support an inference of migration.

The IQR provides a better assessment of human strontium values in this region than the mean and standard deviation. The greatest contrast in the strontium zones is in the third decimal place (.707, .708, .709, etc.). Capo and colleagues (1998) use a difference of .001 to discern migration. However, differences as low as .0005 are used (Hoppe et al. 1999), and studies of intra- and inter-tooth variability suggest that differences within an individual should not exceed .00001 (Meiggs 2009). Using two standard deviations from the mean in this small study area combines values from multiple strontium zones and obscures real differences in isotope values. Only extreme cases of population movement could be identified, like movement from the Pacific Coast to the Central Lowlands, or from there to the Maya Mountains.

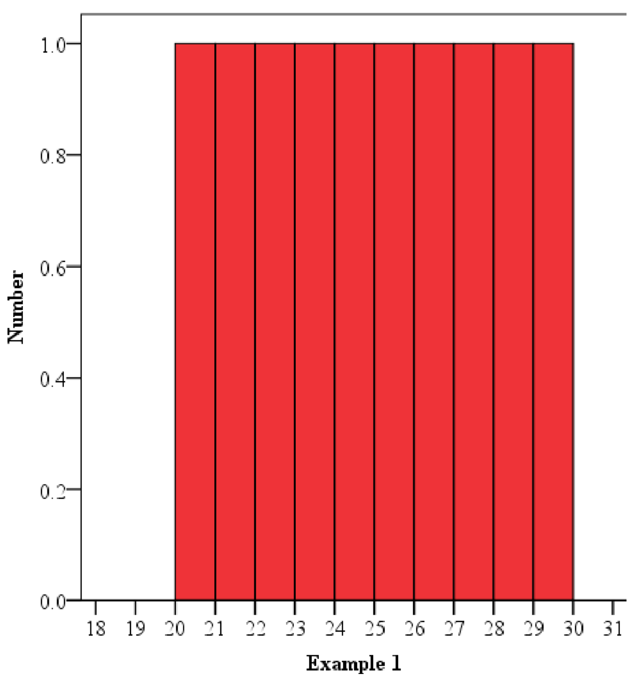

Figure 4.11. IQR example 1.

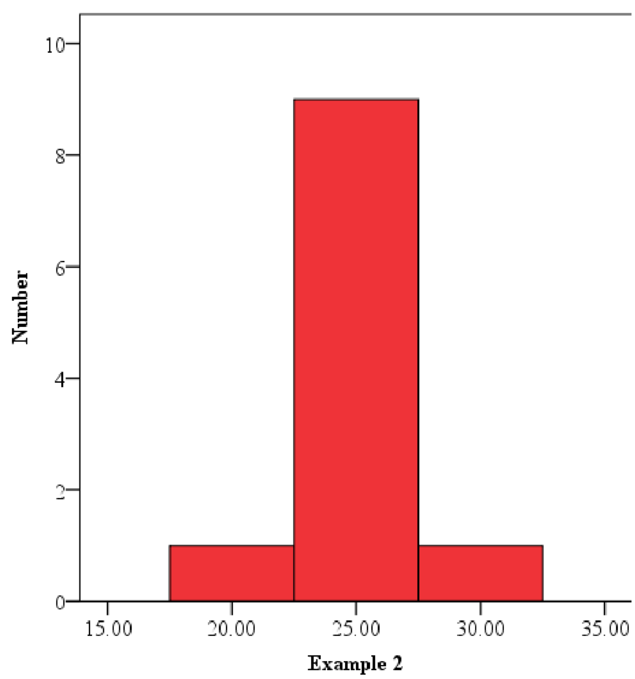

Figure 4.12. IQR example 2.

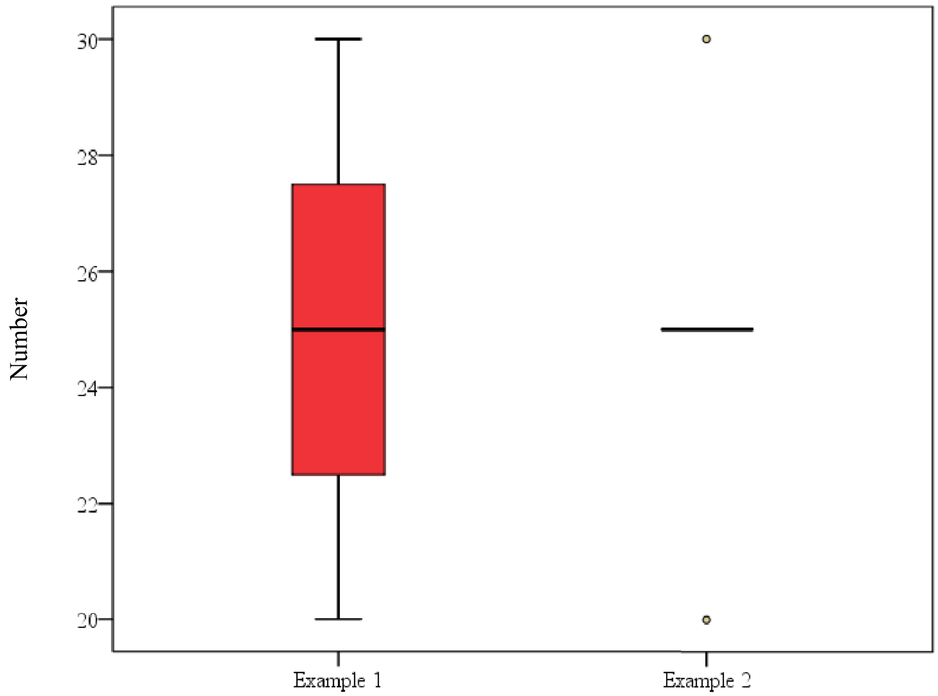

Figure 4.13. IQR comparison.

E. Sample preparation and assumptions

This section describes sample preparation and processing for both human samples and the bone and plant used to generate the map of baseline strontium isotope values. It includes an analysis of the assumptions about tooth selection and enamel formation, especially regarding the influence of the mother's elements to the infant in utero and while nursing. Ultimately, there are many factors that increase the variability in isotope values, but this remains a robust technique for identifying population movement and broader migration patterns.

1. Sample preparation

All samples initially were prepared at the University of Wisconsin Laboratory for Archaeological Chemistry (LARCH). Information for each tooth was recorded before sampling. High resolution photographs were taken of each surface of every tooth (mesial, distal, buccal, lingual, and occlusal), and impressions of the tooth crown were made using medium-body vinyl polysiloxane dental impression material. This is meant to capture the crown dimensions, though standard measurements also were taken for many of the teeth in the study.

The section of the tooth sampled depended on the tooth's preservation and characteristics. No teeth with inlays or other intentional modification were used in this study. Facets, caries, and other features of interest to a dental osteologist also were avoided, as long as a well-preserved section of tooth was still available for the sample. Damage to the teeth normally was minimal, though each step of the process causes wear on the archaeological specimen.

Teeth were sonicated for 15 minutes in Millipore purified water, then a portion of the tooth surface was mechanically cleaned using a Patterson NC-350 dental drill. Removing only 0.5 mm of tooth enamel is sufficient to remove most surface contamination (Schoeninger et al. 2003). Approximately 10 mg of tooth enamel was mechanically cleaned using a microscope to ensure removal of both dentin and any pits or other superficial imperfections that might contaminate the sample. Bone and plant samples are prepared following methods outlined in Price et al. (2000).

Strontium samples were processed in the Department of Geologic Sciences at the University of North Carolina at Chapel Hill under the direction of Dr. Paul Fullager. All samples were analyzed on the VG Instruments Sector-54 thermal ionization mass spectrometer operated by the Isotope Geochron Laboratory, a class-1000 clean lab, directed by Drew Coleman. Strontium was isolated using Sr-Spec ion exchange resin manufactured by Eichrom Industries in micro columns (~35μL resin bed volume) columns. Samples were loaded in single rhenium filaments in phosphoric acid and tantalum chloride solution. Samples are analyzed in triple dynamic multicollector mode with 88Sr=0.1194, which assumes exponential fractionation behavior. The laboratory standard for strontium analyses is NBS-987. Analytic uncertainty in analyses is estimated using the long term reproducibility of the strontium standard ($^{87}Sr/^{86}Sr$ = .710268 ± .000020, 2σ; n=134). Standard error for analyses generally exceeds 0.000011, 2σ.

Checks for visual contamination occur throughout sample preparation, from the initial mechanical cleaning to dissolution in nitric acid, to evaluation of the standard error. If contamination is suspected, from discoloration of the sample to standard error in excess of 0.0016, the sample is re-run. The mass spectrometer is programmed to run each sample thousands of times. An average is calculated for 10 separate batches of data, with problematic batches considered failed samples. At least eight successful batches are needed before the sample run is considered successful. Samples are adjusted according to the results of a standard run with each set (at UNC this value is.710250).

2. Sampling assumptions: tooth enamel v. other tissues

Most archaeological studies of population movement use samples of tooth enamel, because it remains relatively unaltered once it is formed (Hillson 1996). Tooth enamel isotopic ratios represent an averaged diet and geographic range, and present the smallest risk of contamination through diagenesis (Gabaordi et al. 2005). It is relatively non-porous and is composed of hydroxyapatite with very little organic material (Hoppe et al. 2003). With one exception, an individual sampled from the site of Cahal Pech, only tooth enamel is used in this analysis. Archaeological bone is sometimes used to establish local strontium values because it gradually exchanges elements with the surrounding environment. The extent and the speed of diagenetic alteration depend on the local environment, which can vary greatly, even where general preservation conditions appear to be similar (Wright and Schwarcz 1998).

Tooth enamel also provides an excellent correlate for childhood residence, as most tooth enamel forms during the first seven years. This period can be compared with residence later in life, using bone or the burial location as a correlate for an individual's final residence. Sequential sampling of teeth that form during different ages allows comparison of mobility at multiple stages of childhood and adolescence (Buikstra et al. 2004; Price et al. 2010; White et al. 2004b). Sequential sampling of the same tooth in herbivores provides an even greater understanding of mobility, assessing movement that occurs within a year, mainly to understand herding strategies (Balasse et al. 2002; Meiggs 2009). The same method has not been applied to the herders themselves due to differences in the growth patterns of human and ungulate teeth. This study measures only one value in each individual, creating a broad picture of migration with a large sample, rather than a detailed reconstruction of the lives of a few individuals.

Deciduous dentition begins forming in utero and is complete by the age of one year. Formation of the first molar also begins during infancy, with mineralization of the crown beginning near the time of birth. Formation of the enamel is complete by the fourth year. With the exception of the third molar, all other teeth begin forming during this period of early childhood. The incisor and first canine most closely approximate the timing of the growth of the molar, with mineralization beginning after birth and continuing through the child's seventh year. For the most part, mineralization of the maxillary and mandibular dentition is similar, but may vary by periods of several months (Hillson 1996, 2005).

However, the rate and timing of tooth formation varies both between and within populations. Crown mineralization may begin 1-2 months earlier for some teeth in boys than girls, but there is substantial overlap and the pattern is not consistent for all teeth (Hillson 1996). Other factors, including health and prenatal nutrition, are difficult to measure in past populations. This limits the precision of modern tooth formation models as applied to archaeological questions.

3. Sample Selection: differences between teeth

Most scholars use the enamel of the left lower first molar (e.g., Price et al. 2010). Using teeth formed at approximately the same age reduces potential variability in strontium incorporation into the enamel. This could result either from developmental processes or age-related changes in diet, such as weaning. Most teeth used in this study are first molars, but other teeth were substituted for two reasons. First, poor preservation in the Maya region results in incomplete skeletons, a problem aggravated by dental disease that can result in significant structural damage to teeth.

A second consideration is that the lower left molar is important to dental osteologists. Even measuring, photographing, and making a dental impression of the tooth fails to completely substitute for examination of the complete tooth. The antimere was used where present, but other teeth were also used. At one site, premolars were substituted at the request of the project osteologist. In another case, incisors were selected because they formed the basis for the minimum number of individuals in a burial with multiple individuals.

In theory, the lack of fractionation in strontium isotope values should result in similar measures in all body tissues and variability should be the result of isotopic values in the diet at the age the tissue formed. A comparison of 119 teeth in the study shows that variability does exist between different teeth, including those formed at the same age. However, the variability is not large enough to significantly affect the results of the study, but should be explored further. In addition, a small number of deciduous teeth are included in the sample population. These run a greater risk of diagenetic contamination than enamel that is fully formed.

Figure 4.14 shows the interquartile range of values of canines, incisors, deciduous molars, molars, and premolars. The mean and standard deviation for each tooth type are similar, including the deciduous dentition. The outlier and extreme values are not important to this particular question; instead, the emphasis is on the similarities and differences in the local values. Unfortunately, the size of sample populations vary greatly. Only three canines and six incisors were sampled: the incisor teeth show higher values because four of the six samples came from the site of Chaa Creek, which is located in the Macal River strontium zone. The rest of the sites are in the Belize River strontium zone.

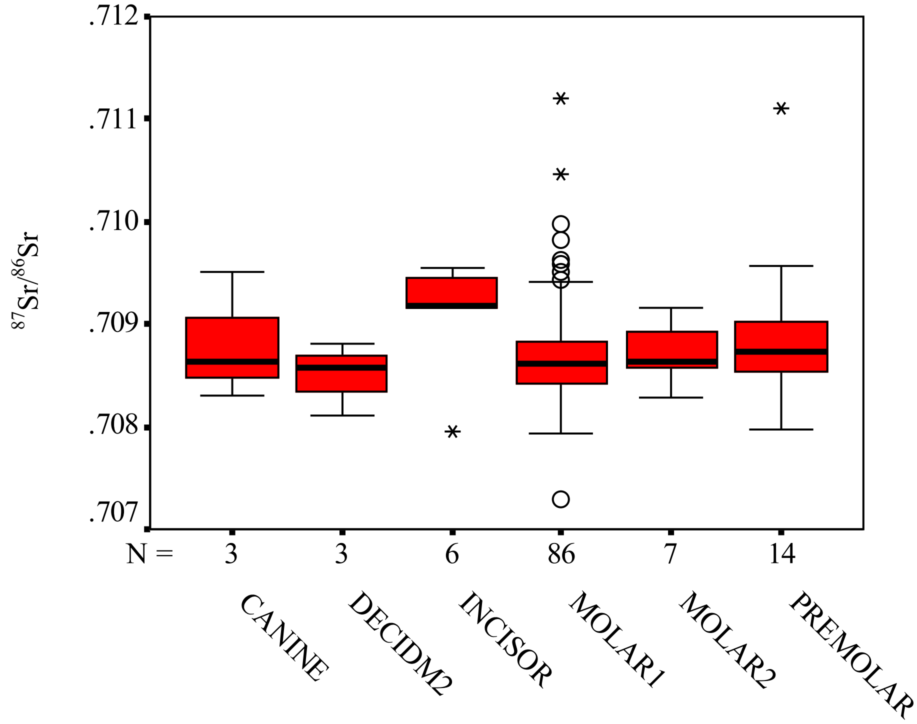

Figure 4.14. Strontium isotope values by tooth type: Black line is median value and box is IQR, with whiskers representing high and low values that are not outliers or extremes (circles and asterisks).

A more detailed comparison, however, shows that there are differences in strontium values between the teeth. A comparison of the means suggests that different tooth types do not come from the same sample population (Table 4.9). There are more individuals with elevated strontium values in the lower first molars than in other teeth, but variability can result from multiple factors. First, all premolars were grouped together, including third premolars from the lower and upper dentition, and premolars with incomplete identification due to wear and completeness.

Table 4.9. Differences in strontium isotope values by tooth.

Tooth and sample size	T	*df*	p-value
Lower (n=45) v. upper molars (n=20)	-6.519	20	< .0001
Lower (n=23) v. upper molars (n=17) at four sites	-1.834	16	0.0853
Lower molars (n=45) and premolars (n=11)	4.278	6	0.0052
Upper molars (n=20) and premolars (n=11)	4.482	6	0.0042

However, a comparison of teeth by site suggests that this is the cause of the variability (Figure 4.15). The median values of teeth identified at each site, including all molars and premolars, is different for each site.

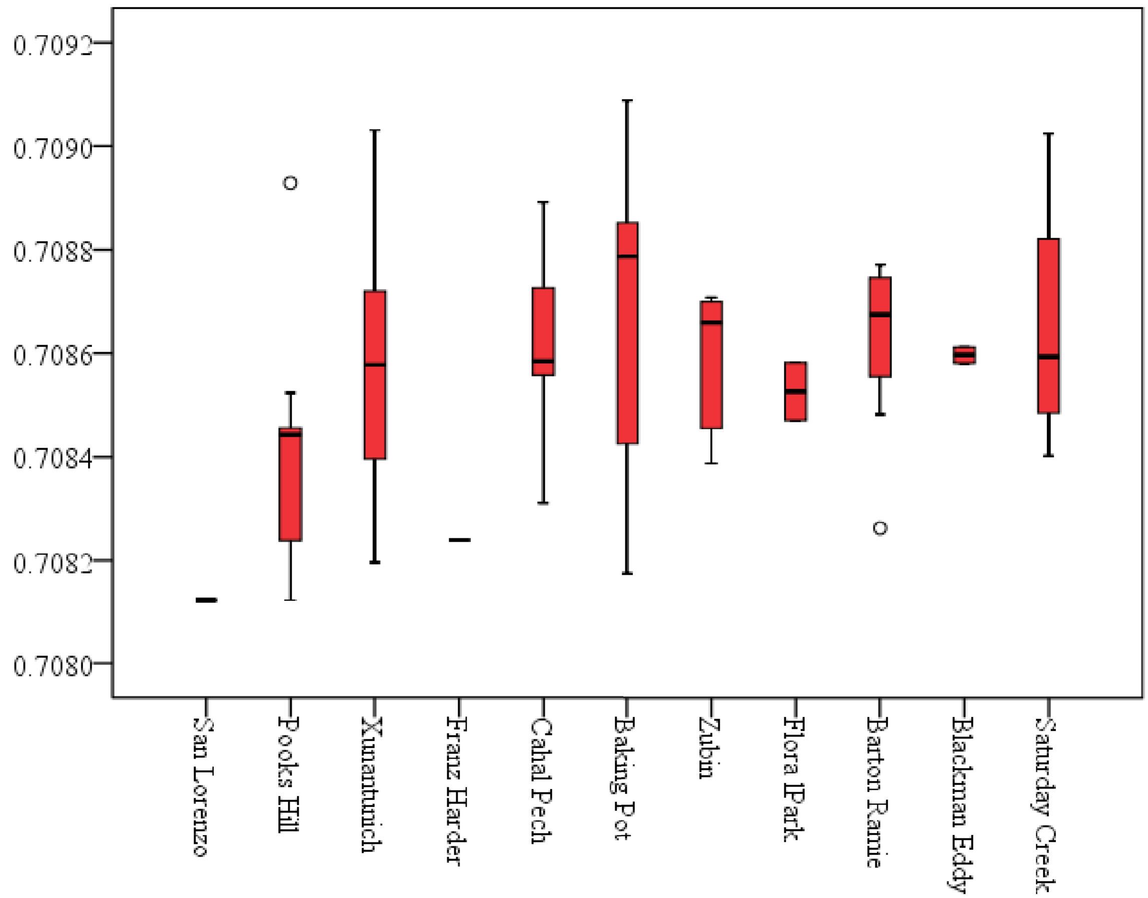

Figure 4.15. Median strontium isotope values for tooth type by site.

The lower molar sample population also includes teeth from more sites, which could cause greater variability in the results. A comparison of upper and lower molars from the same sites, Xunantunich, Barton Ramie, Baking Pot and Pook's Hill, still resulted in a significant difference between the sample populations. However, comparing the median values for teeth sampled at each site shows this to be the cause of the variability rather than the type of tooth sampled. Other factors that are not visible, like sex or status, probably contribute as well but cannot be isolated in this small sample size.

Less variation occurs within an individual. The upper right first molar and lower left first molar were inadvertently sampled for Baking Pot individual G1 P2. The value of the upper molar was .000066 less than the value of the lower molar (.708283 and .708349). Price and colleagues (2010:28) ran multiple samples of tooth and bone from the several individuals at Copán. Extreme differences in the values of individuals, or values that are not identified in the Metamorphic zone, are interpreted as migration. However, most differences between samples are small (Table 4.10).

Table 4.10. Strontium isotope values in the same individual.

Burial	**Strontium values for each sample**	**Value difference**
Hunal 95-2	Tibia and fibula (.70637, .70632, .70633, .70635)	.00005
Margarita 93-2	Tibia (.70634, .70643)	.00009
Mitzil 94-1	URI1 (.70711) LRM1 (.70686) LLM3 (.70685)	.00026
Teal 92-2	LRM1 .70688, LRM3 (.70685)	.00003
Subjaguar 92-3	URI1(.70681) URM1 (.70688) LLM3 (.70682)	.00007
Ent. 37-9	I2 (.70682) M3 (.70683)	.00001

Meiggs (2009) took 2 – 6 samples from multiple ovicaprine teeth and interprets variability in the fourth decimal place as mobility. This provides a reasonable guide for the Copán values and suggests that Mitzil 94-1 had a change in food source that affected the value of the incisor. This presents an interesting possibility given that this tooth forms after the M1 and before the M3, which have similar values.

A comparison of teeth from two whitetail deer mandibles at Copán also resulted in strikingly similar values. $^{87}Sr/^{86}Sr$ measures of three premolars and the first molar from one deer, and three molars from a second deer, have low standard deviations: .000063 and .000026. One value was excluded because of problems during the sample run.

The location of the enamel removed for the sample was also considered, but too many variables exist to discern any real patterns. The Barton Ramie sample population of teeth from twenty individuals provides a good example. Lower first molars were only available for nine of the individuals in the sample. Two upper first molars, two premolars, one third molar, one canine, and two unidentified molars filled out the rest of the sample population. Tooth preservation guided the location on the tooth where the sample was taken. A comparison between the three lower first molars with the distal buccal face sampled, and the sample as a whole, resulted in the same range of strontium values (.0003) and standard deviation (.00015). This allows an analyst to prioritize selecting the best preserved part of the tooth and avoid facets, unusual tooth wear, or other qualitative traits while removing tooth enamel without increasing variability in strontium isotope results.

Given the difficulties in sample selection caused by preservation, skeletal completeness, curation, and the selective burial practices of the Maya, it is important to show that sampling different teeth results in a similar strontium isotope value (given a comparable stage of tooth development). It also is important to remember that there is a limit to the precision and accuracy one can expect from any chemical assay, but the neither this nor the tooth sampled should limit an understanding of the full range of local variability.

4. Are we actually measuring the mothers? Considering the nursing effect

Although there is no trophic fractionation of $^{87}Sr/^{86}Sr$ ratios, the mother's contribution to a nursing infant's strontium values merits additional discussion. The small number of deciduous teeth sampled in this study formed in utero and when the infants were nursing (Hillson 1996). Most other teeth almost certainly formed while the infants were nursing, and then as solid foods were introduced. Wright and Schwarcz (1998) use carbon and oxygen isotope ratios to suggest the introduction of maize by age two at Kaminaljuyú, with nursing likely continuing through the formation of the premolars (also see Wright et al. 2010). Only the third molar would not be impacted by the effect of nursing.

Studies of the retention of elemental lead in body tissues suggest that the mother may transfer significant quantities of lead from body reservoirs to her infant during pregnancy, especially if her diet is calcium depleted (Gulson and Gillings 1997; see summary in Montgomery 2002). Lead stored in the bones decades earlier becomes biogenically available as metabolism changes during pregnancy (Silbergeld 1991). While the half-life of lead in blood is short (ca. 3 years), bone reservoirs may provide the bulk of the lead present in the body. Lead is transferred to the infant during lactation as well, and as a consequence, isotopic signals in the child's tissues could reflect the long-term lead intake of the mother (e.g., Gulson and Gillings 1997).

Montgomery (2002:44) posits that strontium may be transferred in a similar manner. This has enormous implications for this study because it would mean that the δ^{87}Sr values reflect the mothers of most of the individuals in the sample population. While an entirely female sample population would be fascinating, absolutely nothing is known about the burial context, location, or end of life residence for these individuals.

However, the body absorbs, retains, and eliminates each element at different rates. Lead can continue to accumulate in bone with increased exposure (Rabinowitz 1991). Zinc, however, is not stored in bone (Murray and Messer 1981) and the strontium reservoir is considered stable, reaching a plateau even when high dosages are intentionally administered (Dahl et al. 2001). While strontium, like lead, radium, barium, and fluorine, approximates calcium, key differences in how strontium is processed show that $^{87}Sr/^{86}Sr$ isotope values reflect the child's diet while the tooth enamel was forming, not the stored reservoirs of the mother.

Strontium is similar to calcium in that 99% of the amount stored in the body is localized in bone. Like calcium, strontium is absorbed in the gut, stored in bone, and excreted through body fluids like urine or breast milk. However, the actual amount of strontium in the bone consists of only a small percent of the bone's calcium content because the body discriminates against strontium in favor of calcium. As a result, strontium is excreted at a faster rate than calcium. Up to 30% of strontium may be turned over each day (Eisenberg and Gordan 1961).

Strontium is incorporated into the body as it substitutes for calcium during the formation of new bone. Strontium stored in bone reservoirs is incorporated into new bone, along with elements from the exchangeable pool (e.g., the bloodstream and soft tissues). It is more concentrated in newly formed bone tissue than old bone, but bone turnover rates vary by sex, age, the level of physical activity, and anatomical site (Dahl et al. 2001).

The rate at which Sr is eliminated from the body is not fully documented, but estimates show that the rates are highly variable between minerals. Lead turnover occurs at 6-8% each year, with total replacement every 15 years (Rabinowitz 1991). However, strontium remains in the system for a period of up to three years. The elimination of strontium deeper in the bone is much slower than surface accumulations, but the rate of bone remodeling is an important factor (Dahl et al. 2001).

Calcium transfer from the mother to the fetus is also not well-understood, but nutritional status plays a key role. Fetal calcium needs are met primarily by increased calcium absorption during pregnancy, and much of the calcium needed during pregnancy accumulates during the third trimester (Abrams 2007). If strontium follows the same path, it should accumulate in fetal tissues in the same manner. It is possible that some of the mother's stored strontium is transferred to the child during tooth formation, but the isotope ratios mainly reflect the residence during tooth formation, and not before.

F. Conclusion

The detailed map of four distinct ranges of strontium isotope values in the Belize Valley and neighboring regions serves as a baseline for identification of both migrants and the local population. Extensive sampling of biologically available strontium values provides isotopic information not available in geologic maps and can be used to identify population movement over distances of less than 25 km, as well as long distance migration, in areas with heterogeneous geology.

Strontium isotope values in tooth enamel serve as correlates for early childhood residence, but it is important to understand the limitations of the method. Assumptions are present in many steps of the sample selection, increasing the variability present in the data. However, neither selection of the particular tooth, nor sampling different parts of the tooth, appears to significantly alter strontium isotope results. More important is an in-depth understanding of baseline isotopic variability in the study area and all adjacent strontium zones.

A combination of statistical analysis and comparison with baseline faunal values is used to differentiate individuals born and buried in same strontium zone, and those with different origins defined as migrants to the region. It is not possible in all cases to identify population movement between zones with similar strontium isotope values. Likewise, the origins of individuals with marginal values are interpreted in conjunction with other isotopic, contextual and archaeological evidence. There is ambiguity present in identification of migrants, as well as their potential homelands, and it is important to avoid overly precise conclusions. Chapter 5 presents the strontium isotope values of the human population, with a detailed description of the demography of the sample and the burial locations and contexts at each site in the region.

Chapter 5 Migration in the Belize River Valley: strontium isotope results

Chapter Summary

Strontium isotope values for 148 individuals (149 samples) buried at 15 sites in the Belize River Valley provide evidence of in-migration at nearly every site. A comparison of human values to the baseline samples presented in Chapter 4, with supporting statistical analysis based on the interquartile range (IQR), is used to identify individuals with values similar to those at the burial location and those whose values indicate relocation from another strontium zone. Analysis of the values is presented site by site, moving from Xunantunich in the western portion of the valley, to Saturday Creek in the central valley, to discussion of two interments in caves.

The chapter begins with a short review of the study area and related strontium zones, and a summary of the sample population distribution by sex, burial location, time period, and burial context, which is examined in terms of the proposed relationship between burial location and residence at the end of life. The analysis of population movement patterns at each site includes a short summary of how that burial population contributes to an understanding of broader migration patterns in the valley. This includes: 1) where migration is identified, 2) potential origins of migrants in each polity, and 3) the demographic profile of the migrant population.

The chapter concludes with a summary of the strontium isotope findings. An analysis that incorporates information on oxygen, carbon, and nitrogen isotope data, along with patterns of health and body modification for a subset of the population, is presented in Chapter 7.

A. Migration in the Belize River Valley

Population movement at sites located in the Belize River Valley in some ways shows remarkably different patterns: rates of migration range from 0% - 100% of the burial population sampled at each site. This may reflect the diverse sociopolitical relationships and the unique histories at each center. While most movement likely occurred over short and medium distances, interregional migration (see Maya lowland regions in Figure 4.1) also is identified at multiple sites. However, because similar strontium isotope values can exist in more than one place, it is not always possible to identify long-distance migrants.

The differences in migration patterns are most pronounced at major centers: the direction and rate of movement are distinct at each one. However, similarities were present across the valley as well. At many sites, migrants from more than one location are identified, including men, women, and children. Many of them were buried in residential groups and family shrines, and in some cases are interred with locally-born individuals.

This chapter presents detailed information on nearly all of the individuals included in the sample, organized by site and burial location. It begins with analysis of the strontium isotope data for the Belize Valley sample population (including Mitchell's 2006 data), and a comparison of the human values with the modern baseline faunal values presented in Chapter 4. Detailed analysis of the results by site includes 1) the identification of both the migrant and local populations, as defined by strontium isotope values, 2) their burial locations and contexts, and 3) a summary of the findings for each site. A summary of key findings for the entire Belize Valley sample population is presented at the end of the chapter. Each site provides insight into the rate of population movement and its direction.

1. Interaction in the Belize River Valley

Residents of the Belize River Valley had complex social and economic networks that extended into each neighboring region, as described in Chapter 3. Strontium isotope baseline values in the Belize Valley and neighboring regions, including previously published data (Hodell et al. 2004; Price et al. 2008) in Chapter 4, show that each adjacent region has distinct $^{87}Sr/^{86}Sr$. This means that in-migration from the Maya Mountains and the Central and Southern Lowlands can be identified. Longer-distance migration from the Guatemalan Highlands and Pacific Coast also can be identified, along with relocation from Metamorphic strontium isotope zone near the Motagua Valley and Copán.

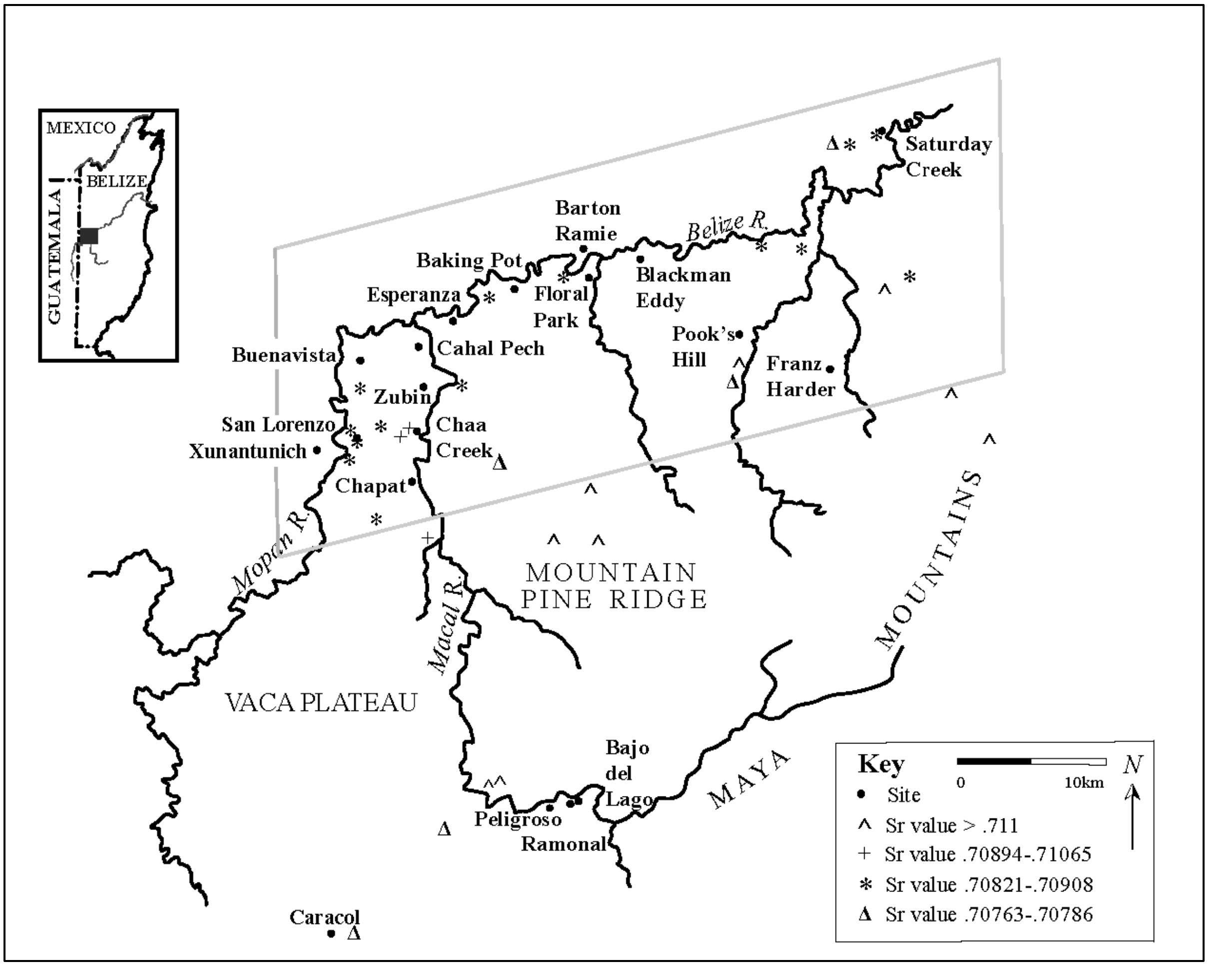

Figure 5.1. Belize River Valley sites and $^{87}Sr/^{86}Sr$ values.

Some movement within the valley can be identified because the Macal River floodplain has different $^{87}Sr/^{86}Sr$ values than the Belize and Mopan Rivers (Figure 5.1). To some extent, this allows the identification of local and intra-regional movement over very short distances. However, there is some overlap between the values of the Belize and Macal River strontium zones, and values those identified in the Northern Lowlands. This limits identification of the non-local individuals within the Belize Valley. Duplicate values in other parts of the Maya lowlands, like the Central Lowland zone values that stretch across the Petén into Chiapas, also limits identification of the origins of individuals with non-Belize Valley origins.

It is important to acknowledge limits at the interpretive level as well. The historical and archaeological record of many sites in the Belize Valley describes site-specific relationships: isotopic chemistry does not usually offer that level of detail. This analysis uses two conservative assumptions to interpret an individual's origin. First, the closest possible strontium zone is considered the most likely homeland for the individual. For example, Belize River strontium values are the same as many identified in the northern Yucatan, therefore an origin near the site where the burial is located - a local one - is considered the most likely. Second, there are a small number of strontium isotope values that could represent either variability within the Belize Valley population or in-migration. Both interpretations are presented, with the understanding that additional data could either resolve the ambiguity in this analysis, or create new questions that result in modification of some interpretations.

B. The Belize Valley sample population

136 individuals (137 samples) were buried in the Belize Valley strontium zone, while 12 individuals were interred at Chaa Creek, in the Macal River zone. Most strontium isotope values (74%) fall within the range of modern fauna. However, individuals with values from other strontium zones are present at most sites. The values that match those of the strontium zone where the site is located are referred to as local. While this implies a site-specific origin, the term local refers to the whole strontium zone. Differences between local values at some sites suggest movement within the same strontium zone, but it is not possible to demonstrate this with certainty.

The mean of the faunal baseline in the Belize River strontium zone is $.70850 \pm .0003$, which results in a two standard deviation range of .70799 to .70917. As described in Chapter 4, individuals with values outside this range are interpreted as migrants. However, because this range exceeds known geologic variability in the region, values beyond the more limited range of faunal baseline values also are considered potential migrants (δ^{87}Sr .70821 to .70908).

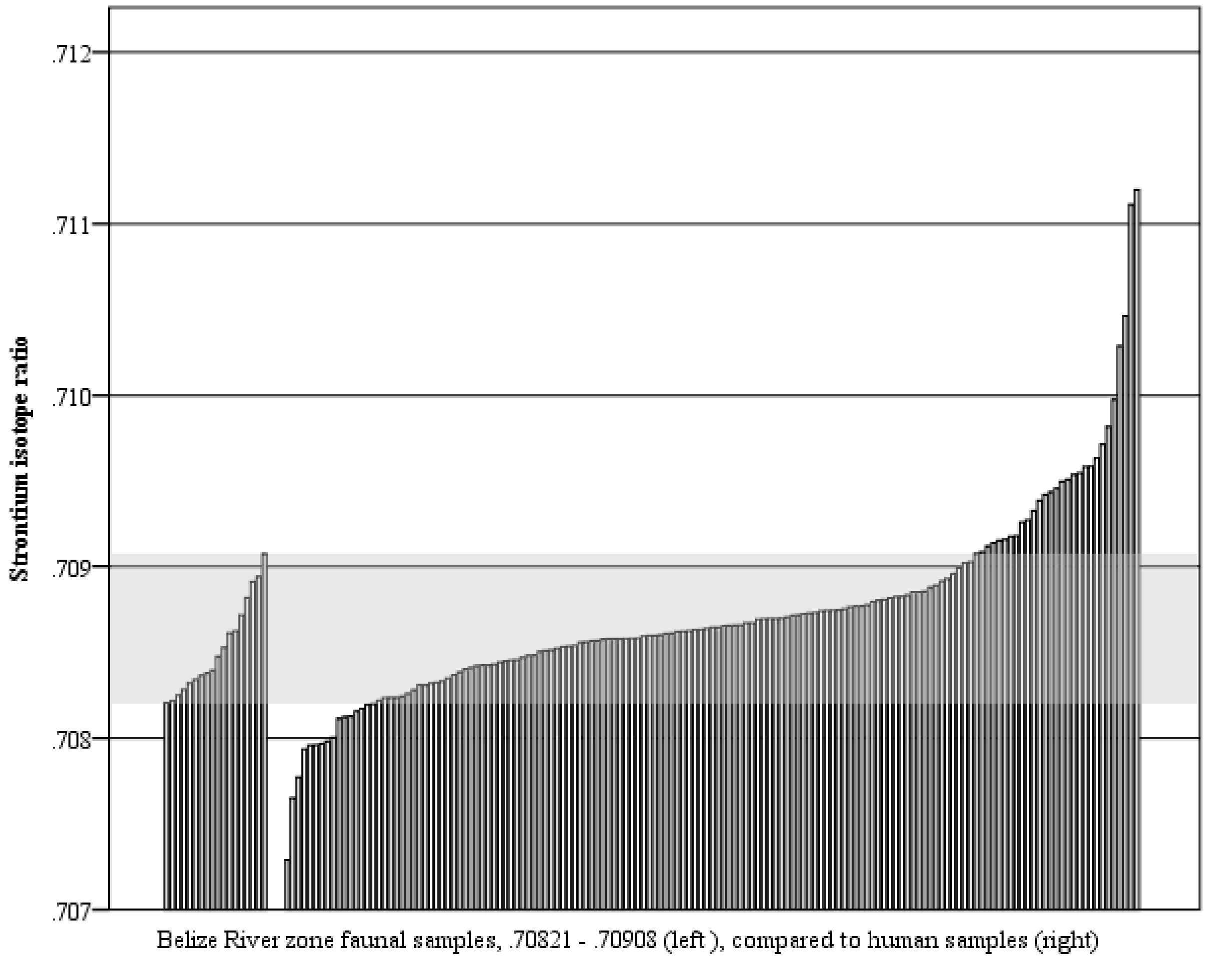

Figure 5.2. Belize River Valley human strontium isotope values bar graph: Shaded area represents faunal values identified along the Belize River (.70821 - .70908).

Figure 5.2 shows the values of the human population: most values increase from ~.7082 to ~.7090, forming a gradient with no marked breaks. It is clear that the gradient of human values extends slightly higher and lower than the range of baseline fauna, suggesting that it reflects most – but not all – of the biologically available strontium values in the strontium zone.

However, clear breaks are visible at .7082 and .7091, suggesting that the non-human values reflect the range of biologically available strontium and are a good predictor for local human values. Multiple clusters are visible with both high and low non-local values.

In the Belize River zone (that is, excluding Chaa Creek), 115 values (83.9%) fall within two standard deviations of the mean. This includes individuals with strontium values identified in other zones. This includes five high marginal values and eight low ones. A number of these clearly suggest in-migration from either the Macal River zone or the Central Lowlands; however, other values likely represent isotopic variability within the strontium zone. If these marginal values represent population movement, 77.4% of the sample population has local values. That is, 16 - 24% of the burial population analyzed in this study was not born in the Belize River zone.

Twelve samples from Chaa Creek show similar trends. Three values are lower than the Macal River zone strontium baseline values, and one is higher. This results in an estimate of 33% non-local individuals at Chaa Creek, which must be considered in light of two key points. First, the burials of three individuals in this sample population predate the Classic period, a larger percentage in this subsample than for the sample population of the valley as a whole. Second, none of the values fall outside of two standard deviations of the mean. While these individuals are quantified as marginal values according to the definition given in Chapter 4, use of the two standard deviations of the mean as a cut-off clearly is an overly conservative measure that grossly underestimates population movement in this study.

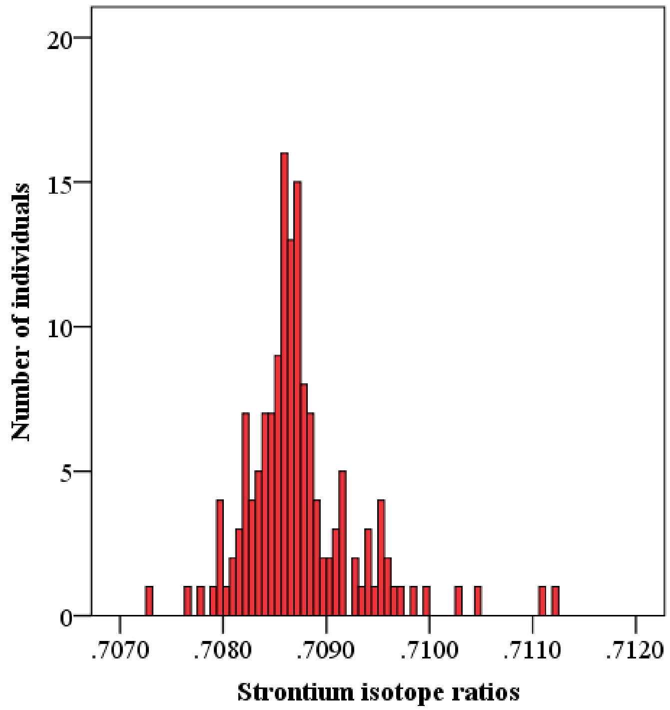

Figure 5.3. Belize River Valley strontium isotope values histogram.

These combined results show an estimate of 15 – 26% population movement in the sample. The marginal values can be better understood in Figure 5.3, which shows several trends in the Belize Valley sample population. First, it forms two groups with outlier values on both ends. This reflects the Belize River and Macal River strontium isotope zones, where distinct average values are identified (.709 - .710 $^{87}Sr/^{86}Sr$). Second, the data are not normally distributed: each end of the curve has a cluster of values. There are a combination of outlier values (two standard deviations from the mean) and marginal ones that form populations distinct from those in the Belize River zone.

The scale of the data also shows that most of the marginal values likely represent non-local individuals. Migration in most studies is identified using isotopic differences of 0.001, which is a conservative measure that fits well with geologic differences that vary between .707

and .709 in the study area. Isotopic differences on this scale also should represent human population movement in this region, which is supported by a comparison of use of the faunal baseline mean and range. Figure 5.4 shows that samples within two standard deviations of the mean include clusters on both tails that likely represent different populations. These are not visible in Figure 5.5, which includes only human values within the range of the faunal baseline. This is a more normally distributed dataset, but likely excludes some local values.

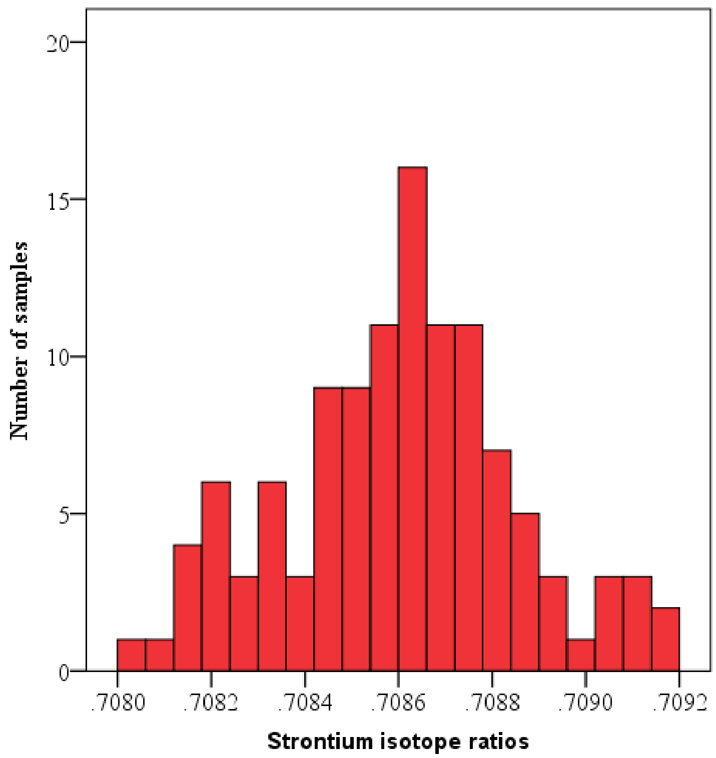

Figure 5.4. Belize River zone strontium isotope values statistical view: Belize River zone values include all sites but Chaa Creek. All samples within two standard deviations from the mean are displayed.

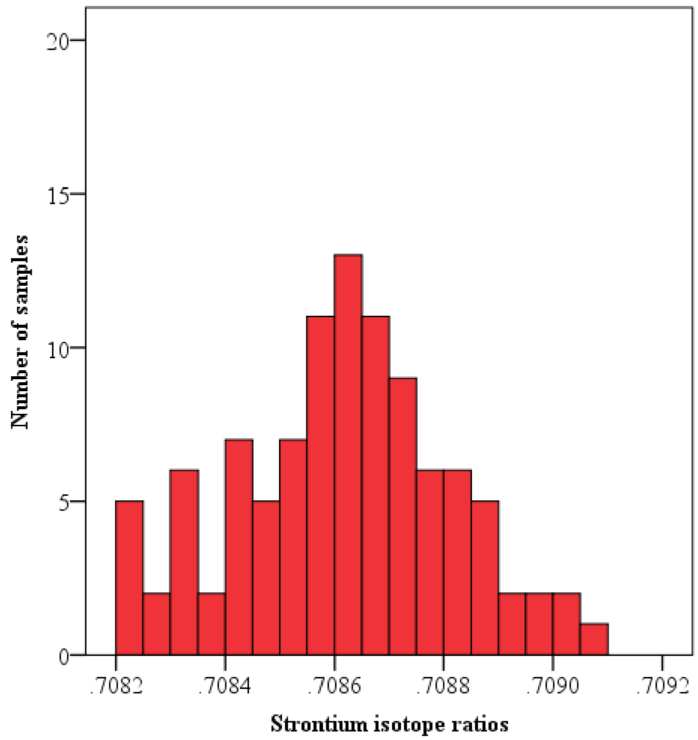

Figure 5.5. Belize River zone strontium isotope values baseline range view: Distribution of Belize River zone values at all sites but Chaa Creek. All samples with values within the faunal baseline range are displayed.

Mean and median values do not significantly differ, but the range and standard deviation are reduced when the marginal values are excluded (Table 5.1).

Table 5.1. Comparison of Belize River zone human values by mean and range of baseline values.

	Mean	s.d.	Median	Range	Values in range
102 samples (within faunal baseline range)	.708615	.000196	.708625	.00086	.70822 - .70908
115 samples **(**within 2 s.d. of the mean)	.708604	.000249	.708614	.00116	.70800 - .70916

Table 5.2 shows a comparison by site of the closest baseline samples and human values conservatively considered local (with the marginal values removed). On average, human values are .0001 higher than the baseline values. The result is similar when marginal values are included. The greatest difference between human and baseline values is found near Saturday

Creek, which is centrally located and has distinct, but variable, faunal baseline values that seem to be reflected in the human population.

Table 5.2. Comparison of human and faunal local values by site: A comparison of human and baseline $^{87}Sr/^{86}Sr$ values without marginal or non-local values. Chaa Creek values from the Macal River zone also match the mean of the faunal baseline

Site	Baseline mean	Human mean	# samples
Xunantunich	.70861 ± .0001	.70862 ± .0003	10
San Lorenzo	.70861 ± .0001	n/a	n/a
Buenavista	.70837 ± .0002	.70847 ± .0001	6
Cahal Pech	.70838 ± .0001	.70865 ± .0002	19
Zubin	.70838 ± .0001	.70860 ± .0001	7
Esperanza	.70841 ± .0001	n/a	n/a
Baking Pot	.70841 ± .0001	.70866 ± .0002	22
Floral Park	.70844 ± .0001	.70853 ± .00008	2
Barton Ramie	.70844 ± .0001	.70862 ± .0002	17
Blackman Eddy	.70843 ± .0001	.70856 ± .00007	3
Pook's Hill	.70844 ± .0001	.70845 ± .0002	8
Saturday Creek	.70895 ± .0002	.70869 ± .0002	7
Chaa Creek*	.70999 ± .0009	.70950 ± .0003	8

Human values are generally more variable than the modern fauna sampled near the sites. Isotopic variability in the local population can stem from heterogeneous geology, imported foods or food additives used to prepare them, and selective use of the local catchment by different households (Price et al. 2008:171). The slightly elevated human $^{87}Sr/^{86}Sr$ average value might be explained by imported foods (Wright 2005b), movement within the valley, or a combination of factors. Heterogeneous geology also is important, and results in substantial variability within the Macal River and Maya Mountain strontium zones.

The Macal River strontium zone is represented by a small number of baseline samples and only one archaeological site, but individuals buried at Chaa Creek reflect the baseline values collected nearby (Table 5.2). Three modern samples have an average value of .710: the two samples collected at site have an average value of .70967, which is similar to the average local human value. Many of the individuals in the Belize Valley strontium zone have isotopic signatures similar to those found along the Macal River. It is not currently known which other sites or settlements may have these values, and is possible that they also are found elsewhere along the northern edge of the Maya Mountains and Mountain Pine Ridge.

Variability within the sample population at each site can be explored further using the IQR, relying on the median value for datasets which are generally not normally distributed. This statistic is not used to identify migration, but to discuss differences within the population.

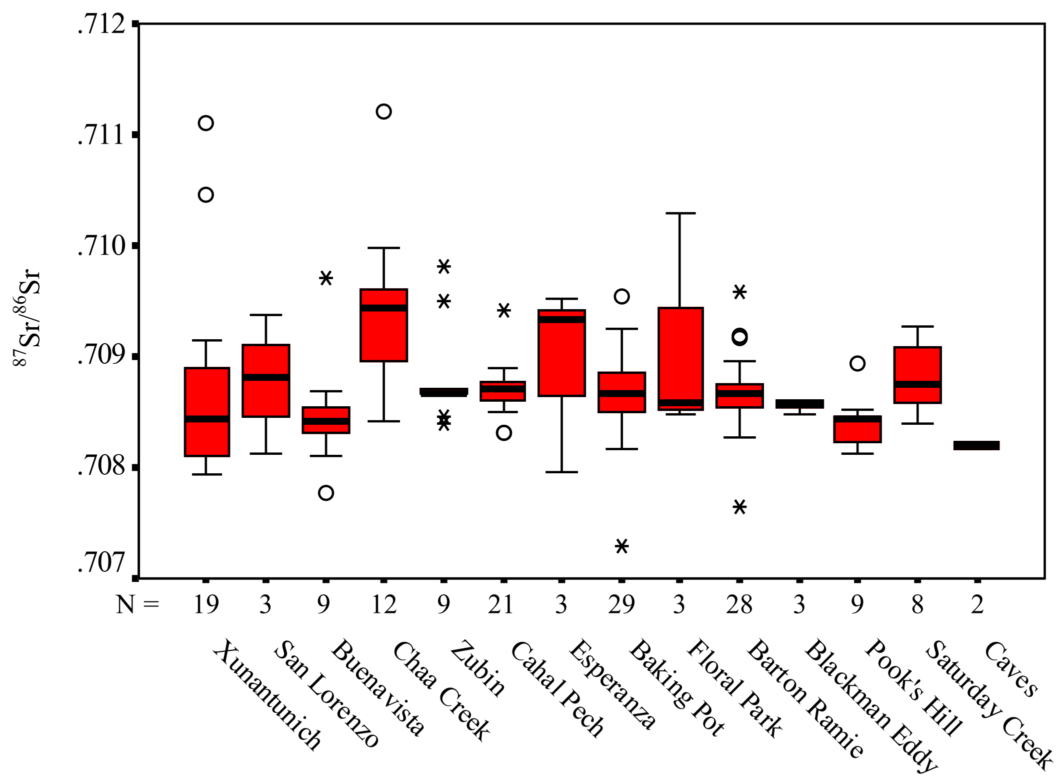

Figure 5.6. Belize Valley strontium isotope values by site: Distribution of $^{87}Sr/^{86}Sr$ values at each site showing the median value (line), interquartile range IQR (box), the highest and lowest values that are not outliers (whiskers), and outlier and extreme values. One individual was sampled twice, so the number of individuals is 28 at Baking Pot.

Most sites have a number of values that are outliers from IQR (Figure 5.6). Comparison of the outliers with the faunal baseline ($^{87}Sr/^{86}Sr$ .70821 to .70908) shows two trends. First, some outlier values are the result of small or tightly clustered datasets. For example, the two low human values at Zubin are well within the range of baseline values identified in the region. The opposite effect is visible in the Xunantunich sample. Values higher and lower than those found along the Belize River are not outliers as a result of the distribution of the data.

Second, some of the marginal values are statistical outliers and some are not. These values could represent isotopic variability not yet identified in the valley, relocation from an area with slightly different values while the tooth enamel was forming, thus causing a small shift in the expected strontium isotope value. An evaluation of burial context, location, and other isotopic information in this and subsequent chapters suggests that both scenarios occurred.

There are 22 individuals who may be considered migrants, along with an additional 13 individuals with marginal values, resulting in a range of 15 - 26% in-migration in the sample burial population of the Belize River Valley. This is a larger estimate of migration than in most published studies (e.g., Wright and Bachand 2009; Price et al. 2008, 2010), but the isotopic variability within the region allows a substantially higher number of non-local individuals to be identified. This estimate of population movement is almost certainly still too low. Individuals moving between areas with similar strontium isotope values - nearly all movement within the region - are not visible isotopically.

Individuals with non-local strontium isotope values are identified at all sites but Blackman Eddy, where the sample consists only of three individuals. However, all other small samples include one or more non-local or marginal values. At least six sites had in-migration from two or more different strontium zones. This includes major and minor centers, as well as small settlements, and includes the smallest samples (Esperanza n=3) as well as larger ones (Baking Pot n=29). Marginal values were identified at six sites distributed across the valley.

Each of the burials and individuals in the analysis is discussed in the next section, which is organized by site. After a short background, the results are discussed in the context of isotopic variability near the site and the burial location and context of the sample population. Each site shows a different aspect of population movement in the Belize River Valley. Yet together they paint a broader picture of migration in the region. Most population movement occurred over short distances, with distinct patterns visible at each site that in some cases, corresponds remarkably well to its historic background. Finally, population movement is visible in every type of site and burial context and seems to crosscut all sectors of the population.

C. The Belize River Valley: site by site analysis of strontium isotope values

1. Xunantunich

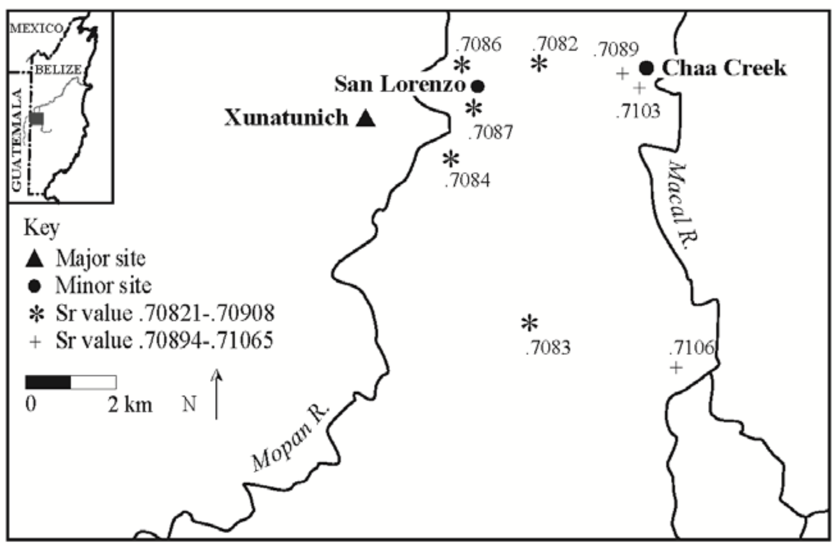

Figure 5.7. Xunantunich and strontium isotope values.

Xunantunich was a major center located in the westernmost extent of the Belize Valley region (Figure 5.7). It is situated on a hilltop overlooking the Mopan River. While some evidence for Preclassic occupation has been identified (LeCount et al. 2002), rapid growth began after AD 600 with a massive building campaign that resulted in the construction of much of the site's central architecture (Yaeger 2010). This is attributed in part to close ties to the kingdom of Naranjo (see

Chapter 2), which is inferred through both architecture and epigraphy (Ashmore 2010; Helmke et al. 2006; Helmke and Awe in press).

The close relationship with the kingdom of Naranjo may even have included the installation of rulers at the site (LeCount and Yaeger 2010). However, by AD 780 multiple lines of evidence support increasing autonomy and significant sociopolitical change. This includes the termination of important structures at the site, like the royal palace Str. A-11. It also is signaled by use of an emblem glyph and erection of public stelae and altars in the site core of Xunantunich. As at many other sites in the valley, the Terminal Classic period saw the end of major use of the center.

Table 5.3. Xunantunich strontium isotope values and burial information: Information on sex and age from Adams (1998), Boada in Braswell (1998), and Piehl (personal communication 2010).

Burial	$^{87}Sr/^{86}Sr$	Sex	Age in yrs	Burial context and information	Date
Str. A-11 Op. 302 B1	.70797	M	Yad 20-23	Burial context: other Flexed body position, head to the north	Late Classic II
Str. A-4 B1 skull 4	.70794	I	Child 10-12	Burial context: other Complete skeleton	Late Classic
Str. A-4 B1 head 1	.70796	I	Adult?	Burial context: other Skull only (may include cervical vertebra)	Late Classic
Str. A-4 B1 mandible D	.70798	F	Ao 16-18	Burial context: other At least partially articulated and flexed	Late Classic
Str. A-4 mandible B	.70843	I	Adult	Burial context: other Skull only	Late Classic
Str. A-4 B1 mandible A	.70914	I	Adult	Burial context: other Skull only	Late Classic
Str. A-4 B1 cist	.70872	I	Mad?	Burial context: ruler Extended, supine position with the head oriented to the south	Late Classic I
Str. A-4 B1 extension	.70842	M?	A?	Burial context: other Flexed, head oriented to the south	Late Classic
Str. A-32 Op. 247 B1	.70800	M?	A	Burial context: other Semi-flexed, body positioned on its side, head to the west and facing up	Late Classic?
Str. A17 Op. 141C B1	.70858	I	C 6-10	Burial context: other Not known	Late Classic?
Group B Op. 211K B1	.70819	F	A	Burial context: residential Semi-flexed, body positioned on its side, head to the south and facing east	Late Classic II?

Str. D-6 Op. 74R B1	.70865	I	A	Burial context: burial shrine Extended, supine position, legs possibly flexed, head to the south	Late Classic
Str. D-6 Op. 74JJ B1	.70899	M	Y-Mad 30-40	Burial context: burial shrine Extended, prone position with the head oriented to the south	Late Classic
Str. D-7 Op. 22F -B1	.70882	I	2-4	Burial context: residential Flexed, body positioned on its right side, with the head oriented to the north and likely facing east	Late Classic II
Group D Op. 21B B1	.70837	I	A	Burial context: residential Not known	Terminal Classic
Group D Op. 21C B1 Ind. #1	.70903	M	Yad 25-29	Burial context: residential Extended, prone position, head to the west	Terminal Classic?
Group D Op. 21C B1 Ind. #2	.71046	M	Oad >50	Burial context: residential Extended (?), supine position, head to the east	Terminal Classic?
Group D Op. 21D B1	.71111	M?	Mad >35	Burial context: residential Extended, supine position, head to the west	Terminal Classic?
Group D Op. 5J B1	.70822	I	C 7-8	Burial context: residential Not known	Late Classic

The sample population comes from diverse contexts, including both residential group burials and non-residential contexts (Table 5.3). This includes an individual interred in one of the ballcourts and several burials associated with termination deposits (Adams 1998; Braswell 1998, 1995; Yaeger 2000; Yaeger 2005). The diverse, non-residential contexts may explain why more individuals with non-local origins are identified at Xunantunich than any other major center. This includes interregional migration and relocation from multiple strontium zones.

1a. Identifying origin: analysis of the strontium isotope values

Three baseline samples found within 2 km of Xunantunich show the expected range of local values for the human population. These range from .70847 to .70872 (average value .70861 ± .0001 ^{87}Sr/^{87}Sr). Only three of the humans in the sample fall within this range, and just half are within the range of baseline values sampled in the Belize River region (Figure 5.8). Nine individuals - 47% of the sample population - have values higher or lower than Belize River zone values. Six of these have values > 2 standard deviations of the mean, but all likely have non-local origins, which results in an estimate of nearly 50% in-migration in this burial population.

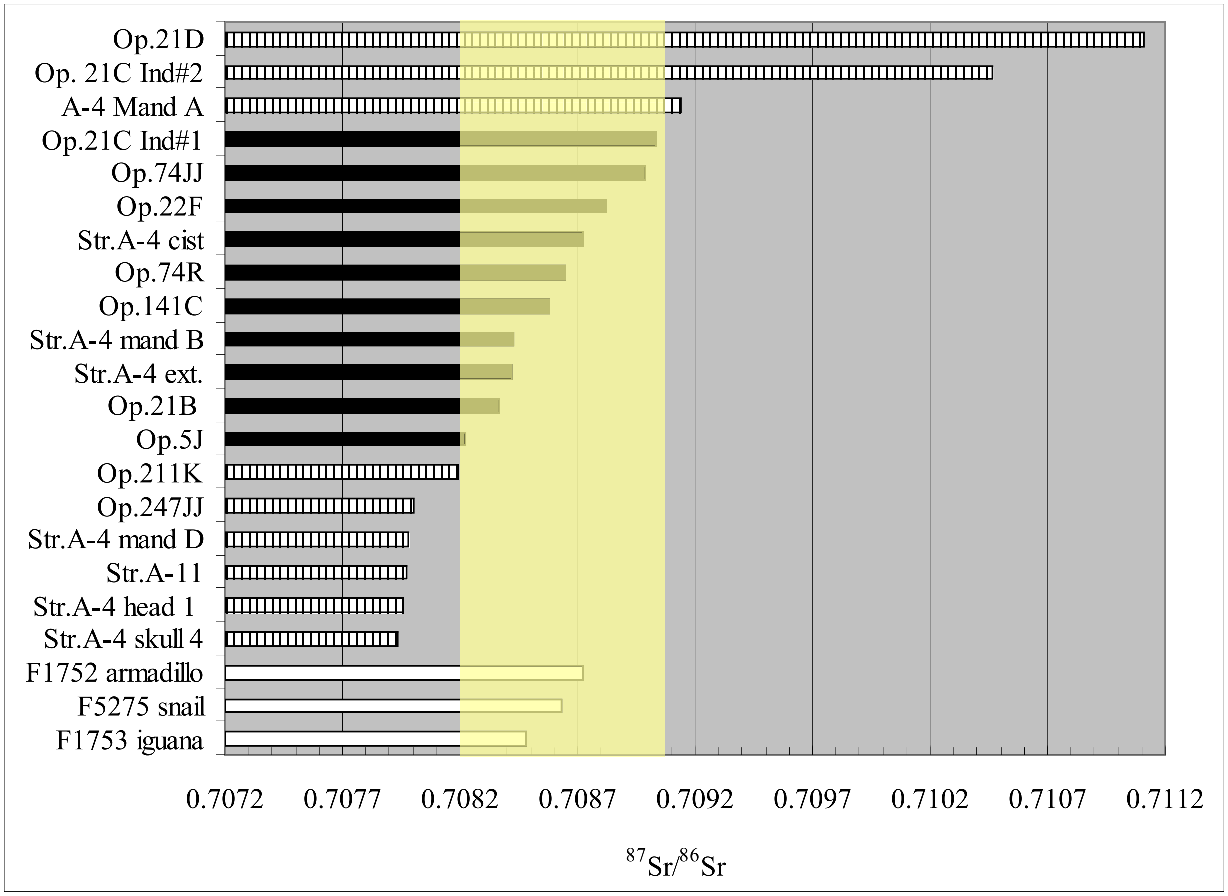

Figure 5.8. Xunantunich strontium isotope values bar graph: White bars represent $^{87}Sr/^{86}Sr$ baseline values and the shaded area represents the range of values identified along the Belize River. Black bars represent each individual in the study (including marginal values): striped bars are individuals with isotope values not found near the site.

There are several clusters, also illustrated in Figure 5.9 (next page). Three individuals have high values, one exceeding .711 that suggests an origin in the Maya Mountains, and two with values between .709 and .710 that are similar to those identified in the Macal River zone. One of these, Str. A-4 mandible A, is a marginal value, one that is within two standard deviations of the faunal mean but is higher than the range of baseline fauna.

Five individuals have values ≤ .7080, which suggest an origin in the Central Lowlands. Five baseline samples collected near Tikal have an average value of .70791 ± .0016, and similar values are identified near El Pilar less than 20 km away from Xunantunich (Hodell et al. 2004). One of these is a marginal value (.7080), but clearly clusters with the Central Lowlands values and not those of the Belize River zone. All are found in atypical burials.

It is more difficult to interpret the third marginal value, Group B Op. 211K (.70819). This could represent variability in strontium isotope values along the Belize River that has not yet been identified, or migration. The burial context described in the following section supports a local origin. However, oxygen and carbon isotope values (Chapter 6) support a non-local origin for both low marginal values.

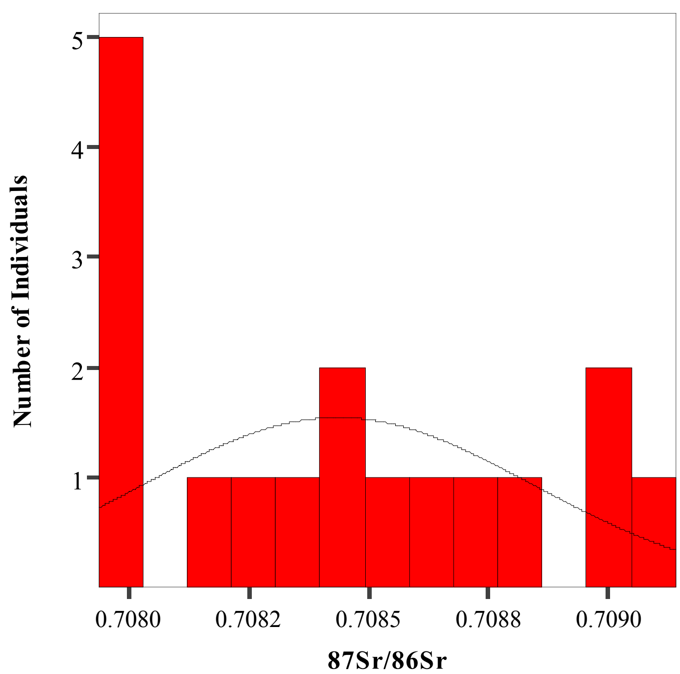

Figure 5.9. Xunantunich strontium isotope values histogram: Three clusters of strontium isotope values are visible in the Xunantunich sample.

Eleven individuals have values that form a regularly distributed dataset (.70819 to .70903) that mirrors baseline values identified along the Belize and Mopan Rivers (.70821 to

.70908). If the marginal values are excluded, the mean of human values within the range of the Belize River baseline is .70862 ± .0003.

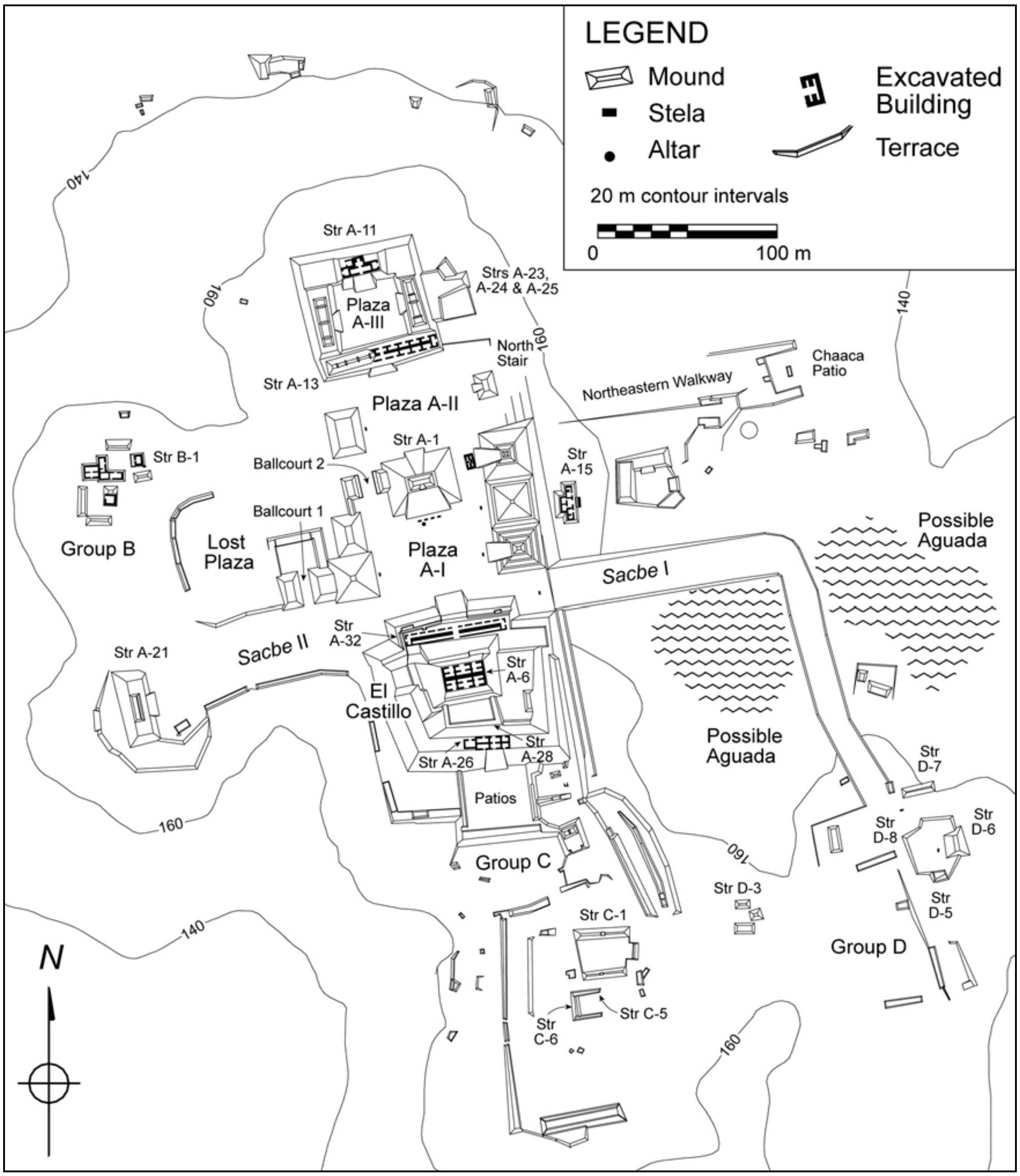

Figure 5.10. Site map of Xunantunich: Map copyright by Angela Keller and Jason Yaeger.

1b. Burial contexts and population movement

Residential burials

Nine individuals buried in two elite residential groups are included in the sample and have variable strontium isotope values. Both households were associated with the ruling elite of Xunantunich, but few wealth objects are associated with either residential group. Group B is located 100 m west of the royal palace complex, and Group D is the approximately the same distance from the Castillo and is connected to the site center by Sacbe I (Figure 5.10).

Group D residential group burials

Eleven burials were excavated in Group D, a patio cluster of 13 structures and two chultunes that likely was the residence for four noble households during the Late and Terminal Classic (Braswell 1998). Braswell suggests that these households were subordinate to the ruling lineage, probably due to ancestral relations rather than power based on administrative or economic functions. Groups with shared kinship ties may also share migration patterns, but the difference in burial contexts is the most likely explanation for the dissimilarity in migration patterns in Groups A, B, and D at Xunantunich. While interregional population movement is visible in Group A and Group B burials, the higher values at Group D suggest in-migration from the Macal River and Maya Mountains strontium zones.

Str. D-6 is the eastern building in a plazuela group and has ceramic evidence for both ritual and domestic use (Braswell 1998). Two of the individuals buried near Str. D-6 have Belize River strontium zone values, though the higher value also is found near the Macal River less than 6 km away. The variability in these values suggests some difference in childhood food sources. Both individuals were oriented to the south and had a small number of burial goods.

The lowest crypt was placed in the floor of a platform near the front staircase. Op. 74JJ was interred in an extended, prone position, and grave goods included a pair of ear flares made of jade and shell and an obsidian eccentric. Two other individuals were buried in front of the building. One was not sampled, and the other was not excavated because the burial was located under a fallen stela (Braswell 1998). A fourth individual, Op. 74R, was buried on top of collapsed facing stones in front of the southern stairs (Braswell 1998:720). A small circlet of shell was identified near the cranium.

Similar variability in strontium isotope values is identified in values of an infant buried in Str. D-7 and a child interred in the quarry. Op. 22F was found in ceramic refuse under a floor near a Str. D-7 staircase and has a high Belize River zone value, despite the orientation of the head to the north instead of the south. In contrast, the Op. 5J child, whose burial context is not known (Adams 1998; Braswell 1998), has a low Belize River zone value. The isotopic variability could stem from either movement within the Belize River zone area, or variability in food sources for the families using this structure to bury their dead.

One of two chultunes was excavated, and contained the remains of five individuals, four of whom were sampled. It is located just west of Str. D-6 and contains one chamber with five niches, each of which contained one or more individuals (Adams 1998; Braswell 1998). Both individuals in the east and west niches were oriented to the south, but only the adult in Op. 21B has a Belize River zone value. Op. 21D, a male placed in an extended, supine position with no prepared grave or burial goods, has a Maya Mountain zone value.

Two adult males in Burial Op. 21C were interred at the same time, but have different isotope values. Individual #2 was a gracile young adult buried in a supine, extended position with his head oriented to the east (Adams 1998). His $^{87}Sr/^{8}Sr$ value is similar to those identified along the Macal River. He had a turtle carapace near his pelvis with a hole drilled in it, but the shell more likely originally rested on his chest.

While the skeletons remained largely in anatomical position, the drawing (Braswell 1998) shows substantial post-depositional movement of bones. The tibia and femur of Individual #2 lay 20 cm apart, and the femur was situated more than 30 cm from the innominate. However, the trunk remained largely intact, with ribs articulating with the spine (Braswell 1998). Braswell states that the chultun was carefully filled with a layer of specially prepared white limestone matrix within a group of stones that formed a cist. The presence of rodent tunnels near the Op. 21D burial, and the complete skeleton of a *tusa*, or pocket gopher, might explain some displacement of bones.

Individual #1 was a robust old-age adult male interred with his head to the west in a prone, extended position, and a high Belize River zone value. He lay directly on top of individual #2, with his upper legs above the cranium (Braswell 1998). The orientation of both individuals differs from the norm for the Belize River Valley, which includes Chaa Creek in the Macal River strontium zone. The layout of the niche, which is an east-west oblong space just over two meters in length, may account for the orientation of the interments.

Group B residential group burial

The only burial excavated in Group B was that of a female interred in the northeast corner of the north patio above the plaza floor (Etheridge 1995, n.d.). At least two other skulls were identified nearby, and skeletal elements were found in adjacent units, including an edentulous mandible that may have been female. Remains of a second adult individual were mixed in with this burial (Adams 1998).

The second individual has a marginal $^{87}Sr/^{86}Sr$ value that is lower than the baseline values collected along the Belize and Mopan Rivers. The southern burial orientation supports the interpretation of this individual as local to Xunantunich. The body was on its side, facing east, with legs flexed at the knees (Etheridge 1997).

Group A non-residential burials

The remainder of the burials sampled at Xunantunich come from diverse contexts and contain individuals with origins that differ from than those buried in the Group D residential group. Ten individuals in six burials include strontium isotope values from three different zones. Four individuals have Belize River strontium zone values, including a child buried in the center of ballcourt 2 and three individuals interred in temple Str. A-4.

Group A Str. A-11 palace burial

Figure 5.11. Xunantunich Op. 302 Str. A-11 burial: photo copyright by Jason Yaeger

Str. A-11 is located at the north end of the site core and is interpreted as the royal residence and court during the Late Classic (MacKie 1985; Yaeger 1998, 2005). Op. 302G Burial 1 is not a typical residential burial, and the individual has a Central Lowland strontium isotope value. The gracile remains of a young adult male were placed on the floor of the east central room with no burial goods or prepared grave (Figure 5.11). The interment likely forms part of the ritual surrounding termination of the room's use, which may reflect a dramatic political change or even replacement of the ruling family (Yaeger 2005, 2010). Four of the five lower rooms were dismantled and filled in with marl and limestone, and the doorways bricked shut. Utilitarian vessels lay broken in the floors of the central and eastern rooms, and deep gashes in interior walls evince intentional removal of facing stones and blocks. These activities occurred in stages, with changes to upper room access, closure of all but the central lower room, remodeling of the frontal terrace, and finally, abandonment of the structure, all likely part of the contraction of the site at the end of the Late Classic (Yaeger 2005).

Several aspects of the burial differ from Belize Valley norms (Schwake 2008; Willey et al. 1965). His head was oriented to the north, and his body placed parallel to the western wall of the room. The skeleton was almost completely articulated, with some post-depositional movement of a small number of elements (e.g., small hand and foot bones). While his lumbar vertebrae remained articulated, the position of the lower body was rotated such that the pelvis and lower legs were in a supine position. His legs were flexed, but not in a typical burial position. His right femur crossed over his body at a 45 degree angle, almost touching his flexed lower right arm. The upper and lower leg remained in anatomical position: however, the femur was rotated 180 degrees so that the inferior surface faced upward. This slight shift likely occurred as the body decomposed. The right lower leg lay parallel to the body. The left femur was positioned at a 135 degree angle, and the left lower leg was flexed perpendicular to the body. The raised elevation of the lower left leg above the right leg and pelvis shows that the floor surface was uneven, perhaps due to the dismantling of the room.

It is unlikely that this position was the result of any post-depositional movement of the body, aside from the rotation of the right femur, as the excellent preservation of the bones and other contextual factors suggest that the room was filled in when the body was deposited. This may also explain the position of the right foot, which is reversed at the ankle, a possible result of the boulder shown in the photo. The body position and orientation differ significantly from the typical burial treatment observed at sites across the valley.

The cranium shows also shows tabular oblique deformation, which is less common in the region than elsewhere in the Maya Lowlands (Vera Tiesler personal communication 2009). More than 80% of the burials studied in the Usumacinta Valley have an oblique head shape, which also is common in the central and eastern Petén and the eastern Chiapanec Highlands. Carbon and oxygen isotope values of this individual (discussed in Chapter 6) also suggest a non-local origin and fit those identified in the central Petén.

Unfortunately, isotopic assays offer limited utility in interpreting burial contexts or the type of migration they represent. There is an association between cranium or skull-only burials, sacrificial contexts, and non-local strontium isotope values (Tiesler et al. 2010). This individual may have been sacrificed as part of the termination event, but no perimortem damage or cut marks were observed on the bones. Since only tooth enamel was sampled, the length of time the individual spent in the Belize Valley is not known. The individual may have been captured from a Central Lowlands zone center or may have resided at Xunantunich for years.

The death of the young male occurred during a perceived shift in political power, at both the regional level with Naranjo's defeat by Tikal in AD 744, and at Xunantunich with the abandonment of the palace and shift in locus of ritual activities at the site (Yaeger 2005). Four other individuals with similar strontium values are interred in a comparable context. The next section describes three interments in Str. A-4, and a fourth in Str. A-32.

Group A Str. A-4 burials

Str. A-4 is interpreted as a temple shrine located on the east side of the plaza and contained multiple burials: individuals from three burials were sampled. The first is a cist in one of two platforms abutting the structure burial that contained polychrome vessels, jade, and obsidian, some of which were coated with cinnabar. This is the most elaborate burial identified to date at Xunantunich (Audet 2006) and belonged to a ruler interred during the early part of the Late Classic. The second is a burial in one of two platforms abutting the structure. It was located above bedrock with no formally prepared grave, but with a small vessel interpreted as a funerary object (Audet 2006:135). Individuals in both interments were oriented to the south and have Belize River zone $^{87}Sr/^{86}Sr$ values.

The third burial context is more complex (Figure 5.12). Five individuals were interred in a floor deposit in the center of the summit of Str. A-4, approximately 1.2 m above the cist. A rich array of Terminal Classic artifacts were found on top of the floor, including seven complete vessels and a large stucco fragment near the back wall. The burial was found in a 60 cm x 70 cm unsealed hole placed in front of the stucco fragment (Audet 2006; Awe 2008). It contained the complete remains of a child and an adolescent female, the skulls of two individuals, and the cranium of a third. This assessment differs from Audet (2006:138-141) and is based on a re-analysis of the remains as part of this study in conjunction with Piehl (personal communication 2010).

Figure 5.12. Xunantunich Str. A-4 Burial 1: Photo from Audet 2006:139.

The adolescent female (mandible D, skull 2) and the 10-yr old child (skull 4), and an individual referred to as head 1, each have Central Lowland zone values similar to the young male in Str. A-11. Another skull-only interment (mandible B) is of an individual with a Belize

River zone value, while the value of the individuals designated mandible A is similar to those identified along the Macal River. No grave goods were associated with the human remains.

The position of the individuals is not clear, but photographs of the deposit show three crania in the uppermost level, with at least partial articulation of lower limb elements for the adolescent individual. The distal femur and proximal tibia are situated in a flexed, vertical position adjacent to a cranium. The position of at least three other long bones is horizontal, placed underneath two other crania. Piehl (personal communication 2010) suggests that mismatched labels of the limbs suggest that the remains of the juveniles were close together. A third cervical vertebra likely belonged to one of these individuals, and according to notation included with the bones, this was head 1.

No other perimortem damage or cut marks were visible, but bone surfaces are poorly preserved. Cut marks are identified on human remains at Xunantunich, but were observed on isolated human remains in a Group B deposit that contained well-preserved bone and artifacts. Nor is this burial the only one with bones missing or added. Mackie (1985:75-77) describes a burial in Str. A-15 where skulls were missing from the otherwise complete remains of an adult, and a child who was later added to the bench. Xunantunich Altar 1 also marks the exhumation of a specific individual (Helmke et al. 2010), a type of post-mortem relocation of human remains also described at Tikal (Harrison 1997).

Another burial in the site center contains an individual with a Central Lowland zone strontium isotope value. While this value falls within two standard deviations of the mean of baseline faunal values, it is clearly outside the range of baseline fauna, instead forming part of the Central Lowland cluster of isotope values. The burial is located in Str. A-32, a range structure *audiencia* building located on a terrace partway up the front of the Castillo. Like the termination events at palace Str. A-11 and temple Str. A-4, modifications to Str. A-32 evidenced dramatic social transformations (Clancy 1998). As part of one of these reconstruction episodes, the individual was placed against the medial wall in the back gallery in a simple pit with no burial goods (Clancy 1998). Like the Str. A-11 male, this probable male (Adams 1998) was buried in an atypical position, oriented to the west instead of the south. Architectural constraints may have been a factor in the burial position and orientation not only for this burial, but for others in the study as well.

1c. Xunantunich summary

Nearly 50% of the sample population has strontium isotope values that are not found near the site. While a number of these are marginal values, burial patterns and a distinct childhood diet (also see Chapter 7) support a non-local origin for these individuals. Non-local individuals may have come from three distinct regions, including the Central Lowlands, the Maya Mountains, and the Macal River zone. However, each of the values has been identified within a day's walk of Xunantunich, though in two of the three cases, values may also represent longer distance migration.

Individuals with different origins were interred together in diverse burial contexts, from interments in residential groups to temple deposits in the site core. However, differences in burial treatment may relate to an individual's origin. Individuals with Central Lowland zone isotope values were buried in atypical body positions and orientations that contrast with those identified for individuals with values found in the Belize Valley. This also likely relates to the type of burial included in the study. The single residential burial that contained an individual with a marginal value and a possible Central Lowland origin is interred in the typical Belize Valley pattern.

While non-local isotope measures have been associated with sacrificial burial contexts in a number of studies, they do not provide evidence in this study for a particular type of migration. However, individuals with Central Lowland zone strontium isotope values are associated with architectural evidence for dramatic political events tied to broader sociopolitical change at the polity. Strontium values are not site-specific, but provide further support for a close relationship between Xunantunich and Naranjo.

The Xunantunich sample provides evidence for interregional population movement, and ties Belize Valley polities to broader sociopolitical change in the Maya Lowlands. It also shows substantial population movement at a site with a relatively short settlement history. Less migration is identified at sites with longer occupation histories, like Cahal Pech and Baking Pot, which have distinct patterns of population movement. Each site in this study presents a snapshot of migration, that when combined, allow identification of population movement in the Belize Valley region of the Maya Lowlands.

2. San Lorenzo

San Lorenzo is a settlement cluster with 17 residential compounds and a number of non-residential complexes located along the Mopan River 1.5 km east of

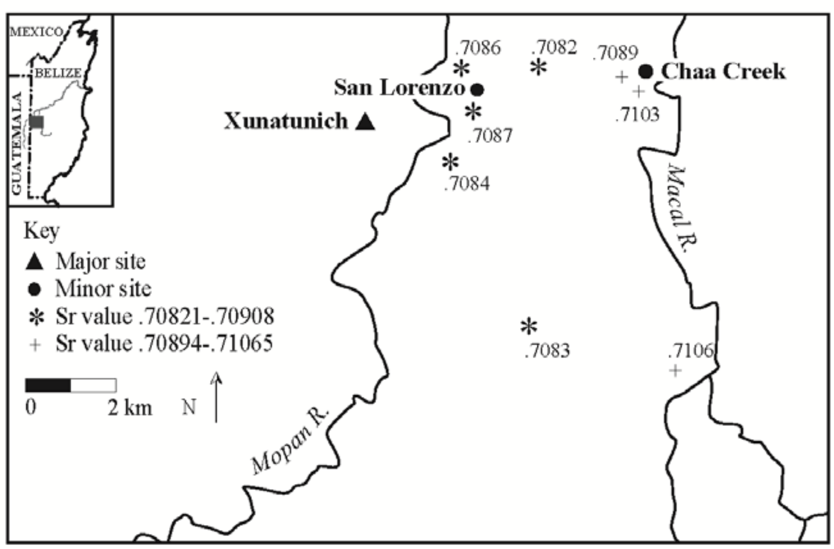

Figure 5.13. San Lorenzo and closest strontium isotope values.

Xunantunich (Figure 5.13). After limited Preclassic occupation similar to that noted at Xunantunich, the settlement grew rapidly after AD 600 and flourished until the Terminal Classic AD 800-900 (Yaeger 2003). San Lorenzo residents were closely connected to Xunantunich, so the extent to which they participated in the same local and interregional interaction spheres is one of the questions research on population movement can address.

Only three burials were excavated at San Lorenzo despite extensive excavations in seven mound groups and a program of test pits in additional mounds by Yaeger (2000) and Chase (1992). Two burials were located in SL-13, a non-residential complex, and one was located in household group SL-22, one of the larger and longest-occupied residences in the settlement (Yaeger 2000). In-migration from one – and possibly two – regions is identified in a small sample that shows a great deal of variability (Table 5.4).

Table 5.4. San Lorenzo strontium isotope values and burial information.

Burial	Sr	Sex	Age in yrs	Burial context and information	Date
Op. 71C B1	.70812	I	30-50	Burial context: residential Extended burial in supine position, head to the north, facing west	Late Classic I
Op. 243U B1	.70881	I	2-4	Burial context: other Partial skeleton; oriented to the south	Late Classic
Op. 243LL B1	.70938	F	35-45	Burial context: other Extended, prone position, head to the south and facing east	end of Late Classic I

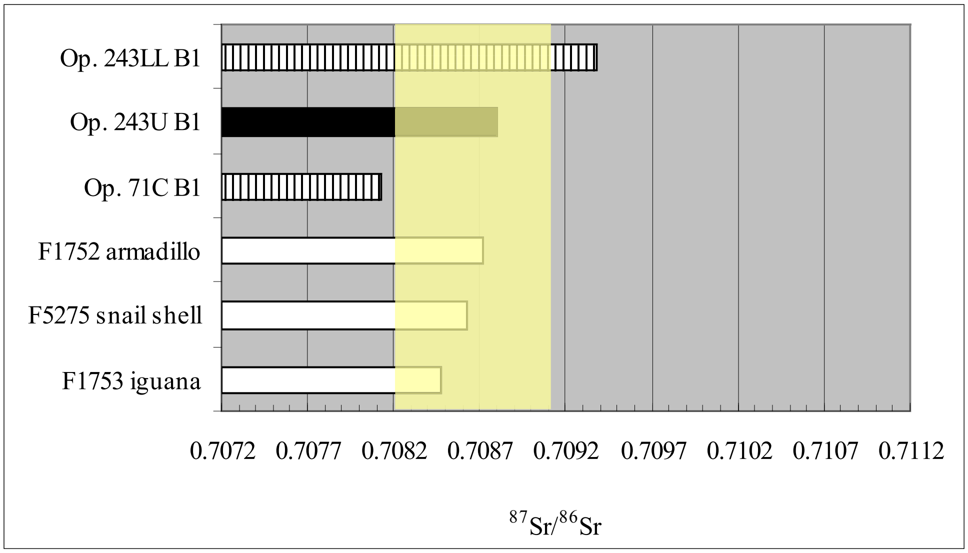

Figure 5.14. San Lorenzo strontium isotope values bar graph: White bars represent $^{87}Sr/^{86}Sr$ baseline values and the shaded area represents the range of values identified along the Belize River. Black bars represent each individual in the study (including marginal values): striped bars are individuals with isotope values not found near the site.

2a. Identifying origin: analysis of the strontium isotope values

Three baseline samples found within 2 km of San Lorenzo show the expected range of local values for the human population (.70847 - .70872) and the average value (.70861 ± .0001), which is the same as the Xunantunich population. Two of the three individuals sampled from San Lorenzo have values that lie outside the range of baseline samples collected along the Belize River (Figure 5.14). Moreover, they differ substantially from one another (Figure 5.15).

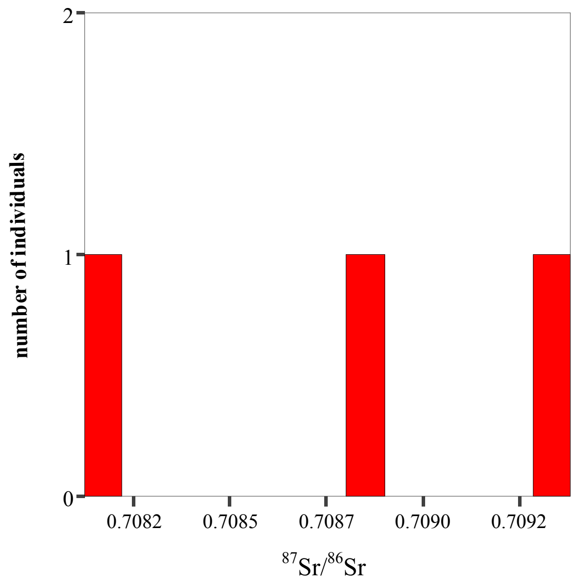

Figure 5.15. San Lorenzo strontium isotope values histogram.

The high value clearly fits within the range of human and baseline samples identified in the Macal River zone near the Mountain Pine Ridge. The low value is a marginal one, lower than baseline fauna but still within two standard deviations of the baseline mean. Depending on whether or not the origin of this individual is interpreted as local, 33.3% - 66.7% of the individuals in this small sample were not born in the San Lorenzo settlement.

2b. Burial context and population movement

Each of the three burials was found in structural fill with some grave preparation, but without grave goods. Two burials were found in SL-13, a non-residential complex which was the largest group and the only one identified with two patios (Yaeger 2000). This may have been the locale for extra-community ritual activities, as it was located adjacent to the San Lorenzo settlement but was not part of it. Yaeger (2003) suggests close ties to Xunantunich, whose rulers may have influenced or overseen construction of the complex, perhaps as a strategy to integrate communities within the polity.

One of the burials contained the remains of a child (Op. 243U) interred in the floor of the plaza north of (behind) SL-13 Str. 1. The child has a Belize River zone strontium isotope value. The individual was interred in sterile soil, and the burial pit was capped by several large stones. The partial skeleton consisted mainly of a cranium, so it was not possible to determine a body position or orientation (Yaeger 2000:345).

Another burial, Op. 243LL, was located in the south patio near a wall on the eastern edge of SL-13 Str. 6. The simple grave was intrusive to a series of refuse accumulations that preceded construction of the wall (Yaeger 2000). The $^{87}Sr/^{86}Sr$ value of the female indicates an origin in the Macal River zone.

The individual in the only residential burial, Op. 71C, was interred early in the Late Classic when the site was initially re-settled. The strontium isotope value is slightly lower than those identified in the Belize River zone. Values decrease over a short distance to the east (Hodell et al. 2004), so it suggests an origin in the Central Lowlands. A non-local origin is supported by a supine body position, with the head oriented to the north and facing west (Chase 1992). Burials with Central Lowland range $^{87}Sr/^{86}Sr$ values at Xunantunich Group A also have atypical burial orientations and body positions.

2c. San Lorenzo summary

It is difficult to identify patterns in this small sample, especially given the lack of similarity in burial location, position, and isotope values. Between 33.3% - 66.7% of the individuals in this small sample were not born in the San Lorenzo settlement. However, it appears that San Lorenzo migration patterns mirror those of Xunantunich, where significant in-migration included individuals from multiple regions. This shows similar interaction spheres for the major center and nearby hinterland settlement with in-migration from the Macal River region and the Central Lowlands.

3. Chaa Creek

Chaa Creek is a settlement zone that consists of 62 sites, including three minor centers, located on locally prominent ridges between fertile agricultural land and the Macal River (Figure 5.16). The settlement is located 6 km east of Xunantunich and 5 km south of Cahal Pech (Connell 2003).

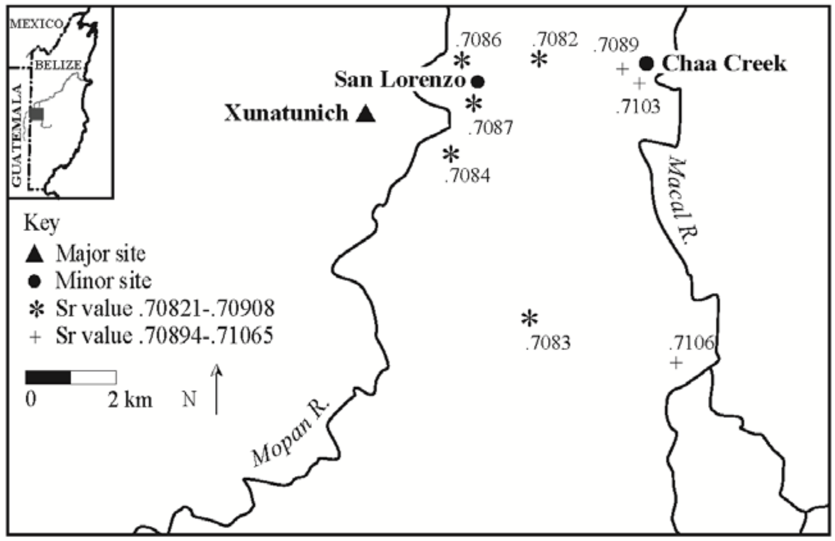

Figure 5.16. Chaa Creek and closest strontium isotope values.

Settlement patterns during the Late and Terminal Classic mirror those of Xunantunich, and a close relationship is proposed between residents of Chaa Creek and Xunantunich (Connell 2003). However, some burial goods show influence from Caracol, and the site's location near the borders between major centers suggests relationships with other polities as well.

The 12 individuals in this study were buried in two of the minor centers, including the Stela Group (CC1) and the Plaintain Group (CC5), a smaller plazuela group (CC7), and a chultun excavated as part of a salvage operation (Table 5.5). Thirty-three percent of the sample population has strontium values that differ from those identified near the site. This is determined using the cut-off of the range of modern fauna sampled near the site. If a mean-based statistical cut-off is used, all four are marginal values. The following discussion will show that use of modern fauna results in a more convincing interpretation of the strontium isotope values than does the statistical assessment.

Table 5.5. Chaa Creek strontium isotope values and burial information: Burial information derived from Connell (2003, 2000) and Adams (1998).

Burial	$^{87}Sr/^{86}Sr$	Sex	Age in yrs	Burial context and information	Date
Op. 190O B1	.70874	M	Oad >50	Burial context: residential shrine Extended position	Protoclassic
Op. 190P B1 intrusive	.71100	M?	A	Burial context: residential shrine Prone position with the head oriented to the south	Protoclassic
Op. 190P B1 disturbed	.70856	M	A	Burial context: residential shrine Body position disturbed by “intrusive” burial	Protoclassic
Op. 161XX#11	.709178	Comingled remains: F Oad, M Mad, M A		Burial context: residential shrine One burial was in an extended prone position, with the head to the south facing east. The remainder were not articulated	LCII-Terminal transition
Op. 161XX#167	.709977				LCII-Terminal transition
Op. 161XX#173	.709435				LCII-Terminal transition
Op. 161XX/31	.708411	I	Child 3-5		LCII-Terminal transition
Op. Q11/12 Q#4	.709540	Comingled remains: F Yad, M A, M Oad >50		Burial context: residential shrine Two crania were located at the south end of crypt: remains were otherwise commingled or disturbed	Late Classic II
Op. Q12 N#5	.709460				Late Classic II
Op. Q11/12 #52	.709181				Late Classic II
Op. 254B B1	.70963	M	35-40	Burial context: residential Extended, prone position, with the head to the south/southeast	LCIIb-Terminal transition
Chultun 2 Chamber 3	.70957	I	I	Burial context: residential shrine Not available	Not available

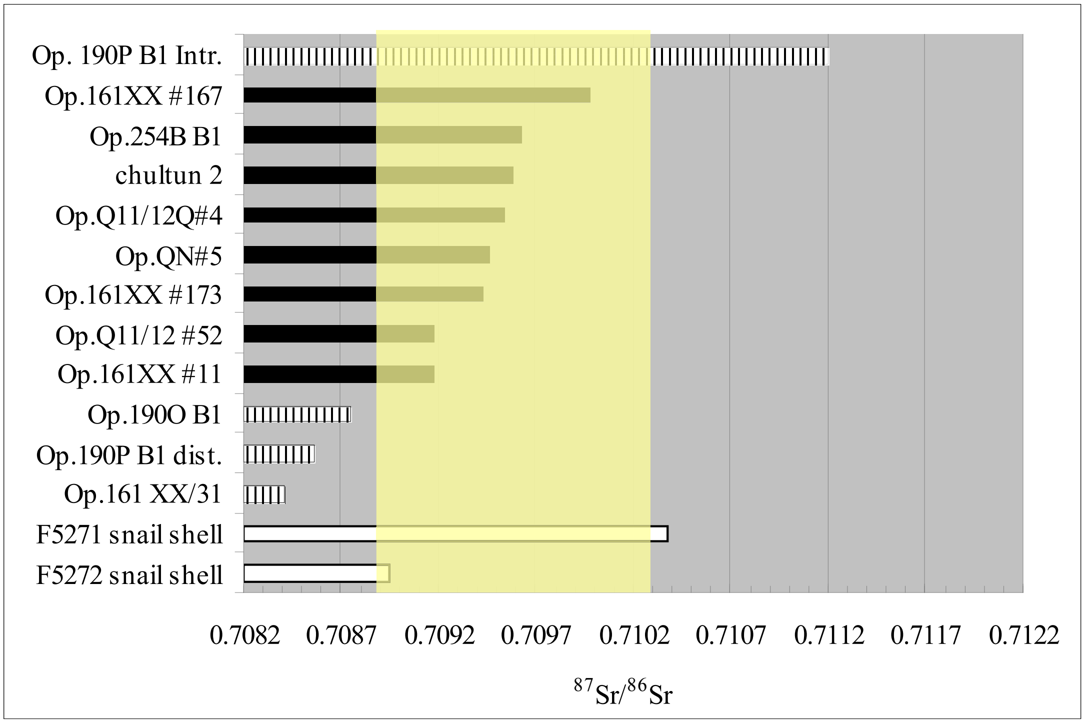

Figure 5.17. Chaa Creek strontium isotope values bar graph: White bars represent $^{87}Sr/^{86}Sr$ baseline values and the shaded area represents the range of values identified along the Belize River. Black bars represent each individual in the study: striped bars are individuals with isotope values not found near the site.

3a. Identifying origin: analysis of the strontium isotope values

Although Chaa Creek is located just a few kilometers from other Belize Valley sites in this study, strontium isotope values near the site are substantially different (Figure 5.17). Two samples collected from fields in front of CC1 and CC5 have high values (.70894 to .7104 $^{87}Sr/^{86}Sr$), and a value of .71065 was identified 6 km upstream. Similar values are identified by Kennedy Thornton near Tipu (personal communication 2009). These form the Macal River strontium zone.

Macal River deposits are very narrow, resulting in substantially lower measures of ~.7083 just 2-3 km away in three samples. The Mopan and Macal tributaries to the Belize River are just 6 km apart, but have distinct strontium values. There is some overlap in the highest

Belize River zone values with the lowest Macal River zone value, but these are identified in the central and upper portions of the Belize River Valley. Average values for the two zones are distinct, and most of the human population at Chaa Creek has Macal River strontium zone values.

Figure 5.18 shows three distinct groups of values. Burial 190P Individual 1 has a strontium signature that suggests an origin in the Maya Mountains or Mountain Pine Ridge, the only location in the Maya region with values exceeding $^{87}Sr/^{86}Sr$ .711. Three other individuals have Belize River zone values lower than those found in the Macal River zone. These values are found near Chaa Creek, but not in its immediate catchment. When these values are removed, Chaa Creek human values have an average (.70950 ± .0003) similar to the average of the two baseline values identified in fields at the site (.70966 ± .001).

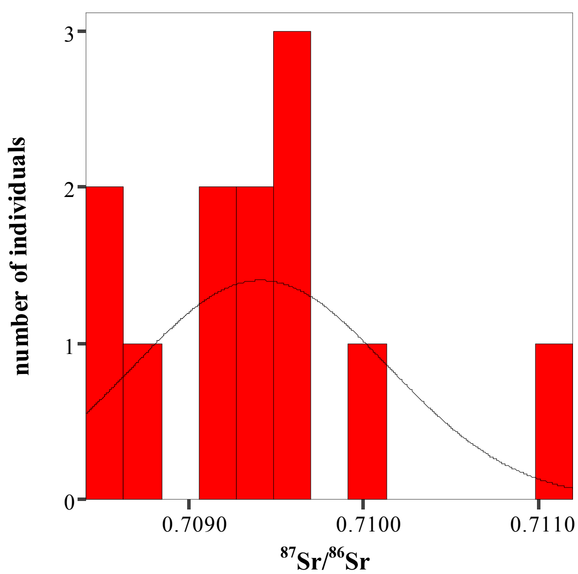

Figure 5.18. Chaa Creek strontium isotope values histogram.

3b. Burial context and population movement

Residential shrine: CC1 Stela Group

Three Protoclassic burials were located in CC1, a minor center that Connell (2000) interprets as a focal point for ancestor worship that predated settlement at the site and continued into the Late Classic. Each of the three individuals has non-local strontium isotope values: two in the Belize River zone range, and one in the Maya Mountain zone range. The crypts were located in the plaza in front of the stairs leading to the main temple structure in the group, Str. M1. The earliest crypt was carved into the bedrock and was in a clear position of prominence. Op. 190O, an elderly male individual, has a Belize River zone strontium isotope value.

Crypt 97-2 contained the remains of two adult males who were interred in two separate events. Op. 190 Burial 1 (disturbed) is the earlier interment, which contains an adult male with a Belize River zone $^{87}Sr/^{86}Sr$ value. A second (probable) male was interred later, disturbing these remains such that the bones were comingled and many could not be assigned to a particular individual (Op. 190 Burial 1 intrusive). The intrusive interment was interpreted as an articulated skeleton placed in a prone position with the head oriented to the south (Adams 1998; Connell 2000).

This burial contained a small cache of vessels placed lip-to-lip with a single human phalanx in one bowl, and another next to it. A carved bone was found next to the intrusive individual's right hand (Connell 1995). This individual's $^{87}Sr/^{86}Sr$ value suggests an origin in the vicinity of the Maya Mountains. A similar value has been identified near Tipu by Kennedy Thornton (personal communication 2009), but to date, average faunal $\delta^{87}Sr$ values that exceed .711 have only been found in the Maya Mountain zone. In either case, the individual did not share a similar origin with the others interred at Chaa Creek, most notably the male with whom he was buried.

Residential shrine: CC5 Plaintain Group

CC5 was a residence for mid-level elites with strong connections to Xunantunich. Three crypts excavated in the group suggest that patterns of ancestor veneration shifted during the Late Classic (Connell 2000). The burials date to the latter part of the Late Classic, just before occupation at the site ended, but each of the crypts likely was used for multiple burial events (Adams 1998; Connell 2000). All but one of the nine individuals have Macal River strontium zone values interpreted as local for the site.

This includes each of the three Op. Q11/12 individuals interred in one of the crypts. A later interment likely disturbed the earlier burial of two individuals. Two of the skulls were in the south end of the crypt, while the mandibles were in the north, and bones were intermingled. Adams (1998) notes the presence of vertebral and foot elements that suggest the individuals originally were interred complete. The floor above the crypt was not re-plastered and bone fragments in the fill on top of the burials suggest its possible re-use.

Crypt 95-1 (Op. 161XX) also contained multiple individuals, including five adults and one child. One elderly female was identified in a prone position oriented to the south, but the remains of the other five were comingled, and the fill contained human bone fragments. A carved shell pendant and a spindle whorl are interpreted as grave goods for the female. Five of the six individuals were sampled, and the child's $^{87}Sr/^{86}Sr$ value is the only one to show a different place of birth. Like the individuals in the Protoclassic burials, the child has a Belize River strontium zone value.

Similar deposits of multiple individuals have been interpreted as sacrificial victims accompanying a principal interment (e.g., Welsh 1988). The crypt lay beneath a small altar with copal residues at the center of a 10 cm thick layer of debris from a domestic assemblage. This included wealth items, like jade and Pachuca green obsidian, and ceramics that represent the entire span of Late Classic occupation. This is interpreted as ritual deposition of a family group's wealth to terminate use of the living space ~ AD 800 (Connell 1995, 2000).

This crypt was not replastered, suggesting it was used more than once. Neither was that of an elderly female who was not sampled because all teeth were lost antemortem. Connell (1995) notes the presence of an arrowhead in the midsection of one individual which could relate to a perimortem injury. However, although poor preservation and matrix adhered to bone surfaces might obscure post or perimortem damage, no trauma or cut marks were visible on the bones.

Connell (2000) suggests that this, instead, was the burial ground for ancestors of the local lineage. He describes temporal changes in ancestor veneration practices. Protoclassic burials showed special treatment for specific individuals, but by the Terminal Classic all ancestors now were included in family burials. He also posits a strong relationship with Xunantunich for this lineage; however, a more complex pattern emerges isotopically. Most non-local strontium isotope values are identified during the Protoclassic, including those from the Belize River zone, while most Late and Terminal Classic interments are of individuals born in the Macal River zone.

Residential and unknown: CC7 and Chultun burials

Both Burial Op. 254B and the human remains in the chultun have values interpreted as local to the Chaa Creek settlement area. Op. 254B was interred between two house mound structures in a complex of patio groups (CC7) in the western portion of the settlement. The burial was associated with a thick refuse deposit, but the individual was interred with a broken bowl placed over the skull in an extended, prone position, with the head to the south (Adams 1998; Connell 2000). The chultun burial was excavated in 1999 when it was discovered during construction work at the resort The Lodge at Chaa Creek. The location of the burial is not far from the structures that contained the other Chaa Creek burials sampled in this study. The highly fragmentary remains include elements of the cranium, femur, humerus, and hand and foot elements distributed across three chambers in the chultun.

3c. Chaa Creek summary

The Chaa Creek settlement shows several interesting aspects of population movement in the Belize Valley. First and most important, two distinct strontium isotope zones are present within a polity. While movement can only be discussed between general areas rather than sites, the results suggest population movement that is potentially within the boundaries of a polity. Thirty percent of the sample of 12 individuals has strontium isotope values that differ from those identified at Chaa Creek; that is, within the Macal River strontium zone.

There also is a shift in the origins of individuals over time. Most individuals with non-local values are identified during the Protoclassic. In contrast, Late and Terminal Classic individuals have local origins, with strontium isotope values that match those identified in the field near the structures where they were buried. The non-local Belize River zone value of the child carries interesting implications: it could mean that families or groups relocated together since one or individuals may have accompanied the child. However, the values of the other individuals in this burial who were sampled are local to the Macal River zone in which Chaa Creek is located.

These results also present two questions about the relationship between origin and burial treatment. Did early residents of Chaa Creek have origins in multiple places in and around the Belize Valley? How did the birthplace place of the men buried in the Protoclassic crypts relate to their status as venerated ancestors? Chaa Creek burial contexts are not unique: burials in residential shrines at other sites also contain individuals with diverse origins. This practice appears to represent a broader pattern.

Finally, this provides an interesting example of a contrast between statistical analysis and archaeological evidence. All four of the individuals identified as migrants have statistically marginal strontium isotope values, yet biologically-available strontium does not vary this much within other strontium zones in Mesoamerica. Moreover, three of the individuals with non-local values were buried before residential settlement is identified at the site. Its initial use was non-residential (Connell 2000), so the individuals buried in the center necessarily lived at a different location. Therefore in-migration – even over a short distance – is the most parsimonious explanation.

4. Buenavista

Buenavista is a major center located south of the Mopan River in close proximity to two other major centers, Xunantunich and Cahal Pech (Figure 5.19). Researchers believe that the site likely reached the peak of its political influence during the late 7th and early 8th century AD, and report substantial interaction with other major centers in the valley and in neighboring regions.

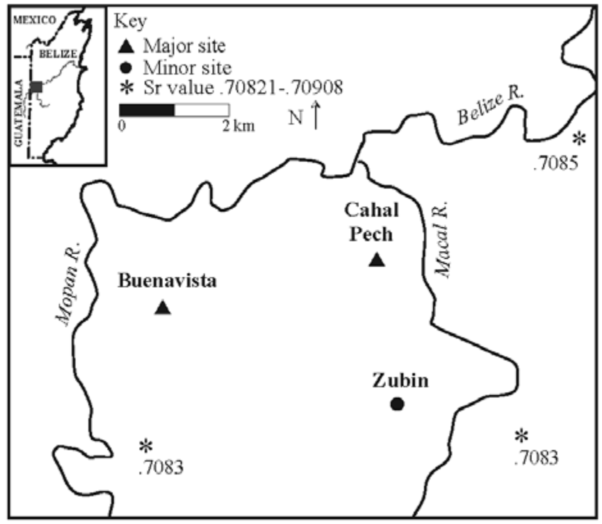

Figure 5.19. Buenavista and closest strontium isotope values.

Ball and Taschek (2004) suggest that the same ruling lineage governed both Buenavista and Cahal Pech, alternating residences during the year. A close relationship between the sites is visible in evidence for ceramic production, and between Buenavista and Baking Pot through ceramic exchange (Reents-Budet et al. 2000, 2005). Analysis of skeletal remains could be used to further explore this proposition, but isotope values will be the same for both sites, as well as other settlement along the Belize River.

Buenavista residents, along with other sites in the Belize Valley, participated in a broader shared ceramic tradition that shows substantial interaction with the Central Petén (Aimers 2004). Significant numbers of vessels produced in the Central Petén have been identified at Buenavista through chemical sourcing techniques (Reents-Budet et al. 2000), and an especially close relationship with rulers of the Petén site of Naranjo during Buenavista’s apogee is suggested by multiple lines of evidence. Ceramic exchange indicates interaction with elites at other major centers as well, such as Holmul, La Rejolla, and Calakmul (Ball and Taschek 2004; Kerr 2010; Ball in Mitchell 2006). Buenavista also may have participated in Caracol's sociopolitical or trade networks after Naranjo's influence waned (Chase 2004). Some imported ceramics were associated with burials, which presents the possibility that they reflect a non-local origin for specific individuals at the site.

Table 5.6. Buenavista strontium isotope values and burial information: Information on sex, age and burial context for Op. 350 is reported from Peuramaki-Brown (2009). Italicized information is from Mitchell's (2006) study.

Burial	**$^{87}Sr/^{86}Sr$**	**Sex**	**Age in yrs**	**Burial context and information**	**Date**
Op. 350 B1	.70811	I	4±1	Burial context: residential Possibly facing a western direction	Late Preclassic
BV-88-B10	*.70853*	*I*	*11*	Burial context: royals and rulers Head oriented to the south	Late Classic
BV-88-B11-1	*.70832*	*M?*	*19*	Burial context: royals and rulers Extended, prone position, head to the south and facing east	Late Classic
BV-88-B12-1	*.70869*	*I*	*13*	Burial context: royals and rulers Body position not described	Late Classic
BV-88-B13-1	*.70971*	*I*	*13*	Burial context: royals and rulers Body position not described	Late Classic
BV-88-B3	*.70833*	*F*	*17-20*	Burial context: residential shrine Body position not described	Terminal Classic
BV-88-B4-1	*.70854*	*M*	*14*	Burial context: residential shrine Extended, prone position, head to the south	Terminal Classic
BV-88-B4-2	*.70777*	*M?*	*45*	Burial context: residential shrine Body position not described	Terminal Classic
BV-88-B1-1	*.70842*	*M*	*45*	Burial context: residential shrine Prone position, head to the south	Terminal Classic

Eight of the burials in Table 5.6 were recovered during excavations by the Mopan-Macal Triangle Project (Ball and Taschek 2004). Mitchell (2006) analyzed four burials at the summit of Str. 1, the tallest building in the site center, and three burials recovered from a courtyard complex interpreted as the royal residence. Nearly all of these burials contained multiple individuals, but the partial remains of some individuals may have come from the fill surrounding the burials. Isotopic assays were only conducted on tooth enamel from the primary individual in each burial, with one exception.

The eighth burial in the sample was excavated by Peuramaki-Brown (2009) as part of the Mopan Valley Archaeological Project. This individual was discovered in what was likely a domestic structure 200 meters south of the site core. The structure is located on a ridge with residential settlement that formed part of the Buenavista polity. Individuals with non-local strontium isotope values were identified in all of these locations.

4a. Identifying origin: analysis of the strontium isotope values

Figure 5.20 shows the location of the three baseline samples collected within 3.5 km of Buenavista. These suggest a range of $^{87}Sr/^{86}Sr$ values for the human population near the site, .70829 to .70863 (average value .70837). The lowest baseline value was collected at Buenavista, and is also the lowest recorded baseline value along the Belize River. Five of the human values lie within this range. A sixth value is slightly higher, but falls within the range of baseline values identified along the Belize River.

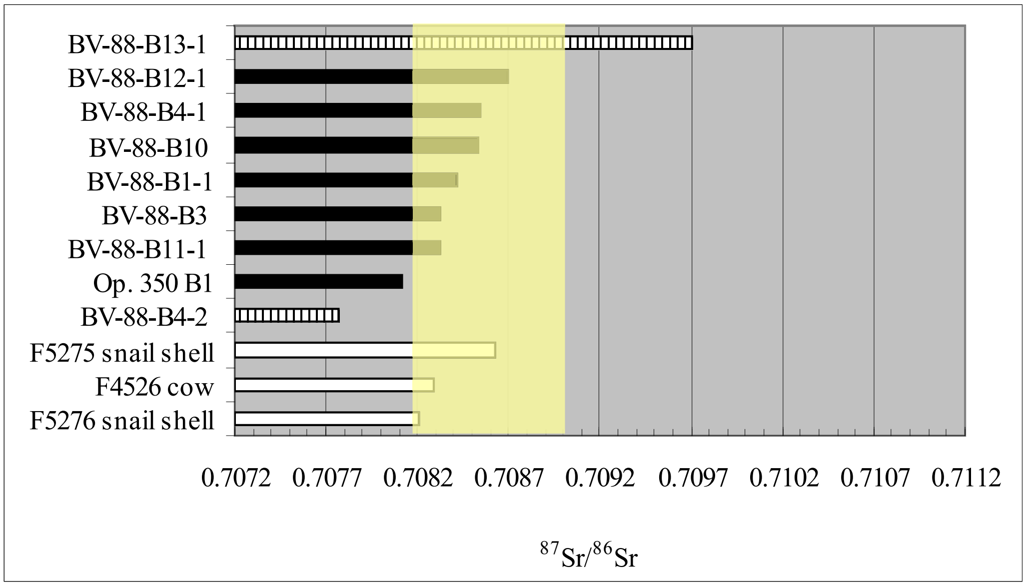

Figure 5.20. Strontium isotope values bar graph: White bars represent $^{87}Sr/^{86}Sr$ baseline values and the shaded a represents the range of values identified along the Belize River. Black bars represent each individual in the study: striped bars are individuals with isotope values not found near the site.

Two values are statistical outliers of the interquartile range (IQR) of the sample population (Figure 5.21). BV-88-B4-2 has a value similar to those identified in the Vaca Plateau and Central Lowlands, and BV-88-13-1 has a Macal River zone value. A third individual, MVAP Op. 350, has a value that is lower than the range of samples identified along the Belize River floodplain. This could either represent a low value that has not yet been identified along the Belize River, or in-migration from another area. The mean of the six individuals with Belize River zone $^{87}Sr/^{86}Sr$ values is .70847 ± .0001, and individuals with non-local strontium isotope values range from 22.2% - 33.3% of the sample population.

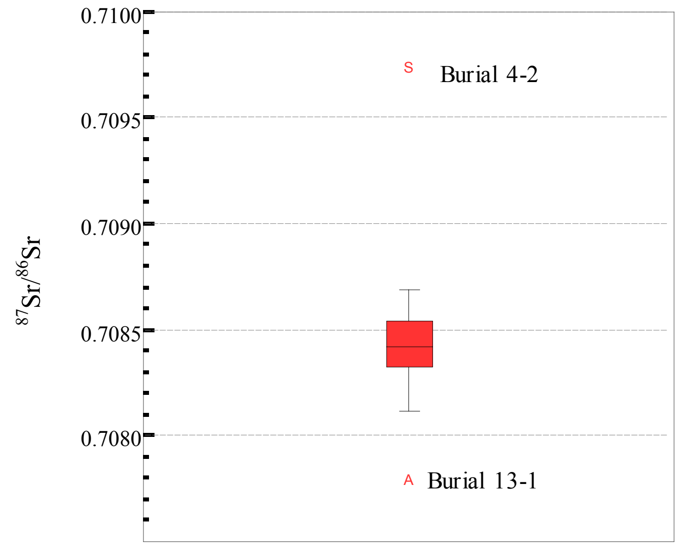

Figure 5.21. Buenavista strontium isotope values box plot.

4b. Burial context and population movement

Royals and rulers: Str. 1: BV-88-13-1, BV-88-12-1, BV-88-10, and BV-88-11-1

The four burials in Str. 1 were interred in separate crypts that were characterized by significant architectural investment and a substantial number of grave goods (Mitchell 2006:127). Only one individual has a non-local strontium isotope value: BV-88-13-1. This was the earliest burial in the sample and contained the remains of two individuals, but the second is represented by only four hand bones (Mitchell 2006). Glyphs on pots in the burial suggest an association with a ruler from La Rejolla, a site that is also affiliated with Caracol (Chase 2004). However, the $^{87}Sr/^{86}Sr$ ratio, .70971, is clearly distinct from the average value of the Vaca Plateau (.70774) where both sites are located. Instead, it matches values in the Macal River strontium zone, the only known location with similar values in the Maya Lowlands.

The other three individuals buried in Str. 1 have Belize River zone isotope ratios. This includes a 13-yr-old interred in Burial 12 (BV-88-12-1), which also contained 24 bones of an older adolescent that were not sampled (Mitchell 2006). Burial 10 (BV-88-10) postdated Burial

12 and contained the remains of two subadults, the relatively complete remains of an adolescent and a seven-year-old child. It is not clear which individual was sampled. Burial 11 (BV-88-11) contained the remains of an adolescent and twelve bones of a child that may have been intrusive (Mitchell 2006). The drawing suggests that the adolescent was placed in a prone position with his head to the south and facing east (Mitchell 2006:135). The Buenavista vase, a polychrome made at Naranjo (Kerr 2010), was included with this burial. However, both of the individuals sampled in Burials 10 and 11 have Belize River zone values, as suggested by the position and orientation of the body.

Residential burials: BV-88-B4 (Individuals 1 and 2), BV-88-B3, BV-88-B1-1, and Op. 350

Three burials were located in the eastern structure of a residential group interpreted as the royal household. The burials were placed next to each other in a series of benches, and Mitchell (2006:127) describes some difficulty in associating some of the partial remains with a particular burial. BV-88-B4 is the earliest burial in a small, low bench that included two individuals, both of which were sampled (Mitchell 2006). The primary individual (Individual 1) was buried in an extended, prone position with the head to the south. This individual has a local strontium signature (.70854). Individual 2, an older individual whose body position is not described, has a low strontium isotope ratio similar to those identified across the Central Lowlands as far west as Palenque and Tonina, to the north at Calakmul (Price et al. 2008), and to the south at Caracol.

BV-88-B3 was placed on top of Burial 4 in the core of the same bench and consists only of cranial elements and teeth. Bones from a neonate also were present, but are not clearly associated with either burial (Mitchell 2006). This individual has a strontium isotope value that falls within the range of Belize River zone values local to the site.

The third burial in the sample was BV-88-B1. Multiple individuals were interred in a pit that was dug into a later construction sequence of the same bench and not replastered (Mitchell 2006). An individual with tabular oblique cranial modification was interred with the partial remains of a child and an adult, along with significant quantities of grave goods (Mitchell 2006:29). One of these was a carved bone that may show a glyph naming Buenavista, suggesting that this was the final ruler of the governing lineage, or the last recognized king of the polity (Helmke et al. 2008). The burial coincided with the final use (and partial destruction) of the structure. The individual was interred in the standard Belize Valley prone and extended position with a southern orientation, and has a strontium isotope value that corresponds closely to the average baseline value near the site.

A final burial was discovered in a household on the ridge 200 m west of the ceremonial center (Peuramaki-Brown 2009). A Preclassic vessel contained cranial fragments and teeth, along with other materials, and was placed in what appeared to be a prepared grave. The $^{87}Sr/^{86}Sr$ value of this child is lower than the others at the site and the baseline values along the Belize River. This child clearly had a different primary food source than the individuals interred in the site core (during their childhoods).

This is not surprising because there are spatial, temporal, and social differences between the burials in the Buenavista sample. This burial predates the others by hundreds of years, and while change over hundreds or thousands of years will not affect strontium values, a shift in food procurement practices might. The burial locations are spatially distinct, and dietary differences between residential groups are isotopically visible at Cahal Pech, Xunantunich, and other sites in the Belize Valley (also see Chapter 6).

This difference might also be the result of relocation from another strontium zone, possibly while the child's tooth enamel was forming. Population movement also is suggested by the probable western orientation of the child's remains. This is not common in Belize Valley burials; however, a southern orientation became standard only during the Late Preclassic (Willey et al. 1965) and the interment of this infant may predate that practice.

4c. Buenavista summary

The strontium results from Mitchell's (2006) analysis of eight individuals, and the individual analyzed as part of this study, highlight four important findings. First, nearly 25% of the sample had non-local origins. While the body position and orientation of many individuals were not described, the burial treatment of those born locally was similar to those with non-local isotope values. Second, individuals buried with imported ceramics have local Belize River zone strontium values. This suggests that foreign goods may reflect individual, family, or polity connections during life more than foreign origin. This is a consistent finding in isotopic analyses in the Maya region (e.g., Wright and Bachand 2009; Price et al. 2010; Wright 2005a).

A third finding is the documentation of both interregional – possibly long distance – and local population movement in elite contexts. Additional movement between sites with similar strontium isotope values also is possible, especially given the close relationship posited with Cahal Pech (Ball and Taschek 2004; but see Audet and Awe 2005). A final point relates to age: two of the three individuals relocated during childhood, or earlier. This suggests the movement of family groups, and supplements epigraphic documentation of elite population movement during the Late Classic (Houston and Inomata 2001; Martin and Grube 2000).

5. Cahal Pech

Cahal Pech is a medium-size Maya center situated 3.5 km south of the confluence of the Mopan and Macal Rivers, as shown in Figure 5.22 (Healy et al. 2004a). The burial population at Cahal Pech is one with great time depth: use of temple monuments in the site core and shrines in residential groups spanned centuries, from the Preclassic Period ~1200 BC through the Late and Terminal Classic AD 900 (Aimers et al. 2000).

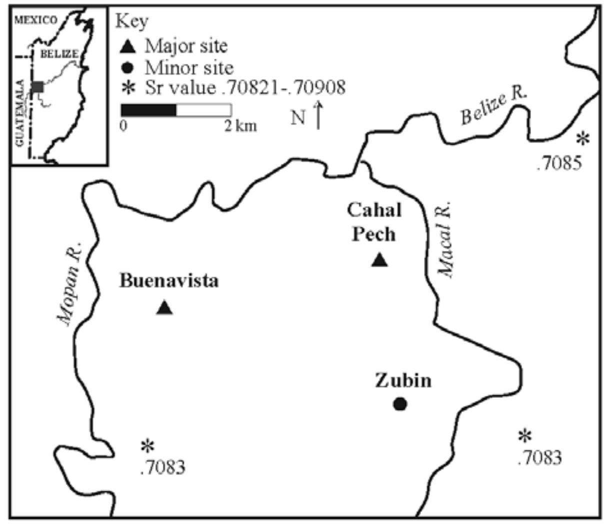

Figure 5.22. Cahal Pech and closest strontium isotope values.

The sample population is drawn from thirteen burials in the site core and nine samples from three outlying groups, each located within ½ km of the site center (Figure 5.23). The burials in this sample were excavated by the Belize Valley Archaeological Reconnaissance Project (BVAP) and the Belize Valley Preclassic Project. It also includes six burials excavated by the Mopan-Macal Triangle Project and analyzed by Mitchell (2006).

It is a significant finding that all but one individual has a local Belize River zone strontium isotope ratio, and that the single outlier of the 20 samples likely came from only a short distance away (Table 5.7). Cahal Pech was a major center and was located at the confluence of two major river trading routes. Interaction with other sites in the valley, as well as with Caracol, is visible through multiple lines of material evidence (Aimers et al. 2000; Helmke and Awe in press). This does not mean that no in-migration occurred. Movement within the valley is not visible isotopically, and although individuals with non-local origins are identified in most published studies, they usually form only a small percentage of the sample population (e.g., Buikstra et al. 2004; Krueger 1985; Price et al. 2008; Wright and Bachand 2009).

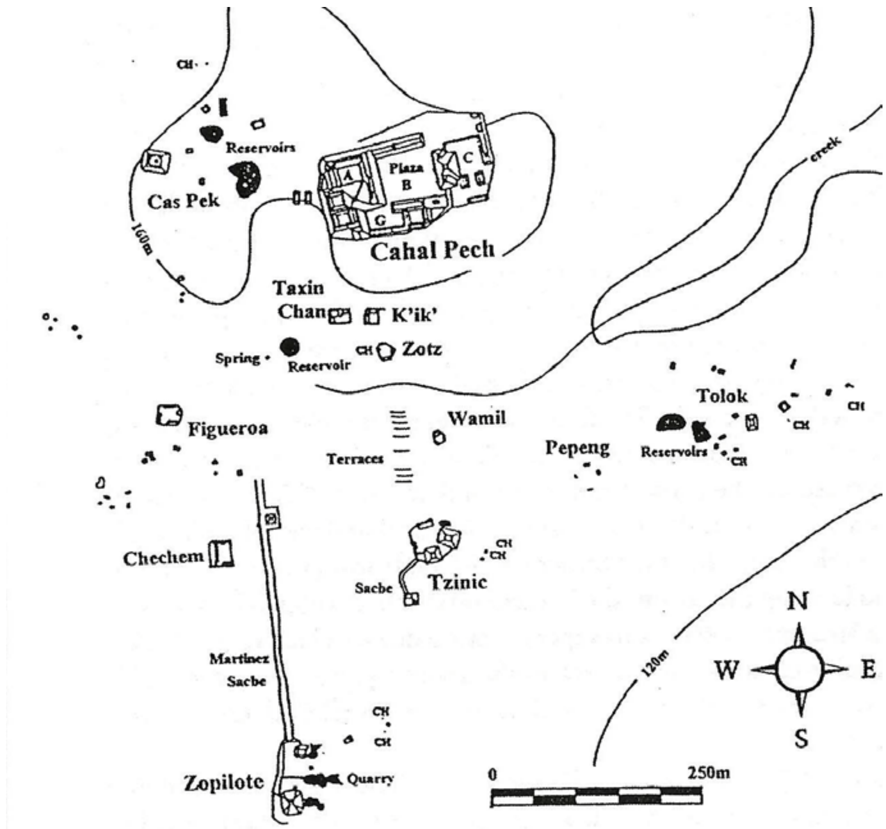

Figure 5.23. Cahal Pech site map: The site of Cahal Pech and the architectural groups discussed in text. Map from Healy et al. (2004b:104).

Table 5.7. Cahal Pech strontium isotope values and burial information: Strontium isotope values for Cahal Pech and Zotz, Tolok and Zopilote. Data from Mitchell (2006) is italicized.

Burial	$^{87}Sr/^{86}Sr$	Sex	Age in yrs	Burial context and information	Date
Str. A2 B1	.70851	I	A	Burial context: unknown N/A	AD 600-700
Str. B2-2	.70865	I	A	Burial context: unknown N/A	AD 200-450
Plaza B Op. 1g cache 7	.70859	I	I	Burial context: other Skull in a crypt, facing west, located south of an extended burial	Middle Preclassic
Str. B4 Burial 1/06	.70862	I	I	Burial context: other Cache with disarticulated remains	Late Preclassic

Str. H1 Plaza H Tomb 1	.70859	M	A	Burial context: royals and rulers N/A	Terminal Classic
Plaza A A3-1 burial	.70856	I	I	Burial context: royals and rulers N/A	Unknown
Zotz 2/B1 1992	.70873	M	A	Burial context: residential shrine N/A	Late Classic
Zotz 2/B3 1992	.70873	M	A	Burial context: residential shrine N/A	Late Classic
Zotz 2/B5 1992	.70889	I	I	Burial context: residential shrine N/A	Late Classic
Zotz B7 1991	.70874	I	I	Burial context: residential shrine N/A	Late Classic
Tolok 2-92	.70831	I	A	Burial context: residential shrine Extended position, head oriented to the south	Late Classic
Tolok 4	.70831	I	Yad – Mad	Burial context: residential shrine Extended position, head oriented to the south	Late Classic
Zopilote Tomb 1 B2	.70942	M	Yad	Burial context: other Cranium placed near feet of B1	AD 580-630
Zopilote Tomb 1 B1	.70885	M	Yad	Burial context: royals and rulers Extended body position, head to the south and facing west	AD 580-630
CP-89-B1	*.70861*	*M*	*18-20*	Burial context: royals and rulers *Body position not described*	*AD 400-450*
CP-89-B2	*.70881*	*F*	*17-19*	Burial context: royals and rulers *Head probably oriented to the south*	*AD 200-450*
CP-89-B3	*.70877*	*F*	*16-20*	Burial context: royals and rulers *Body position not described*	*AD 550-650*
CP-89-B4	*.70869*	*M*	*35*	Burial context: royals and rulers *Extended, possibly prone, crypt oriented N-S*	*pre-AD 150*
CP-89-B5	*.70877*	*F?*	*16-24*	Burial context: royals and rulers *Body position not described*	*AD 500-550*
CP-89-B6	*.70872*	*M*	*20-34*	Burial context: other *Body position not described*	*Late Classic*

5a. Identifying origin: analysis of the strontium isotope values

Three baseline samples found within 5 km of Cahal Pech show the expected range of local values for the human population. $^{87}Sr/^{86}Sr$ values of modern fauna range from .70829 to .70853 (average value .70838 ± .0001). Like most other sites in this study, human values are more variable and are slightly higher (average value .70865 ± .0002). However, all but one has $^{87}Sr/^{86}Sr$ values within the range of Belize River zone values (Figure 5.24). That is, 95% of the individuals have Belize River zone strontium isotope values.

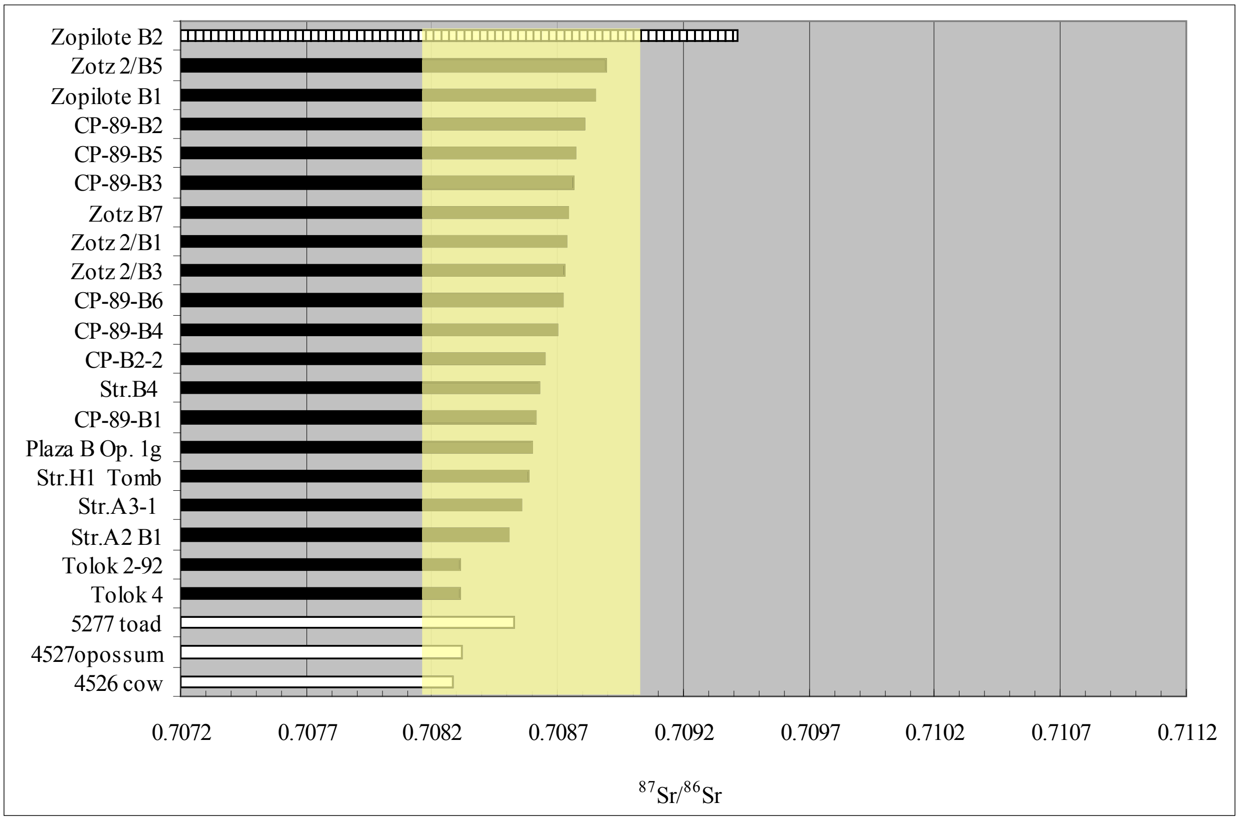

Figure 5.24. Cahal Pech strontium isotope values bar graph: White bars represent $^{87}Sr/^{86}Sr$ baseline values and the shaded area represents the range of values identified along the Belize River. Black bars represent each individual in the study: striped bars are individuals with isotope values not found near the site.

The value of one individual is higher than the rest and shows an origin in the Macal River strontium zone. These values also lie within the greater Belize Valley region, and are found less than 5 km upstream along the Macal River. However, the difference between this value and others at the site is highlighted by the similarity in values identified in individuals in the same burial locations.

For example, the individuals in Mitchell's sample (marked "CP-") have nearly identical values (average value .70873 ± .00007). Values of the Zotz individuals also are tightly clustered (Zotz average value .70879 ± .00009), and both differ markedly from the two individuals sampled at Tolok (average value .70831 ± 0). In a larger sample, this could suggest different food sources for the residential groups. In fact, the strontium isotope values are so similar that the Tolok individuals are outlier values of the IQR; however, they closely match baseline values near the site so are considered to be part of the locally-born population (Figure 5.25).

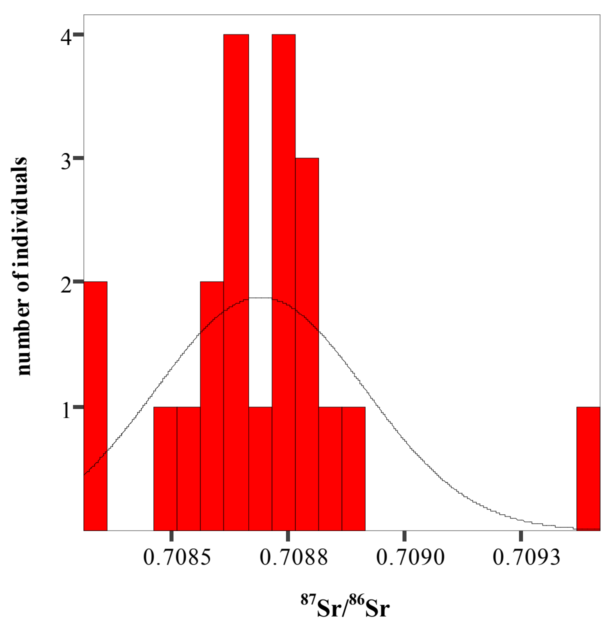

Figure 5.25. Cahal Pech strontium isotope values histogram.

5b. Burial context and population movement

Strs. A2, A3, B1, B3, B5, and H1

None of the individuals interred in monumental architecture in the site core have non-local strontium values. Most burials were located in structures surrounding Plaza B, the largest of the plazas in the site core. One individual was buried in Str. A2, which divides Plazas A and B. A second individual was interred in Str. A3 in Plaza A. Each has a value similar to those identified along the Belize River. Two other individuals with atypical burial treatment are reported in Str. B4 and Plaza B. The head of the skeleton is placed in a bowl separate from the rest of the skeleton. The Cahal Pech B4 burial consists of a head placed in lip-to-lip Polvero Black bowls surrounded by long bones and figurine heads in the four cardinal directions (Jason Yaeger personal communication). Both are interpreted as ancestors and both have Belize River strontium isotope values. The burial in Plaza B consists of separate interments of a skull and a headless body that may be the same individual (Garber et al. 2007; Garber and Awe 2008).

Burials in three other structures in Plaza B were analyzed by Mitchell (2006). Strs. B1, B2, and B3 are defined as an E-Group (Awe 2008) and contained more than six distinct burials. Four of the individuals were interred in Str. B1. Protoclassic Burial 4 (CP-89-B4) and Burials 2 (CP-89-B2) and 3 (CP-89-B3) each were interred in pits or crypts dug into platform floors and associated with different construction episodes (Mitchell 2006:125). Each was found with multiple grave goods and has local strontium isotope values.

Str. B2 contained multiple burials, one of which was an Early Classic interment, and each of these individuals has local strontium values. Burial 5 (CP-89-B5) was interred in the adjacent structure on the plaza, Str. B3. This interment was roughly contemporaneous with Burial 3 and also contained associated jade ornaments and other burial goods. An additional burial described by Mitchell (2006) is Burial 6 (CP-89-B6), which was located in Str. B5 on the southern side of the plaza in building fill between rooms in the structure. This contained the only individual with no funerary goods or investment in grave architecture. This individual also has a strontium isotope ratio local to the area.

A tomb placed in front of Str. H1 also contained the burial of an adult male with a strontium isotope value that suggests a local origin. The tomb was not well constructed, but was associated with an altar, and burial goods include thirteen vessels and obsidian. These suggest veneration of a locally important figure (Awe 2008).

Although the focus of this study is the period spanning the Late and Terminal Classic, more than half of these individuals have earlier dates: three were interred during the Preclassic and three during the Early Classic. When only the later periods are considered, identifying one migrant in a sample of ~12 burials is similar to findings from other sites.

Residential shrines

Two residential groups near the site core include structures interpreted as residential ancestor shrines with occupation spanning the late Middle Preclassic to Late Classic periods. Each residential shrine originally had a circular structure that continued to be used for burials after later construction altered the form of the buildings (Aimers et al. 2000). The Tolok group is located ~250 m southeast of the site core (Healy et al. 2004b). It contains a small patio group and is interpreted as the residence of farmers who were closely integrated with Cahal Pech. Strs. 14 and 15, an overlapping earlier and later version of the circular platform structure, contained at least 13 individuals in burials dated to between 600 BC and AD 900. Two Late Classic individuals were sampled from cists that included jade, shell, and ceramics (Aimers et al. 2000; Powis 1992; Powis and Hohman 1994). Each of these individuals has a local strontium isotope value.

Several other residential groups are located south of the site core, including the Zotz group. This formal patio cluster lacks imposing architecture despite its location just 100 m from the site's monumental architecture (Healy et al 2004b). Four mounds on a small platform include Str. 2, a residential shrine originally constructed as a circular platform on the eastern side of the group (Aimers et al. 2000; Awe et al. 1992). Use of the platform began during the Middle Preclassic and continued through the Early Classic: Late Classic burials in the same location suggest that residents still knew the location and use of the original round structure. There is additional evidence for ritual activity suggestive of ancestor veneration, including burned copal residues and postmortem movement of bones, as described in the beginning of the chapter (Song 1995). These three individuals also have local strontium values.

Terminus structures and causeways

Zopilote is interpreted as an outlying shrine 500 m from the site core that consists of two temples and a third structure at the end of a causeway. There is no associated residential architecture, but use of the group and its structures spanned the Preclassic through the Terminal Classic (Cheetham 2004). Two tombs were discovered, one with the Late Classic interment of a stela that is attributed to an earlier period, the remains of two or more infants, and incisors and phalanges representing at least twenty adults in "finger bowls" (Awe et al. 2009a, 2009b; Cheetham 2004; Song 1995).

Terminus structures were the focus of ritual activity, and Tomb 1 is interpreted as the burial place of a young adult male ruler at Cahal Pech (Cheetham 2004). The cranium of another young adult male was placed near his feet between two partial hemispherical bowls. The burial had a rich assortment of goods, including jade and whole polychrome vessels. While the primary individual has $^{87}Sr/^{86}Sr$ values similar to those identified near the site, the cranium of the young adult male does not. Instead, his values are similar to those found in the Macal River strontium zone.

To date, strontium isotope values between .7092 and .711 have only been identified near the lower Macal River. Warfare-related iconography on a vase in the tomb may support the interpretation of this individual as a captive or retainer (Cheetham 2004), which situates the conflict within the Belize Valley. Even if ancestry also played a role in the joint burial of these two individuals, the strontium isotope values demonstrate a relationship between two parts of the Belize Valley situated very close together.

5c. Cahal Pech summary

Only one of the twenty individuals in this sample, including Mitchell's (2006) results, has a value that is not found in the vicinity of Cahal Pech. This individual is represented only by a cranium that is interred with another individual at Zopilote, a terminus structure in a non-residential group. Non-local strontium isotope values are associated with cranium or skull-only burials at other sites in this study. However, the lack of non-local individuals in burial shrines and in residential contexts differs from patterns identified at other sites in the study.

None of the Zotz or Tolok individuals interred in residential shrines have non-local values, though other similar burial contexts in the valley did. Burials spanning the Preclassic to the Late Classic periods in the site core also have local, Belize River zone values. Individuals could have relocated from an area with similar isotope values, which includes any location along the Belize River or even distant locales in Northern Lowlands. However, the similarity of values in each of these residential burial locations supports a shared origin for major food sources, which suggests that their origins were local ones.

Dissimilarities between burial contexts sampled at major centers should account for some of the differences: Xunantunich and Baking Pot burial contexts in monumental architecture were more variable than those at Cahal Pech. Moreover, migration was identified in residential group contexts at each of these sites, but not in the sample population at Cahal Pech.

6. Zubin

Zubin is a minor center located on the Macal River less than 3 km south of Cahal Pech (Figure 5.26). It may have served initially as a pilgrimage center for residents of other sites during the Middle Preclassic (Iannone 1996). Initially, there was no associated settlement, and Iannone (2003) suggests that Str. C9 served as a shrine that resembles those described historically by Vogt. Zubin was first settled only after AD 675, when its main plazuela group became the residence for a moderately wealthy household that was surrounded by dense settlement. The focus for ritual then shifted to Str. A1 on the eastern side of the courtyard, which served as the locale for ancestor worship and related activities for residents of the household and/or site.

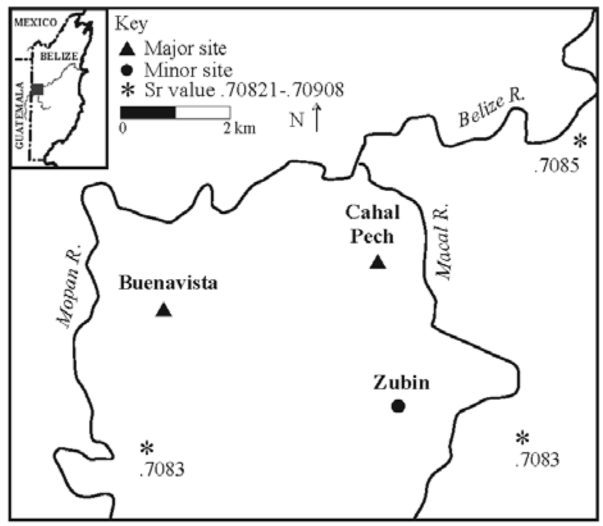

Figure 5.26. Zubin and closest strontium isotope values.

Iannone (1996) sees the use of the site shifting from community to more localized use, but one in which regional interaction still is evident. Polychromes have pseudoglyphs, suggesting knowledge - but only limited understanding - of elite interactions at other sites. The presence of jade and marine shell in some burials shows participation in interregional trade networks.

However, Iannone (1996) interprets the use of the shrine as a means for linking ancestors to the local landscape (McAnany 1995, 1998). This implies that earlier burials in Str. C9 may include individuals from other sites. These values also may differ from those of later interments in Str. A1, who likely resided at or near the site.

The sample includes nine individuals from six burials in these two structures. Many of the burials were associated with construction episodes and likely formed part of termination and dedication rituals (Iannone 1996). Two individuals with non-local strontium isotope values were buried during the Late Classic. However, two additional individuals – in burials pre-dating the Late Classic - have strontium isotope ratios that differ from the other individuals. Three groups of strontium isotope values demonstrate some difference in childhood diet for nearly half of the individuals sampled. However, all of the values can be found in the Belize Valley (Table 5.8).

Table 5.8. Zubin strontium isotope values and burial information: Age, sex, and burial context information derived from Iannone 1996 and Schwake 1996.

Burial	$^{87}Sr/^{86}Sr$	Sex	Age in yrs	Burial context and information	Date
Str. A1-B1	.70866	I	Adult?	Burial context: residential shrine Extended, supine, head to the south	AD 675-750
Str. A1-B3 #1	.70866	M	30-45	Burial context: residential shrine Extended, prone, with arms at sides	AD 675-750
Str. A1-B3 #2	.70870	F	18-25	Burial context: residential shrine Extended, prone, head to the south and arms at sides	AD 675-750
Str. A1-B3 #3	.70987	M	Yad-Mad	Burial context: residential shrine Extended, prone, head to the south and arms at sides	AD 675-750
Str. A1-B3 #4	.70866	M	14-20	Burial context: residential shrine Extended, prone, head to the south and arms at sides	AD 675-750
Str. A1-B6	.70950	I	I	Burial context: residential shrine Extended, prone, head to the south and arms at sides	AD 675-750
Str. A1-B9	.70871	I	27-40	Burial context: residential shrine Extended, supine, head to the south	AD 200-300

Str. A1-B10	.70839	I	4-5	Burial context: residential shrine Extended, prone, head to the south	AD 100-350
Str. C9-B1	.70846	I	I	Burial context: residential shrine Supine, head to north and facing west	650-350 BC

6a. Identifying origin: analysis of the strontium isotope values

Three baseline samples found near Zubin show the expected range of local values for the human population, which is an average value of .70838 ± .0001. However, Macal River zone values are identified less than 5 km away. Chaa Creek, where the Macal River zone was initially identified, is just upstream. At Zubin, most values reflect Belize River zone strontium isotope measures (Figure 5.27).

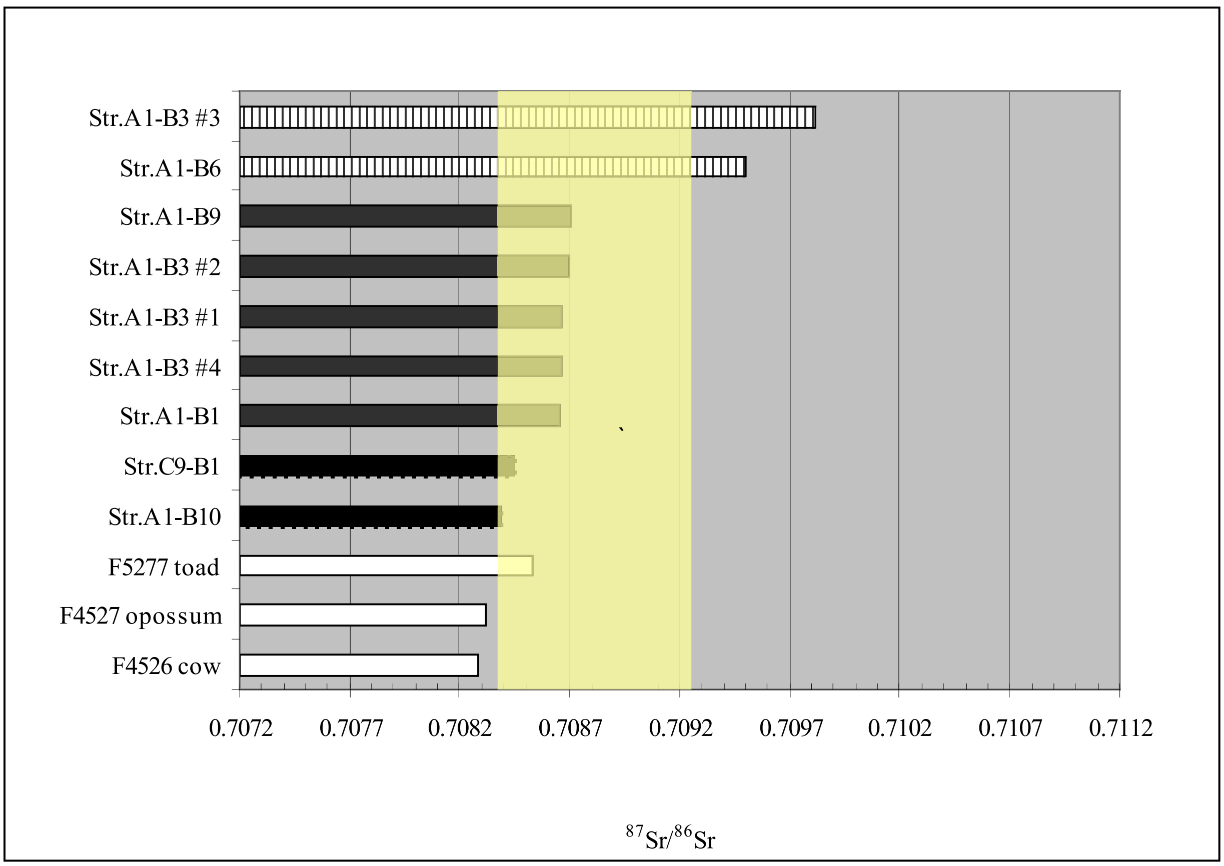

Figure 5.27. Zubin strontium isotope values bar graph: White bars represent $^{87}Sr/^{86}Sr$ baseline values and the shaded area represents the range of values identified along the Belize River. Black bars represent each individual in the study: striped bars are individuals with isotope values not found near the site.

Five of the nine human values have such similar strontium isotope ratios that the rest are statistical outliers (IQR). The two high values match human and baseline samples identified to the south along the Macal River. When the two Macal River zone values are removed, the seven remaining individuals have an average isotope signature of .70860 ± .0001.

The two low values are nearly identical to the local baseline samples near Zubin and fall within the range of Belize Valley zone isotope values. They also fall within 2 standard deviations from the mean of the Belize River faunal values. These individuals were buried before there was associated settlement, so their values likely indicate origins elsewhere in the same strontium zone. This suggests that, at minimum, 22.2% of the individuals interred in the Zubin residential shrine were born in another location.

6b. Burial context and population movement

Residential shrines

Individuals in six burials in two structures were sampled. Four were sampled from interments of single individuals, while five individuals came from two burials with multiple individuals. Six individuals (in three burials) were interred during the Late Classic. Individuals in three earlier burials were included to increase the sample size and to better understand temporal change at the site. Grave goods were identified in nearly all burials.

The Middle Preclassic and Early Classic: Str. C9 Burial 1 and Str. A1 Burials 9 and 10

The individual in the earliest burial in Str. C9 has a local strontium isotope value, but one that differs from others at the site. Since there is no evidence for settlement at the site, this could indicate an origin elsewhere in the Belize Valley. The northern orientation of the individual may reflect burial practices of earlier time periods observed at Barton Ramie. Willey and colleagues (1965:531) describe a northern orientation for burials until the Late Preclassic.

Burials 9 and 10 were interred in simple crypts with the southern orientation and body position typical of the Belize Valley, and both have Belize River strontium isotope values. Ianonne (1996) notes possible dedicatory associations with the child in Burial 10. Burial 9 was associated with termination rituals, and the combination of unusual burial goods and dentition (the teeth have jade and hematite inlays), suggested to excavators that the individual had a special role, perhaps one linked to divination.

Str. A1 Burials 1 and 6

All of the individuals in Late Classic burials had a similar body orientation and were placed on the axial alignment of the building in its penultimate phase. Burial 1 contained two individuals, and was associated with Burial 2. Both were located in simple crypts with multiple grave goods, including fauna, and both had strontium isotope values similar to the average values near the site.

Str. A1 Burial 3 Individuals 1, 2, 3, and 4

This cist contained the remains of five individuals and was located in the final sequence of the building. The individuals were placed one on top of the other, with individual #1 on top and individual #5 (not sampled) on the bottom. Grave goods were associated with individuals 1-4, and included ceramic vessels and two drilled large feline teeth. Individuals 1 and 2 have cranial modification and filed teeth, and individuals 3 and 4 have modified dentition. The relationship between these four individuals and the fifth is unclear: individual 5 was a probable male adult with no associated grave goods, but whose position in the cist suggests some primacy.

However, Ianonne (1996) also suggests that the burial had undertones of sacrifice, and that some individuals might not have local origins. One individual does have a non-local, Macal River zone value. However, there were no patterned differences in burial treatment between individuals with Belize and Macal River zone values. The grave location, presence of grave goods, and burial style show no notable distinctions in burial treatment.

6c. Zubin summary

More than 20% of the individuals in burial shrines have non-local strontium isotope values. The isotope values document short-distance relocation, as the Macal River zone is less than five km away at its closest point. At its farthest identified point, it is still less than one day's walk away. Both individuals with Macal River zone strontium isotope values were buried in an extended, prone position with the head oriented to the south. In general, sites in both the Belize and Macal River zones are located in the Belize Valley and have similar burial norms. However, it would not be prudent to assume that there should be no variation in burial treatment for individuals with different origins, even within the region. There may have been differences, too, that are not visible archaeologically or are not identified as patterns in this sample.

Local values are very closely clustered, with two exceptions. The strontium isotope measures of the two individuals in the earliest burials suggest a different childhood food source. This likely indicates a different residence because there is no evidence for settlement identified at the site before the Late Classic. One of these individuals was oriented to the north instead of the south, like the Preclassic Buenavista child, but a southern orientation became common only during later periods.

The three sets of isotope values mirror other evidence at Zubin that shows a change in use of the center over time. Individuals buried in the non-residential shrine have isotope values that differ from individuals interred in the shrine used by the household group. However, individuals with a third set of isotope values also were buried in the household shrine. This could indicate the continued importance of the site for the broader region, as well as the ability of the Maya social structure to accommodate population movement within the region.

7. Esperanza

Esperanza is located on a large platform on hilly terrain near the floodplain of the Belize River, as shown in Figure 5.28 (Driver and Garber 2004). The site consists of a single plazuela group located north of a temple mound, Str. A4. House mounds, and possibly agricultural terraces, were identified in areas adjacent to the site (Schubert et al. 2001).

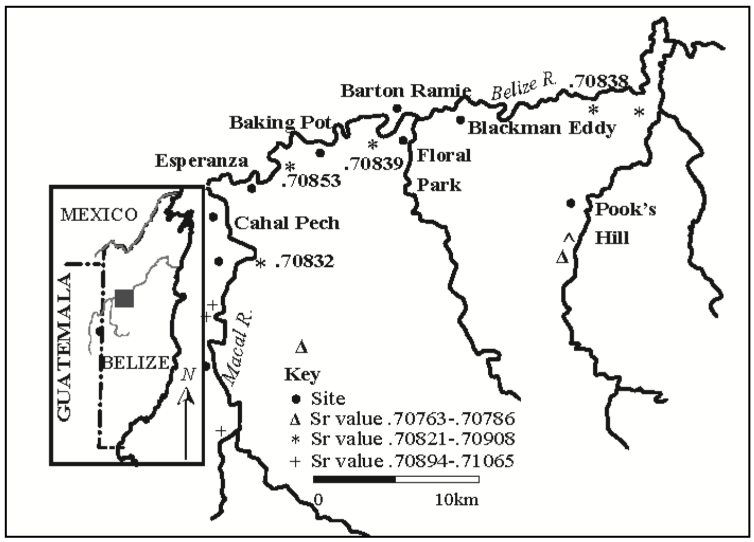

Figure 5.28. Esperanza and closest strontium isotope values.

Esperanza is considered to be a minor center that served as the residence for individuals of average socioeconomic status that was occupied and constructed entirely during the Late Classic. Conlon and Moore (2003) interpret minor centers in the valley as autonomous entities that participated selectively in the economic and social activities of larger centers. Although Esperanza is situated at an equal distance from Cahal Pech and Baking Pot, no strong affiliation with either center has been identified.

In fact, the $^{87}Sr/^{86}Sr$ values of three individuals suggest origins in other strontium zones; that is, their values differ from any identified in the Belize River zone. Two burials were found in Str. A4, the eastern structure of the plazuela group, which is interpreted as the burial shrine for residents of the group. Each burial contained the partial remains of multiple individuals (Driver and Garber 2004; Schubert et al. 2001). None of the three individuals sampled have local Belize Valley strontium isotope values (Table 5.9).

Table 5.9. Esperanza strontium isotope values and burial information: Esperanza burials found in the residential shrine Str. A4 were sampled and none had strontium values similar those identified near the site. The burials were excavated during 2000 by the Belize Valley Archaeological Project (BVAP).

Burial	$^{87}Sr/^{86}Sr$	Sex	Age in yrs	Burial context and information	Date
Str. A4 2b-4-B2?	.70933	I	adult	Burial context: residential shrine Could not be determined	Late Classic
Str. A4 2d-1 B3	.70951	M?	adult	Burial context: residential shrine Could not be determined	Late Classic
Str. A4 2c-1 B2	.70796	I	adult	Burial context: residential shrine Could not be determined	Late Classic

7a. Identifying origin: analysis of the strontium isotope values

Baseline samples found between 2 and 10 km from the site range from .70832 - .70853 (mean value .70841 ± .0001). None of the three individuals in the burial shrine at Esperanza have values within the Belize River zone (Figures 5.29 and 5.30). Op. 2c Burial 2 has a value similar to those identified in the Central Lowlands (including the Vaca Plateau). The other two values fit well with the range of strontium measures identified in the Macal Zone, also located only 10 km from the site.

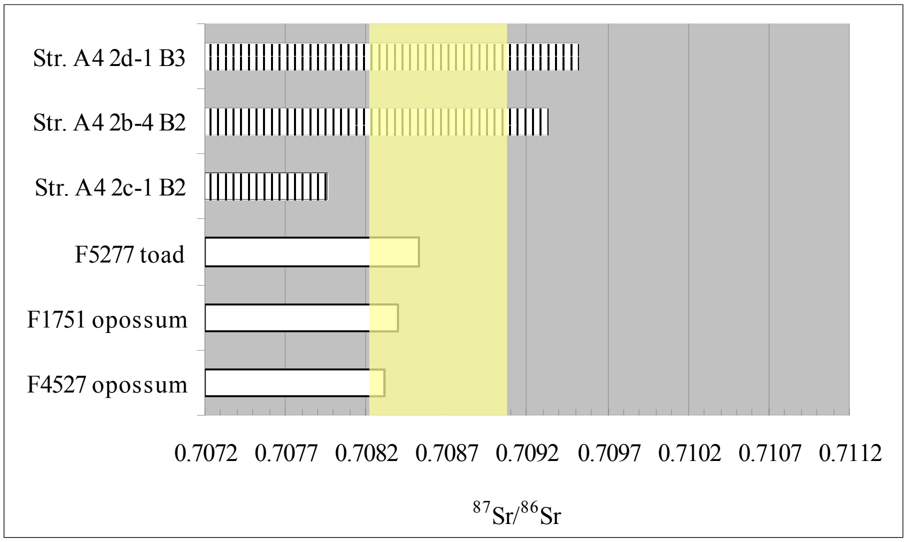

Figure 5.29. Esperanza strontium isotope values bar graph: White bars represent $^{87}Sr/^{86}Sr$ baseline values and the shaded area represents the range of values identified along the Belize River. Black bars represent each individual in the study: striped bars are individuals with isotope values not found near the site.

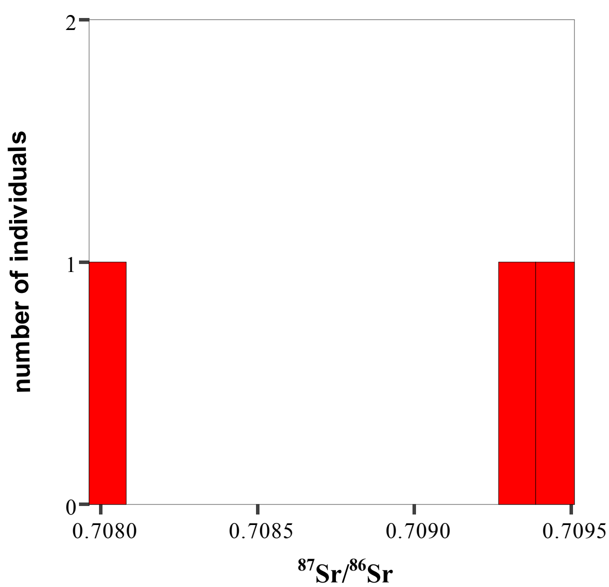

Figure 5.30. Esperanza strontium isotope values histogram.

7b. Burial context and population movement

Residential shrines

The first burial was uncovered on the eastern side of the structure as excavators cleared trenches left by looting activity. Although no burial goods were identified, the burial was covered with a dense lens of chert flakes. Duplicate lower limb bones and teeth in Op. 2c, along with additional bones in Op. 2b, show that the remains consist of at least three individuals (see Appendix A). Two of these individuals were sampled. These individuals had origins in different strontium zones, one with a value lower than Belize River values (.70796) and one with a Macal River zone value (.70933).

The second burial, 2d-1 B3, also contained the remains of two individuals, but only one was sampled due to antemortem tooth loss in the second individual. This burial was located along the center line of the front of the structure (Schubert et al. 2001) in close proximity to a circular altar. However, the relationship between the interments and the altar is not described. This individual also has a Macal River zone value (.70951).

7c. Esperanza summary

None of the three individuals have strontium values similar to those identified near the site (.7084) or in the Belize River strontium zone. The values instead show that the individuals had origins in two different zones, both of which can be found only a short distance from the site. It is possible to identify the origin of the individual with a Macal River zone value since similar values have not been identified elsewhere in the Maya lowlands; however, Central Lowland values are widely distributed so multiple homelands are possible for the individual with the low non-local value.

No information is available on burial orientation or location of the Esperanza individuals, and the remains are poorly preserved. In addition, looting and post-excavation treatment limits observations on health and body modification. One of the individuals in the Op. 2d burial has B4 type dental filing (Romero 1970), and both had significant antemortem tooth loss. Both are commonly observed in the Maya lowland burial population.

Esperanza was established later than other sites in the study, which may explain why these three individuals have isotope values that differ from those found near the site. The origin of two individuals likely is within the Belize Valley strontium zone, but the other could represent either local or long-distance relocation. Could this help to explain how new settlement in the Belize Valley occurred? It suggests that social networks were multi-directional and that households were formed by individuals from different locations, both within the valley and possibly from neighboring regions.

8. Baking Pot

Baking Pot is a major center located between Cahal Pech and Blackman Eddy on the Belize River, as shown in Figure 5.31 (Conlon and Moore 2003). Like Cahal Pech, Baking Pot was occupied continuously from the Late Preclassic to the Postclassic (Audet and Awe 2005),

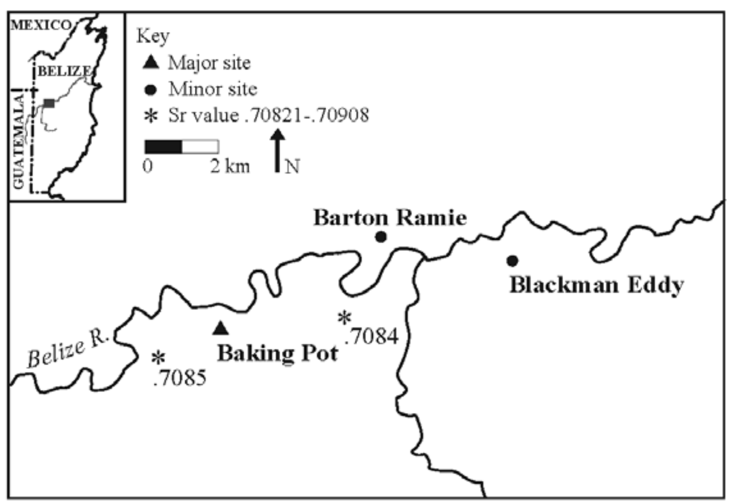

Figure 5.31. Baking Pot and closest strontium isotope values.

with its population at its highest level ~AD 830 (Audet 2006). Burial contexts range from royal interments in tombs to burials in outlying residential groups.

Baking Pot residents likely participated in the same networks as those in other major centers in the valley, with heavy influence from Naranjo and the Central Petén region (Audet and Awe 2002, 2004; Leventhal and Ashmore 2004; Ball and Taschek 2004). However, Baking Pot had diverse connections within the Belize Valley and likely was an autonomous polity for most of the Late and Terminal Classic (Audet and Awe 2005; Reents-Budet et al. 2005). Audet (2006) suggests that the location of the site along the Belize River and its rich material culture represents preferential access to river trade, with its associated social connections, that are not evident to the same extent at neighboring sites like Xunantunich. The presence of foreign vessels from multiple regions documents interaction with individuals at Naranjo, Caracol, Holmul, Pusilhá, and even as far south as the Motagua Valley and Copán (Reents-Budet et al. 2005).

The burial sample includes 28 individuals (29 samples) that date mainly to the Late and Terminal Classic, though dates for ten burials are not available (Table 5.10). Individuals buried at Baking Pot came from different areas within the valley, as well as from at least one long distance location. These individuals are identified in diverse burial contexts, and there is greater variability within residential group burials than is identified in other major centers in this study.

Table 5.10. Baking Pot strontium isotope values and burial information: Burials are from BVAR and Ricketson excavations: see Appendix B for detailed reference information. Burials are referred using the original nomenclature, but revised naming conventions are given by Helmke and Awe (2008).

Burial	$^{87}Sr/^{86}Sr$	Sex	Age in yrs	Burial context and information	Date
Group 1 Plaza 2 B1 (w/extension)	.70828 .70835	I	Yad <23	Burial context: other Prone position with flexed legs and arms resting on legs. Head to the south, slightly tilted to west	AD 590-680
Str. E B1	.70909	I	Adult	Burial context: royals and rulers Extended position with the head to the south	AD 580-690

B1-9 crypt	.70857	F?	Oad	Burial context: royals and rulers Extended, prone position, head to the south	Late – Terminal Classic
Str. B1 B1	.70883	I	I	Burial context: royals and rulers Extended, supine position, with the head to north and facing west	AD 780-890
Str. 96-1	.70878	M	Y-Mad	Burial context: residential Extended, prone, head to the south	Late – Terminal Classic
Str. 96-2	.70828	I	Oad	Burial context: residential Extended, prone, head to the south	Late Classic
Str. 96-3	.70863	F	Oad	Burial context: residential Extended, prone, head to the south and facing west	Late Classic
Str. 102 B1	.70825	I	Oad >60	Burial context: residential Extended supine position with the head to the south and face to the west right foot crossed over left	Late Classic
Str. 112-1-1	.70916	F	Mad	Burial context: residential Extended, prone, head to the south	Early Classic
Str. 112-1-2	.70892	M	Adult	Burial context: residential Skull and long bones at the feet of burial 112-1-1	Early Classic?
Str. 190 B3	.70851	M	Adult	Burial context: other Cranium only	Tiger Run Late Classic I
Str. 190 B5	.70817	M	Late Ao	Burial context: other Cranium only	Tiger Run Late Classic I
Str. 198 B1	.70864	I	Infant 3±1	Burial context: residential Information not available	Late Preclassic
Str. 198 B2	.70863	I	Infant	Burial context: residential Information not available	Late Classic
Str. 209 B1	.70883	M	Oad	Burial context: other Extended, supine position and facing east	AD 800-900
Str. 209 B2	.70866	I	Yad 19-23	Burial context: other Extended, prone position, head to the south	AD 550-650
Str. 209 B3	.70886	F	Oad >55	Burial context: other Prone position, head to the south	AD 650-900
Str. 215 B1	.70858	I	I	Burial context: residential shrine Prone position, head to the south	Not known
Str. 215 B2	.70885	I	I	Burial context: residential shrine Prone position, head to the south and facing west	Not known
Str. 215 B4	.70955	I	I	Burial context: residential shrine Prone position, head to the south	Not known
Str. 215 B6	.70908	I	I	Burial context: residential shrine Prone position, head to the south	Not known
Atalaya B1-B	.70926	F?	Mad	Burial context: residential Extended, prone position, head to the south	Late Classic

Mound G (Str.A17) Burial 3 61487	.70843	I	M-Oad >40	Burial context: shrine Flexed on left side, head to the east and facing south	Late Early Classic – Late Classic
Mound G (Str.A17) Burial 7 61485	.70822	M	Adult	Burial context: shrine Extended, prone position, head to south and face turned slightly to the east	Late Early Classic – Late Classic
Mound G (Str.A17) Burial 9 61486	.70867	F?	Adult	Burial context: shrine Extended, prone position, head to the south and facing west	Late Early Classic – Late Classic
Mound G (Str.A17) Burial 11 61678	.70884	M	Adult	Burial context: shrine Extended, prone position, head to the south	Late Early Classic – Late Classic
Mound G (Str.A17) Burial 15 61484	.70851	I	I	Burial context: shrine Extended, prone position, head to the south, possibly facing east	Late Early Classic
Excavation 9 61663	.70729	I	Adult	Burial context: unknown No information available	Not known

8a. Identifying origin: analysis of the strontium isotope values

Three baseline samples found within 2.5, 6, and 8 km from Baking Pot show expected values for humans living near the site, with $^{87}Sr/^{86}Sr$ measures ranging from .70832 - .70853 (average value .70841 ± .0001). Three individuals have values that are statistical outliers (more

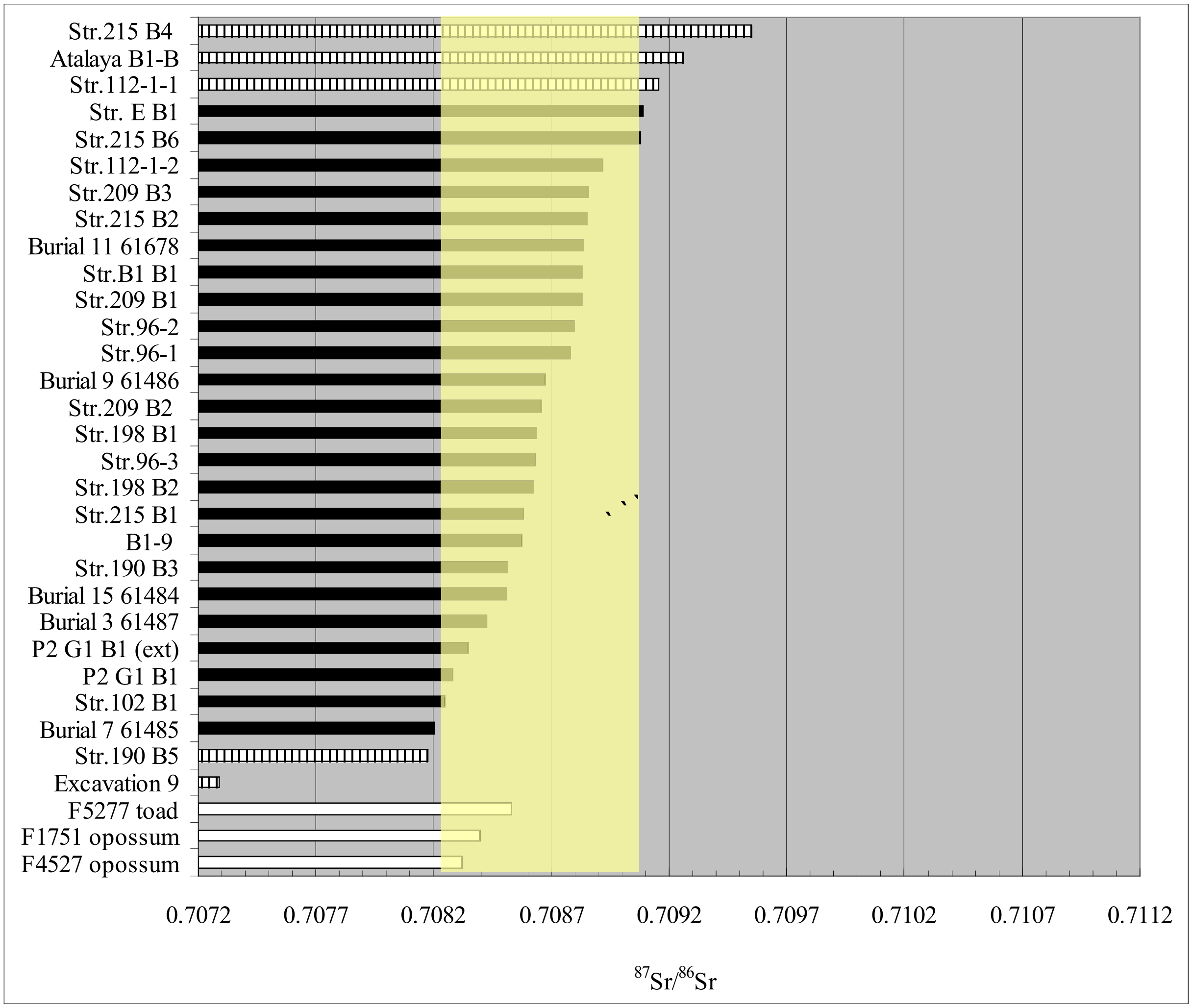

Figure 5.32. Baking Pot strontium isotope values bar graph: White bars represent $^{87}Sr/^{86}Sr$ baseline values and the shaded area represents the range of values identified along the Belize River. Black bars represent each individual in the study (including marginal values): striped bars are individuals with isotope values not found near the site.

than two standard deviations from the mean of baseline fauna). Two high values match Macal River zone values and one low value suggests an origin in the Southern Lowlands (Figure 5.32). Four other individuals have marginal values, two that are slightly higher than baseline values, and two that are lower. When these values are removed, the average strontium isotope measure for Baking Pot individuals is .70862 ± .0002. If the marginal values of these individuals represent migration, 25% of the 28 individuals are non-local. If not, the in-migration rate is lower

(11% if the 28 individuals). It is likely that five of these individuals have non-local isotope values, which represents 17% of the sample population.

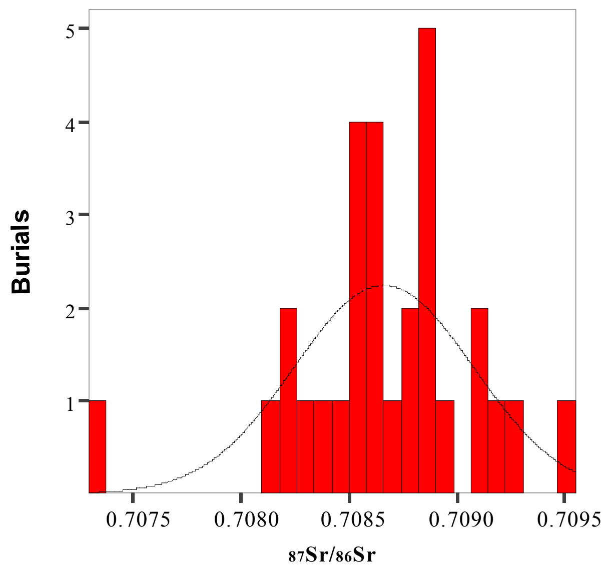

Figure 5.33. Baking Pot strontium isotope values histogram.

Individuals with values in excess of .709 form a separate group, as does the low outlier value .70729 (Figure 5.33). Values that exceed .709 may represent migration from the Macal River zone. Two high values are statistical outliers. Two others are only marginally higher than baseline values. These are similar to the .70908 baseline value identified at Saturday Creek; consequently, these values may represent a Belize River origin closer to the coast. One of these marginal values was not previously identified (Freiwald 2011).

Values that are slightly lower, or higher, than the baseline values may represent migration. They may also represent unmapped variability along the Belize River. These values, as well as statistical assays using the median or mean values, serve only as a guide to interpret the human values (Somerville 2010). In either case, they represent a different childhood dietary source than other individuals in the Baking Pot sample population.

The local values are bimodally distributed, with one set of values that is similar to the average of the baseline fauna, and another with values that exceed .7088. A comparison of burial locations and contexts shows that these clusters do not correspond to burial locations of types, but instead are distributed across the site.

8b. Burial context and migration

Public architecture: royals and rulers

Three of the individuals were buried in temples in the site core. The most notable result is a Belize River zone strontium value for the Terminal Classic ruler in Str. B1 (Burial 1), who was interred with seven non-local vessels that suggest strong ties to sites in the Central Petén. The other two individuals also have Belize River strontium isotope values, including another individual interred with a large number of burial goods in the same structure and a royal individual buried earlier in Str. E (Burial 1) with predominantly local goods.

Structures B and E are located across from each other in Group 1. Str. B, now called Str. A1, contained the plaster-covered cist of an individual (Burial 1) who likely ruled during the Terminal Classic, indicated by the discovery of a K'awil jade pendant, along with a substantial number of grave goods (Audet 2006). Seven of the ten whole vessels in the cist were of foreign origin: two were chemically sourced to Buenavista, three were sourced to the Holmul or Central Petén area, and another vessel has a distinct source in the eastern Petén or western Belize (Reents-Budet et al. 2005). One vessel was produced under the patronage of a Naranjo king who ruled from AD 693-728. At minimum, this suggests widespread interaction, and it presents the possibility that this ruler had foreign origins. His body also lay oriented to the north rather than the south (Audet 2006).

The royal individual in one of two tombs in Str. E (now called Str. A5) also was interred with thousands of grave goods that form one of the richest funerary assemblages in Belize and include an *ahau* glyph (Audet 2006). This structure forms part of an E-Group Complex. Most of the skeleton (Burial 1) was removed in antiquity, so body position and orientation were inferred from the remaining skeletal elements (Audet and Awe 2005). Ceramics sampled from the associated cist were all locally produced (Reents-Budet et al. 2005). The strontium isotope value is slightly higher than the baseline values, but is still considered local. The third individual, B1-9, was interred with a large number of burial goods in a crypt under room 2 in the core of Str. B1 (A1) (Piehl 2008). This individual also had local strontium values.

Residential burials

Interments of thirteen individuals were located in five residential groups, including Structures 96, 102, 112, 198, and M-164 of the Atalaya group. Non-local individuals were identified at two of the five groups sampled. Str. 198 is the north mound of the Yaxtun plazuela group, which is connected to the main group (A) by causeway 3 (Helmke and Awe 2008). Burial 198-1 had no grave goods and Burial 198-2 had a single conch shell bead. A preliminary analysis identified 198-1 as a 3-5 year old child and 198-2 as an infant aged 20 ± 8 months (Audet 2002). A later analysis (Kokkalis 2005) estimated distinct ages for the burials (198-1: juvenile, 198-2: <2 years): however, the age classes and interpretation remain the same. An infant and child buried in the plazuela group during two distinct time periods have strontium values local to the site.

Ties to the Macal River region are present in the Atalaya residential group, a four mound residential patio group 250 m south of Group II (Conlon and Moore 2003). One of two individuals in a burial identified in the eastern structure has a non-local value of .70926. However, nothing distinguishes this burial from other residential interments at Baking Pot. Burial 1 individual B was interred in the fill of a bench in a simple grave with no burial goods. The burial occurred concurrent with construction of the final floor surface and bench, and included an older female (who was not sampled) (Conlon and Moore 2003).

The Early Classic burial in Str. 112 contained two individuals in a cist with a small number of grave goods. Individual 1 (112-1-1) was the principal individual, and Burial 2 (112-1-2) consisted of a partial skeleton placed near the feet. Both values are high: the $^{87}Sr/^{86}Sr$ measure of 112-1-1 has only been identified near the Macal River zone. The other value is interpreted as local to the Belize River floodplain.

Strontium values for six individuals from the other three residential groups show consistent, local Belize River zone values. The individual interred in the construction fill of the platform of Str. 102 has a value on the low end of the Baking Pot range of local human values, while both individuals in Str. 198 have values similar to the average of the baseline fauna. The burials in Str. 96 were closely associated, the graves placed one on top of the other in the center of the platform. Each of the three individuals sampled had a small number of grave goods and was interred in the typical Belize Valley body position and orientation. Strontium values have a slightly greater range than local baselines values, but fit well with those identified in the upper Belize River valley.

Residential and other ancestor shrines

Str. 215 is the eastern structure of a small, four mound plazuela group 100 m north of Str. 190 and is interpreted as a burial shrine (McRae 2004). Six burials were identified during excavations, and many were disturbed by modern plowing activities. However, each of the four individuals sampled has a strontium value that suggests a different childhood residence. Burial 1 has a strontium value that matches local baseline values identified near the site. This individual was tentatively identified as juvenile, but lacks a cranium (Kokkalis 2005). Burial 2 has a high, but presumably local value, and was interred with numerous grave goods (McRae 2004). These individuals have values that fit each of the modes of local Baking Pot strontium isotope values.

Burial 4 has a clearly non-local value, .70955, one that has only been identified near the Macal River. However, these fragmentary remains were intermingled with those of in individual in Burial 5. Excavators tentatively observed that Burial 4 was a juvenile (McRae 2004). Although an age is not known, the strontium isotope value is sampled from permanent dentition. The individual in Burial 6 also has an isotope value identified with the Macal River region, but one that also is found in the coastal portion of the Belize Valley. The skull is missing, but the presence of conch ear flares (and teeth) suggests that it originally was present (McRae 2004).

Ricketson's (1931) excavations focused on a mound now referred to as an ancestor shrine in Str. A17 in Group A (former designation: Mound G, Plaza III, Group I). Ten burials were located in the fill of Str. A17 and five others were placed in and around its retaining walls. Four of these individuals were sampled and each has a local Belize River zone strontium isotope value. Burials 9 and 11 were located between the 2nd and 3rd plaster floors, and Burial 7 was interred above them, close to other burials with a similar body position and orientation. Burial 3 was located outside the retaining wall, interred in a depression dug into the plaster floor.

Burial 15 was located in a stone vault in the center of the mound, and contained the only individual with a significant quantity of grave goods. While osteologists described the presence of multiple individuals not reported in the excavations (Ricketson 1931), the tooth in this sample is associated with a skeleton that had modified dentition similar to Ricketson's (1931) description of the primary individual. This individual also has a local strontium isotope value (.70851).

Burial context: other

A fourth burial in the main plaza in Group A was placed beneath floor 2b on the axis between Structures A1 and A5. No burial goods were identified, but the southern orientation suggests a local origin. Two teeth for this individual were sampled, and both show local values (Audet 2006; Swain 2005).

Terminus structures and causeways

Structures 209 and 190 are terminus structures associated with causeways and linked to political activities by stelae and altars that served as loci for ritual activities in the site core (Awe and Audet 2003; Helmke and Awe 2008). Each contained multiple burials and caches that showed extensive interaction with other sites in the valley and with other regions. However, none of the five individuals sampled from these two structures have strontium isotope signatures that can be interpreted as non-local to the Belize River area.

Str. 190 is the principal terminus structure on causeway 2 (Helmke and Awe 2008). Four burials were identified along the central access of the structure (Audet 2006). The individual in Burial 3 was placed in a pit intrusive to the plaster floor on the north side of the structure. Crania in Burials 3 and 5 had evidence for trauma that resulted in a periosteal reaction in the bone tissue (Piehl and Awe 2009). The individual in Burial 3 has a locally-identified value, while the one in Burial 5 has a marginal value interpreted as non-local to the Belize River strontium zone.

Str. 209 is located on the causeway linking Groups 1 and 2. The location and material culture associated with the structure suggests that it was associated with non-household activities (Audet and Awe 2002). Three burials identified on the central axis of the structure are included in this study, and each was interred with imported vessels. Burial 1 was located in a cist under the terminal phase stairs on the west side of the platform with seven whole vessels, including a vase from western Belize and a plate sourced to Buenavista (Reents-Budet et al. 2005).

Burial 2 contained one individuals interred in a simple cist with limestone capstones on a floor and was associated with an intriguing artifact; a flute-like object of unknown origin that may have come from the Motagua Valley or coastal Mexico. This suggests a special identity for this individual, or at least some connection to distant regions (Audet and Awe 2002; Reents-Budet et al. 2005). The individual in Burial 3 was interred in a tomb in the center of the platform beneath the terminal phase floor next to Burial 4. A rich array of burials goods included jade and a vessel sourced to the Caracol area (Reents-Budet et al. 2005). However, each of these individuals has a Belize River zone value.

Burial context: not known

Unfortunately, there is no contextual information for the individual who likely moved the longest distance. Values similar to .70729 are found in the Southern Lowlands. The individual labeled Excavation 9 most likely was buried in Str. A17, but is not described in Ricketson's (1931) report. This individual was identified by one researcher as a probable female, but Tiesler's assignment of sex is indeterminate (personal communication 2009).

8c. Baking Pot summary

More than 17% of the Baking Pot sample population has non-local strontium isotope values. If all individuals with non-local values or those considered marginal are included, the estimate is as high as 25%. This figure is best understood as an estimate not only because of the marginal values, but also because migration along the Belize River is not visible in this study. Several other trends stand out. First, individuals relocated to Baking Pot from multiple places, both within the Belize Valley and over long distances.

Second, there is variability within the local values, or those that are similar to modern fauna sampled along the Belize River. This variability is also found in each burial location. Individuals in other residential group burial shrines at Pook's Hill and Zubin have very similar values, and at Cahal Pech, values at the site are generally grouped by burial location. At Baking Pot, no more than two individuals in each burial location sampled will have similar values. For example, the four individuals in Str. 215 have a Macal River zone, a marginal high value, a value in each mode of the bimodally-distributed strontium isotope values.

Many Baking Pot burials in non-residential contexts included a substantial number of imported grave goods; however, these did not reflect the individuals' origin or homeland as identified by their $^{87}Sr/^{86}Sr$ values.

9. Floral Park

Floral Park is a minor center located near the major centers of Baking Pot and Blackman Eddy (Figure 5.34). The site consists of two residential compounds that are interpreted as residences for wealthy, but not necessarily elite, rural farming households. Group 2, one of the residential compounds, is a complex plazuela group that is located northwest of the site's ceremonial architecture.

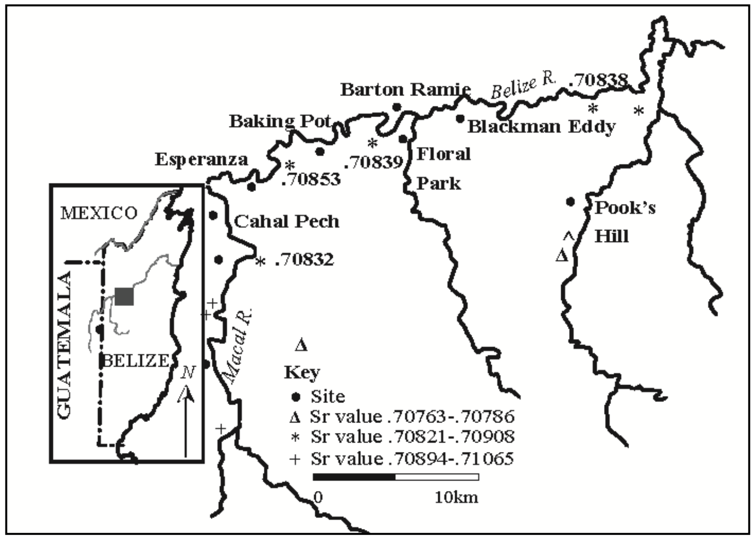

Figure 5.34. Floral Park and closest strontium isotope values.

On the east side of the plaza is Str. 2A, a residential shrine in which members of the household likely were interred (Driver and Garber 2004). The structure has multiple building episodes, but the individuals were buried at different times during the Late Classic. The site core of Floral Park is surrounded by house mounds (Iannone 2004), and it is possible that extrahousehold members of the extended family or lineage also were buried in the shrine.

Relationships between residents of Floral Park and those of other centers are not well understood. There is insufficient evidence to suggest a subordinate status to the closest major centers, Baking Pot, Lower Dover, or Blackman Eddy. Wealth indicators that suggest a degree of autonomy at other minor centers also are missing, but it is possible that control of productive agricultural land afforded a measure of independence for Floral Park residents that may have resulted in distinct trade and social networks (Driver and Garber 2004).

Table 5.11. Floral Park and strontium isotope values and burial information: Three individuals recovered from the Floral Park residential shrine. For detailed osteological information, see Appendix A. The burials were excavated by the Belize Valley Archaeological Project (BVAP) during 1994 and 1995 (Brown et al. 1996).

Burial	$^{87}Sr/^{86}Sr$	Sex	Age in yrs	Burial context and information	Date
Str. 2A B2	.70847	I	M-Oad	Burial context: residential shrine Could not be determined	Late Classic
Str. 2A B6	.70858	I	Yad	Burial context: residential shrine Could not be determined	Late Classic
Str. 2A B9	.71029	F?	Y-Mad	Burial context: residential shrine Prone position, head oriented to the south, facing down or west	Late Classic

9a. Identifying origin: analysis of the strontium isotope values

Two of the three individuals in this small sample have strontium isotope values similar to modern fauna sampled near the site (Table 5.11 and Figure 5.35). Baseline samples collected 1 - 7.5 km from the site range from .70838 to .70853 (average value .70844 ± .00008). This is slightly lower than the mean $^{87}Sr/^{8}Sr$ value for the Belize River zone (.70850), which is a close match to the average value of the individuals in Burials 2 and 6 (.708525). The individual in Burial 9, however, has a strontium isotope value that suggests a different childhood residence than the other two individuals. The only strontium zone where similar values are identified is the Macal River zone (average $^{87}Sr/^{86}Sr$ value .71051).

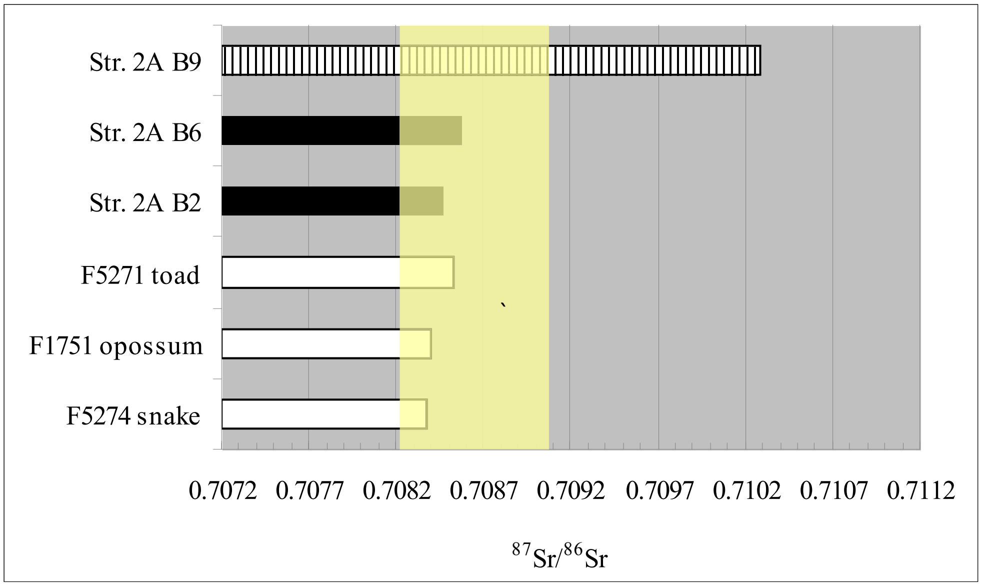

Figure 5.35. Floral Park strontium isotope values bar graph: White bars represent $^{87}Sr/^{86}Sr$ baseline values and the shaded area represents the range of values identified along the Belize River. Black bars represent each individual in the study: striped bars are individuals with isotope values not found near the site.

9b. Burial contexts and population movement

Str. 2A is interpreted as a residential burial shrine with an attached circular structure (Brown et al. 1996; Piehl 2006:580). Most of the burials were highly fragmentary with poorly preserved bones (Appendix A). Burial 2, which consists of only 20 bone and tooth fragments, was located under a staircase leading to the structure's summit, as was Burial 1 (not sampled). Several other burials and fragmentary bones were found in the structure's fill, but were not sampled because teeth were not present.

Burial 6 is described as a secondary interment consisting of long bones placed on the north-south axis of the building with a cylinder jar, ceramic figurine, and other ceramic fragments (Brown et al. 1996). Osteological analysis shows that two individuals were present, and that one individual consists of a mostly complete skeleton. Burial orientation and body position is not noted for the individuals in Burials 2 or 6.

The individual in Burial 9, however, was interred in a prone body position with a southern orientation that is commonly described in the Belize Valley (Schwake 2008). Str. 2A B9 was buried in a cist intrusive to the summit, but without grave goods. This individual's $^{87}Sr/^{86}Sr$ value is similar to those found in the Macal River strontium zone.

9c. Floral Park summary

Only three of the nine sets of human remains identified in the Floral Park residential group burial shrine have teeth that could be included in the isotopic analysis. However, one of these individuals had strontium isotope values that clearly reflect a distinct, non-local childhood residence. The strontium isotope value of two individuals is similar to baseline values sampled near the site. However, the $^{87}Sr/^{86}Sr$ value of the Str. 2A B9 individual is similar to the mean value of fauna sampled along the Macal River, near the foothills of the Mountain Pine Ridge section of the Maya Mountains.

The burial treatment of this individual reflects typical Belize Valley burial norms, but a combination of taphonomic factors, including poor skeletal preservation, looting, and post-excavation treatment of bones, limits observations on health and body modification. These are limited to filed incisors of Str. 2A B9 and an osteomyelitic reaction on at least one lower limb of Str. 2A B4, an individual who was not sampled.

Two broader observations are possible. Individuals with Macal River values also are identified in burials at Buenavista, Xunantunich, Cahal Pech, Baking Pot, and Barton Ramie, and in individuals buried in the household shrine at Zubin. Movement within the region appears to have been common, forming networks that may explain how some smaller centers were settled as population grew in the valley.

10. Barton Ramie

Barton Ramie is located in the central portion of the Belize River Valley (Figure 5.36) and is best known for Willey and colleagues' pioneering 1954-1956 excavations. The site consists of small clusters of house mounds and residential groups with occupation that lasted from the Middle Preclassic to the early Postclassic.

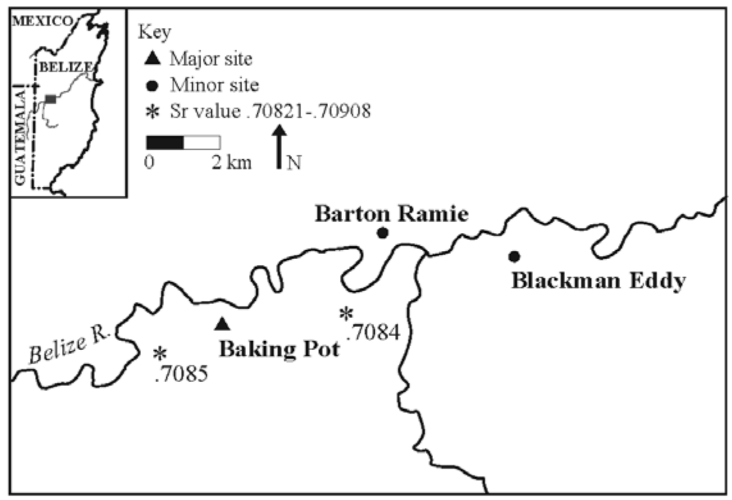

Figure 5.36. Barton Ramie and closest strontium isotope values.

Descriptions of Barton Ramie excavations serve as a reference for household archaeology, Belize Valley burial practices, and eastern lowland dietary customs (Gerry 1993; Gerry and Krueger 1997; Schwake 2008; Welsh 1988; Willey et al. 1965; Yaeger 2003). Individuals buried at the site also were used in one of the first studies of population movement using strontium isotope assays (Krueger 1985).

Driver and Garber (2004) suggest that one minor center within the Barton Ramie settlement was affiliated with Blackman Eddy. However, the relationship between the eight groups of mounds and plazuela groups and other settlement in the valley is not well understood.

Nor does Barton Ramie figure prominently in discussions of interregional interaction. Like other sites in the Belize Valley during the Late Classic, it may have been under the control or influence of Naranjo (Aimers et al. 2000; Audet and Awe 2005).

The twenty individuals included in this sample were taken from four of the loosely-defined clusters of mounds (Figure 5.37). Many of the 122 burials from the 1950s excavations were only partially uncovered or left *in situ*, with observations on age, sex, and burial treatment made under these conditions in the field (Willey et al. 1965). The sample in this study is drawn from large trenches or horizontal excavations in BR-1, BR-123, and BR-144, and test pits, generally in the center of the mounds, in BR-75, BR-130, and BR155. Published studies were an important consideration in sample selection: every attempt was made to build on Gerry's (1993) dietary study by sampling strontium isotopes in the same individuals. It was not possible to ascertain which individuals Krueger (1985) sampled, so unfortunately, these values are not considered in this analysis.

Three of the twenty Barton Ramie samples - 15% - have strontium values that indicate a different origin (Table 5.12). None of these individuals, however, had burial treatment or imported grave goods that suggest a non-local origin. Krueger's data is presented separately (in italics), and one of these individuals also has a non-local value (12.5% of the eight individuals).

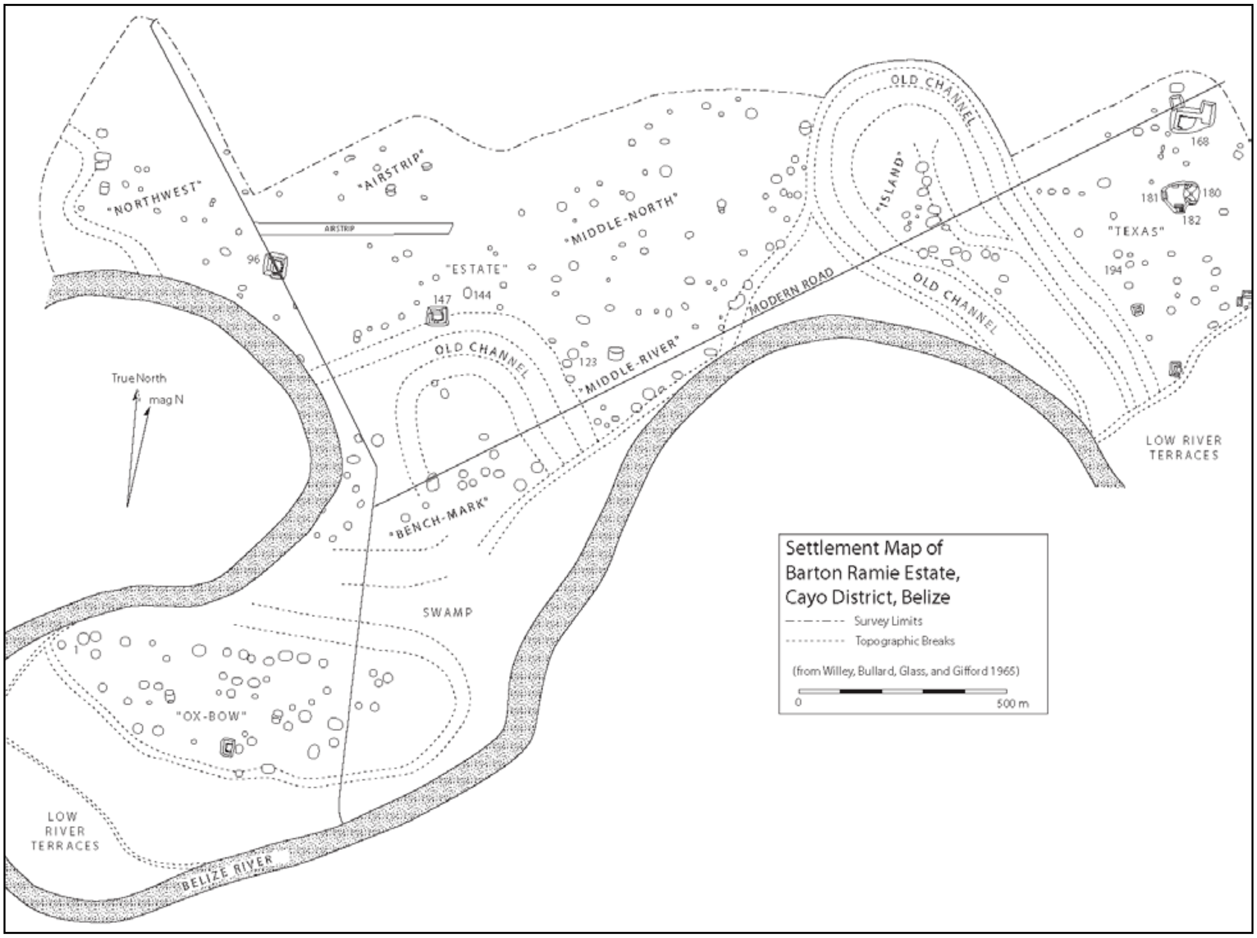

Figure 5.37. Barton Ramie site map: Map from Yaeger (2003), redrawn from Willey et al. (1965).

Table 5.12. Barton Ramie strontium isotope values and burial information: Information on sex, age and burial context from Willey et al. (1965), with modifications to age and sex assignments from Tiesler (personal communication 2009) and observations made during sampling for this study. Detailed reference information can be found in Appendix B. Data from Krueger (1985) are in italics. Spanish Lookout spans the Late to Terminal Classic, from AD 700-900, and New Town refers to occupation that continued into the Postclassic period (Gifford 1976; see comments by Yaeger 2003).

Burial	$^{87}Sr/^{86}Sr$	Sex	Age in yrs	Burial context and information	Date
BR-1 B6 N8857.36	.70858	I	Adult?	Burial context: residential Seated position, facing west	Spanish Lookout
BR-1 B10 N8857.141	.70864	M	40-60	Burial context: residential Extended, prone position, head to the south and facing east	Spanish Lookout
BR-1 B25 N8857.142	.70875	I	14-18	Burial context: residential Extended, supine position, head to the south and facing east	Spanish Lookout

BR-75 B2 N8857.127	.70860	M?	Adult	Burial context: residential Extended, prone position, with the head to south. Hands under pelvis, arms straight	Spanish Lookout
BR-123 B3 N8857.9	.70895	F	Adult	Burial context: residential Extended, prone position, with the head to the south	Spanish Lookout
BR-123 B5 N8857.25	.70868	F?	Adult	Burial context: residential unknown	Spanish Lookout
BR-123 B8 N8857.32	.70869	M	Adult	Burial context: residential Extended, prone position, with the head to the south	Spanish Lookout
BR-123 B9 N8857.33	.70959	F	Adult >45	Burial context: residential Extended, prone position, with the head to the south and the lower legs flexed	Spanish Lookout
BR-123 B11 N8857.83	.70854	I	5-6	Burial context: residential Probably extended, with the head to the south	Spanish Lookout
BR-123 B12 N8857.84	.70826	F?	Adult	Burial context: residential Extended, prone position, with the head to the south and facing down	Spanish Lookout
BR-123 B18 N8857-7	.70916	M?	Adult	Burial context: residential Extended, prone position, with the head to the south	Spanish Lookout
BR-123 B22 N8857-8	.70858	I	4-5	Burial context: residential Extended, prone position, with the head to the south and facing down	Spanish Lookout
BR-123 B23 N8857.42	.70856	M?	12-18	Burial context: residential Extended, prone position, with the head to the south, and the lower legs flexed	Spanish Lookout?
BR-123 B25 N8857.55	.70873	M	Adult	Burial context: residential Extended, prone position, with the head to the south and facing down	Spanish Lookout
BR-123 B28 N8857.134	.70848	I	20-35	Burial context: residential Extended, prone position, head to the south, and facing west	Spanish Lookout?
BR-130 B5 N8857.17	.70877	M?	Adult	Burial context: residential Seated (?)	Spanish Lookout
BR-144 B1 N8857.21	.70875	F?	Adult	Burial context: residential Probably extended, head to the south and facing west	Spanish Lookout or New Town
BR-144 B2 N8857.22	.70765	M?	Adult	Burial context: residential Extended, prone position, head to the south and facing down	Spanish Lookout or New Town
BR-144 B3 N8857.23	.70875	M	Adult	Burial context: residential Extended, prone position, head to the south and face down	Spanish Lookout or New Town
BR-155 B3 N8857.137	.70868	M	40-50	Burial context: residential Extended, prone position, with the head to the south	Spanish Lookout or earlier
BR-12	*.70871*			*No information available*	
BR-14	*.70851*			*No information available*	
BR-15	*.70853*			*No information available*	

BR-2	*.70884*			*No information available*	
BR-24	*.70858*			*No information available*	
BR-38	*.70844*			*No information available*	
BR-39	*.70867*			*No information available*	
BR-40	*.70918*			*No information available*	

10a. Identifying origin: analysis of the strontium isotope values

Strontium isotope values from three baseline samples collected within 2 - 8 km of Barton Ramie range from .70838 to .70853 (average value .708435 ± .00008). The human population is more variable: values range from .70765 to .70958. Two of these values, BR-144 B2 and BR-123 B9, are statistical outliers, while the third is higher than baseline values found along the Belize River (Figure 5.38). When these three values are removed, the mean strontium isotope value of Barton Ramie sample burial population is .70862 ± .0002.

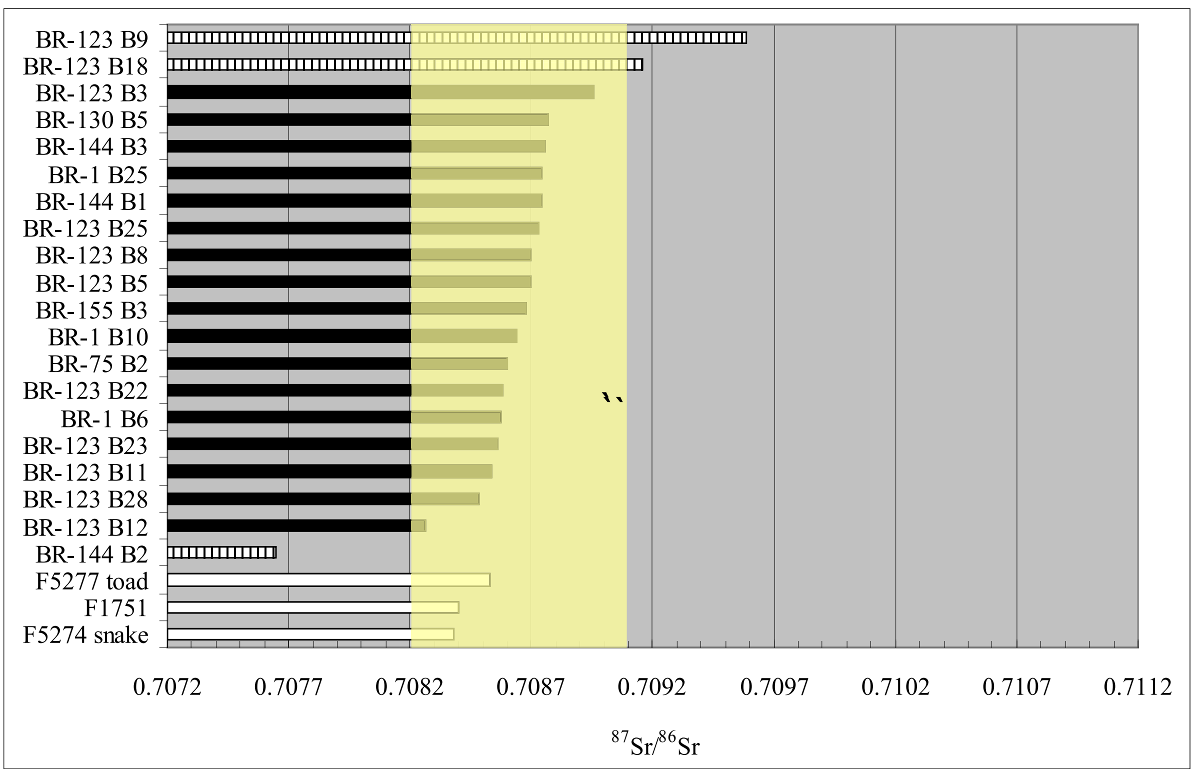

Figure 5.38. Barton Ramie strontium isotope values bar graph: White bars represent $^{87}Sr/^{86}Sr$ baseline values and the shaded area represents the range of values identified along the Belize River. Black bars represent each individual in the study: striped bars are individuals with isotope values not found near the site.

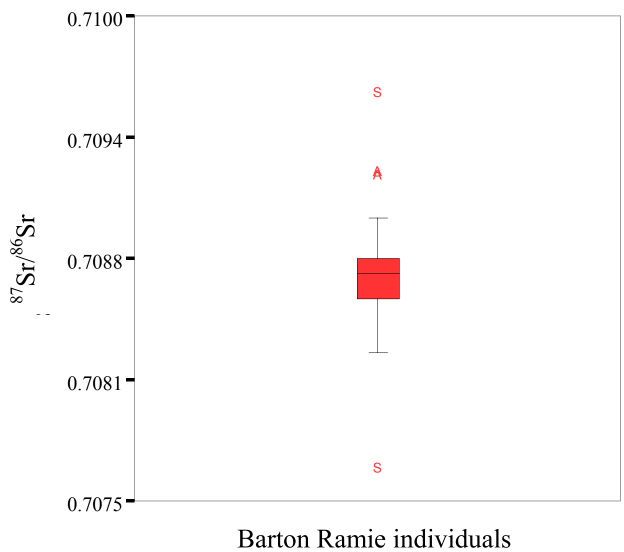

Figure 5.39. Barton Ramie strontium isotope values box plot.

10b. Burial contexts and population movement

The three individuals with non-local values have origins in two distinct areas (Figure 5.39). Two individuals (three if Krueger's sample is included) have values similar to those identified in the Macal River zone. The low value is within the range of values identified in the Southern Lowlands (Hodell et al. 2004). The high values demonstrate movement within the Belize Valley, while the low value represents interregional migration. The range of the 17 remaining values (.70829 - .70896) is a near exact match to baseline values in the central part of the Belize River zone (.70822 - .70908).

Residential burials

Mound BR-1: *B6, B10, B25*

Each of the individuals sampled in mound BR-1 has $^{87}Sr/^{86}Sr$ values that suggest a local origin. Willey and colleagues (1965) discovered 24 burials, some of which were associated with Str. F, a circular structure early in the sequence of architectural modifications to BR-1 (Aimers et al. 2000). This layout typically is associated with burials, and circular structures often were re-used centuries after the circular building was replaced by a different structure (Aimers et al. 2000; Powis and Hohmann 1994). As with most burials at the site, graves were described as simple pits, but there was some variability in burial patterns, including among individuals with Belize River zone isotope values.

BR-1 B6 was unique not only for the large quantity of grave goods associated with the burial, but because the individual was placed in a seated position, facing west. Burials in the Central Petén frequently have western and northern orientations (Welsh 1988; Schwake 2008), but this individual has a Belize River zone value.

The individual in Burial 10 was interred beneath Burial 6 in the floor of a terrace in a prone body position, with the head oriented to the south. The left hand lay under the pelvis and the right arm was extended, next to the femur (Willey et al. 1965). In contrast, the individual in Burial 25 was placed in a supine position, with the upper body turned onto its right side and both arms in a flexed position. Willey and colleagues (1965) relate the body position to the proximity of a retaining wall for the circular structure (which the burial postdated). B4 type filing of the upper incisors, a common dental modification, also is described. Both individuals had a small number of grave goods.

Mound BR-75: B2

BR-75 is the largest of twenty closely-spaced mounds in the eastern portion of the site. Excavators discovered three burials, one of which is included in this sample. The individual in Burial 2 was placed on what appeared to be a burned surface on a stone slab cist that covered Burial 3. While Burial 3 contained no funerary goods, Willey and colleagues (1965) interpreted burned material (including maize) on top of the cist as a burial rite also that included Burial 2 and two vessels located that were located near the individual's head. However, the excavation report also states that these individuals may have been interred at different times (Willey et al. 1965). The individual in Burial 2 was buried in a prone position, oriented to the south, and has a local strontium value.

Mound BR-123: B3, B5, B8, B9, B11, B12, B18, B22, B23, B25, B28

BR-123 is located in the central section of the site, and likely formed part of a plazuela group that was one of the most extensively excavated at the site. Thirty-five burials were discovered: 11 individuals are included in the study, and two have values that suggest an origin in the Macal River strontium zone. Each of the individuals included in this study was interred in an extended or partially extended body position with a southern orientation with the exception of the individual in Burial 5, whose body position is not known.

Nine individuals have local strontium values, including Burial 3, an adult female, and Burial 12, a 5-6 yr-old who excavators surmise was her child. Four additional burials in this residential group, B22, B23, B25, and B28, were located in the fill below one of the upper floors, including a child, an adolescent, and two adults. There is substantial variability in the quantity of grave goods: Burial 22 had multiple grave goods, while none were found with Burial 23 (Willey et al. 1965).

In contrast, the individual in Burial 18 has a Macal River strontium zone value (.70916). This probable male was associated with four vessels, but was buried in close proximity to other burials, at least one of whom has a local strontium value. A female was interred in Burial 9 (Tiesler personal communication 2009) above floor F, along with more than ½ dozen other individuals above or just below this floor surface. She was buried with a southern orientation, with her legs flexed so that the lower legs lay parallel to the upper ones (Willey et al. 1965). While a flexed position was not common, this burial treatment does not appear to relate to origin, sex, or age.

Mound BR-130: B5

BR-130 is located in the central northern area of the site approximately 250 m from BR-123. Willey and colleagues (1965) placed a test pit into BR-130 and found five burials, most of which were only partially excavated. Only one is included in this study. The individual in Burial 5 was likely in a seated position and accompanied by two vessels. Burial 5 was located under Burial 3, which contained an individual who also may have been placed in a seated position. A seated burial position is not common in the valley, but is also identified at Saturday Creek and in mound BR-1. All three of these individuals have local strontium values, suggesting that this position may relate to status, age, or some difference in individual identity other than place of origin.

Mound BR-144: B1, B2, and B3

BR-144 is a medium-size mound with seven burials discovered in a single test pit located to the west of BR-130 in the central section of the site. Three of the individuals were included in this study and have local strontium isotope values. While Burials 1 and 3 were only partially excavated, Willey and colleagues (1965) reported prone burial positions oriented to the south.

The individual in Burial 2, however, has an isotopic signature that indicates an origin in the Southern Lowlands. Neither the location of the burial nor the body position and orientation suggest a non-local origin: Burial 2 was placed directly above the comingled remains of Burials

3 and 4. The individual was interred in a prone position with a southern orientation, with the left arm was flexed and placed at the jaw and the right arm extended under the pelvis.

Mound BR-155: B3

BR-155 is located near BR-144, and is referred to by Willey and colleagues (1965) as a tiny mound (Willey et al. 1965). No burial goods were reported in any of the six burials, but some were only partially excavated. The individual in Burial 3 was buried in extended, prone, and oriented to the south. While the Burial 3 individual was distinguished from others at the site by F9 type filing of the upper incisors, the strontium value is local to the Belize River zone.

10c. Barton Ramie summary

Fifteen percent of the burial population sampled at Barton Ramie has non-local strontium isotope values, and if movement from places with similar isotopic signatures also occurred, the rate of migration is higher. The non-local individuals came from two distinct areas. A female and a probable male with Macal River strontium zone values were buried in the same structure, showing movement within the Belize Valley, which also has been identified at other sites. The origin of the third non-local individual most likely represents interregional migration.

Barton Ramie results show two key aspects of population movement within the Belize Valley. First, migration included individuals in hinterland settlement and residential groups interpreted as commoner residences: it was not limited to elite individuals or those residing at major centers. Second, a great deal of mobility is not visible without isotopic assays. Burial treatment of those born locally was similar to those who relocated to the site. Conversely, individual who received distinct burial treatment, like the seated burials, have Belize River zone isotope values. No patterns were visible within the variability that existed in body position and orientation that appear to relate to origin; in fact, the non-local probable male was buried in close proximity to individuals with strontium isotope values interpreted as local to the site. Some individuals had burial goods, and some did not: only 1/3 of the individuals were buried with goods (Willey et al. 1965). Only one of the individuals with non-local isotope values had modified dentition, which was present only in a small number of individuals at the site. The intimate nature of a household burial, in which the dead are incorporated into the lives of the living generation after generation, tells a story of assimilation in which the place of birth played a less important role than other factors in an individual's identity.

11. Blackman Eddy

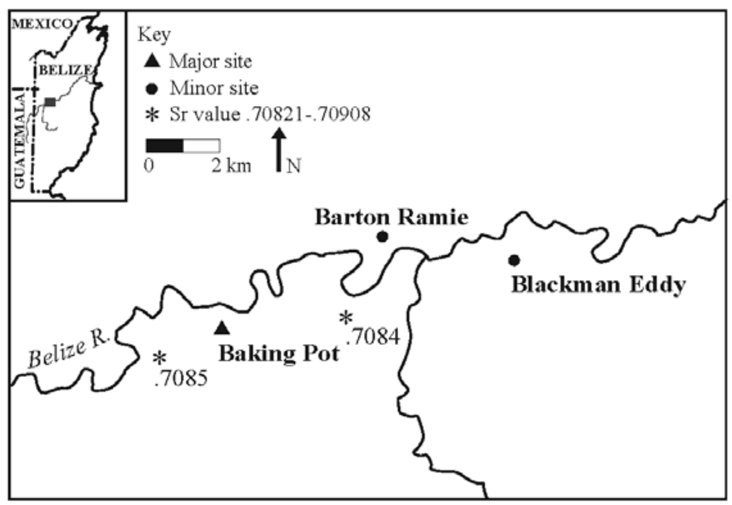

Figure 5.40. Blackman Eddy and closest strontium isotope values.

Blackman Eddy is a major ceremonial center located on the south side of the Belize River 2 km from Barton Ramie (Figure 5.40). Garber and colleagues (2004) suggest that it may have been the administrative center for the region. The site core consists of two plazas aligned on a north-south axis, and burials were discovered in structures lining both plazas.

Blackman Eddy has a settlement history that begins during the Preclassic, which is an important research focus at the site. Burials recovered from Str. B-1 in Plaza B show the center's continued prominence during the Late Classic, where grave goods like jade and polychromes show participation in broader elite interaction spheres. Networks of Blackman Eddy elites likely were similar to those of other centers along the Belize River during the Late Classic.

Burials also were recovered from Str. A-4, a tripartite structure on the east side of Plaza A. Both Strs. A-4 and B-1 were severely damaged by looting and bulldozing operations, but contexts remained sufficiently intact to allow excavators to make comparisons with ancestor shrines at other sites (Garber et al. 2004). They suggest that the individuals buried in Str. A-4 had close ties to the site and as venerated ancestors, their association with construction sequences of the building demonstrated their connection to the local landscape (i.e., McAnany 1995). Blackman Eddy has a long occupation history with ritual deposits in building's in the site core spanning thousands of years.

The long occupation history of Cahal Pech may relate to local isotope values for all but one of the individuals buried in the site core and residential groups nearby. While only three individuals were sampled from Str. A4 at Blackman Eddy, each of these also has local isotope values that closely matched baseline values identified near the site (Table 5.13).

Table 5.13. Blackman Eddy strontium isotope values and burial information: Blackman Eddy osteological analysis is included in Appendix A. Burials were excavated during 1990 excavations by the Belize Valley Archaeological Project (BVAP) and described in Garber et al. (2004).

Burial	$^{87}Sr/^{86}Sr$	Sex	Age in yrs	Burial context and information	Date
Str. A-4 2C-B1	.70848	I	A	Burial context: royals and rulers Extended, head oriented to the south	Late Classic
Str. A-4 2C-B2	.70861	I	C	Burial context: other Not described	Late Classic
Str. A-4 2C-B3	.70858	I	Ao-Yad	Burial context: other Not described	Late Classic

11a. Identifying origin: analysis of the strontium isotope values

Strontium values for each of the individuals fall within the range of local Belize River zone signatures. Three modern samples were collected along the Western Highway between two and ten kilometers from Blackman Eddy. These range in value from .70838 to .70853 (average value .70843 ± .00008). Strontium values for the individuals buried in Str. A-4 fall within this range, with an average value of .70856 ± .00007 (Figure 5.41). This is similar to the average value of the central valley (.70853) and of valley as a whole (.70850).

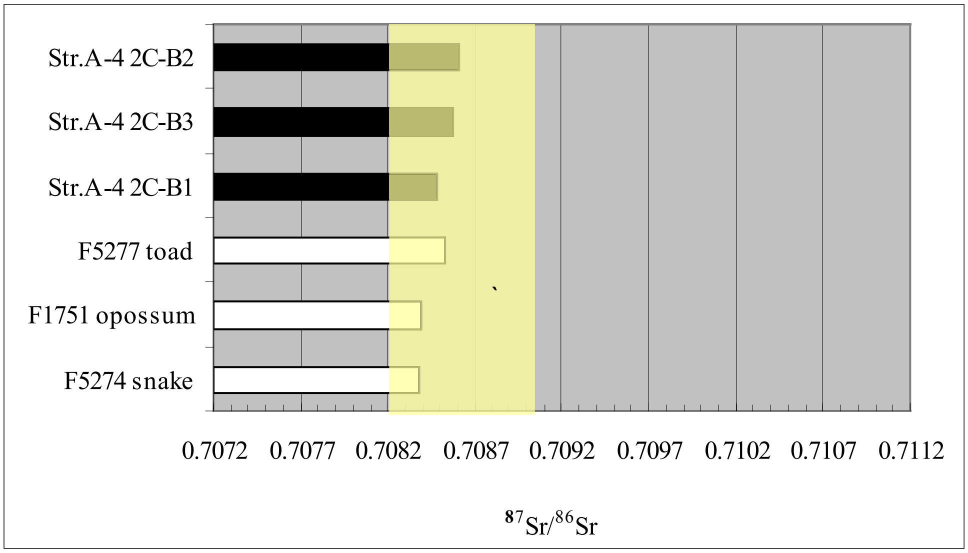

Figure 5.41. Blackman Eddy strontium isotope values bar graph: White bars represent $^{87}Sr/^{86}Sr$ baseline values and the shaded area represents the range of values identified along the Belize River. Black bars represent each individual in the study.

11b. Burial contexts and population movement

The three individuals were discovered as excavators cleared part of a looter's trench in Str. A14. The adult referred to as Burial 1 was interpreted as the principal individual in a narrow crypt constructed with roughly dressed limestone. An adult was interred in an extended position, with the head oriented to the south. While no associated grave goods were reported, excavators interpreted the remains of two other individuals, a child and an adult, as secondary deposits for the primary individual (Garber et al. 2004). Located to the east of the crypt, the child burial is described as a poorly preserved set of remains consisting of a skull with four long bones passing through it. The secondary adult burial is also reported as a skull and long bones, suggesting to excavators veneration of important ancestors.

Osteological analysis of the burials suggests that each individual was originally interred complete. Burial 1 contained the poorly preserved remains of one individual, including upper and lower legs, ribs, scapulae, vertebrae, and skull elements. A single trait of the skull suggests that the individual was a male, though the skeleton overall had a gracile appearance. While the possible male had significant antemortem tooth loss and remodeling of the mandible, the age is indeterminate.

The individuals in Burials 2 and 3 also likely were interred as complete bodies, though each is represented only by a partial set of remains. Burial 2 contains portions of the vertebral column, both clavicles, ribs, and several possible hand and foot bones, in addition to skull and long bone elements. Development of two teeth associated with the remains suggests an age range of 3.6 -6.4 years. This estimate is supported by bone size, with the exception of a tibia and femur fragment. Their size and preservation, which resembles the poor preservation of Burial 3, suggest that they belong to that individual.

The individual in Burial 3 also likely was interred complete. In addition to skull and long bone fragments, rib and pelvis fragments were identified. Duplicate elements from a smaller individual also are present, and likely belong to Burial 2. Like Burial 2, information on age is provided by the teeth. These show minimal wear that suggests an age category of adolescent to young adult (Ubelaker 1989 in White 2000). Details are provided in Appendix A.

Each of the strontium signatures is local to the Belize River strontium zone, which supports the original interpretation of the context as one of local significance. Moreover, the values are very similar, suggesting a shared origin for foods consumed during childhood in the vicinity of the site.

11c. Blackman Eddy summary

The three individuals in burial shrine Str. A-4 have average strontium isotope values that fit well with those identified in the Belize River zone. Values this similar suggest a shared origin for major food sources. This statement carries greater weight when interpreted in conjunction with values from Cahal Pech, where burials in the same location have strontium values that formed clusters within the local values at the site. Each of these sites had long occupation histories and little measureable in-migration.

The link between long-term occupation of an area and local strontium values is limited by two methodological considerations. First, despite the recent focus on Preclassic occupation of the valley, the Late Classic period remains the most well-known era in the Belize Valley. Additional excavation work may reveal earlier occupation at other sites like Esperanza that could change the proposed connection between relatively late settlement histories and the high rate of in-migration identified at Xunantunich and Esperanza.

Second, similar isotope values along the Belize River means that movement among sites within the strontium zone is largely invisible. Cahal Pech and Blackman Eddy may have had in-migration from sites within the Belize River Valley that cannot be recognized using isotopic assays.

12. Pook's Hill

Pook's Hill is a plazuela group located near Roaring Creek, which flows into the Belize River near the modern city of Belmopan (Figure 5.42). The number of structures with domestic assemblages suggests that an extended family or lineage with an estimate of 20 members likely resided at the site (Helmke et al. 2006).

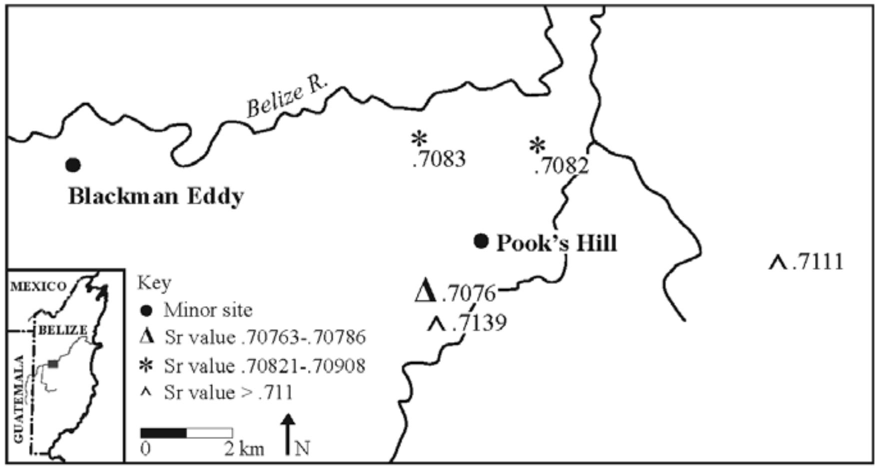

Figure 5.42. Pook's Hill and closest strontium isotope values.

Burials were found in and around multiple buildings, as well as in nearby caves, but the burials in this study were located in Str. A-4. This non-residential building is located on the east side of the plaza, and had a layout distinct from other buildings at the site in each of its construction phases, from its original square or sub-rectangular shape to its final configuration as a round shrine with a double terrace (Helmke et al. 2006; Helmke 2003). Helmke and colleagues (2006) note the increased presence of foreign vessels in the Belize Valley during the Terminal Classic, and changes in architecture at several sites suggest increased influence from the northern Yucatan.

Late Classic round structures were unusual in the Maya Lowlands, and their appearance during the Terminal Classic often draws comparisons with architecture at Chichén Itzá. Yucatecan influence is proposed for at least three sites in the Sibun River valley, a river system flowing parallel to the Belize River less than 20 km away (McAnany et al. 2004). It is an intriguing possibility that the transformation to a circular layout at Pook's Hill reflects contact with similar foreign networks. A change in burial style also was noted at the same time: Burial 4A-3, a richly equipped grave, contained multiple individuals.

Other medium and long distance social networks are evidenced by artifacts at Pook's Hill. Helmke and colleagues (2006) interpret a Primary Standard Sequence (PSS) reference on a vase found at the site as that of an historic individual also identified at the Central Petén site of Uaxactun. They note that similar statements are often linked to presentation of captives taken in raids or rites related to ancestors, but the vase is not connected to a particular burial at the site. Pook's Hill likely had closer ties to the minor center of Chaac Mool Ha, less than 1 km away, and the major center of Cahal Uitz Na, located less than 5 km to the south (Helmke 2006).

Table 5.14. Pook's Hill strontium isotope values and burial information: Demographic and burial information comes from published reports (Bassendale 2000; Helmke 2000a, 2003; Helmke et al. 2001, 2006) and unpublished information (Jennifer Piehl personal communication 2010). The burials were excavated between 1999 and 2002 by the Belize Valley Archaeological Reconaissance Project (BVAR).

Burial	$^{87}Sr/^{86}Sr$	Sex	Age in yrs	Burial context and information	Date
Str. 4A LP	.70852	I	Yad?	Burial context: residential shrine Head oriented to the south: possibly extended position	AD 700
Str. 4A-1	.70893	M?	Mad	Burial context: residential shrine Oriented to the south, prone position, facing west	AD 830-950
Str. 4A-2	.70845	I	Y-Mad 30-40	Burial context: residential shrine Oriented to the south, possibly in an extended, prone position, facing west	AD 500-700
Str. 4A-3 B	.70813	F?	Yad	Burial context: residential shrine Oriented to the south, facing west	AD 830-950
Str. 4A-3 C	.70833	M	M-Oad 40-50	Burial context: residential shrine Oriented to the south, facing west	AD 830-950
Str. 4A-3 G	.70824	M	Mad	Burial context: residential shrine Oriented to the south, facing west	AD 830-950
Str. 4A-5 A	.70844	M	Mad	Burial context: residential shrine Oriented to the south, facing west	AD 830-950

Str. 4A-6	.70846	M?	Yad	Burial context: residential shrine Oriented to the south, prone position, facing west	Late-Terminal Classic
Str. 4A-7	.70823	I	I	Burial context: residential shrine Oriented to the south, prone position, facing west	Late-Terminal Classic

12a. Identifying origin: analysis of the strontium isotope values

Three baseline samples found within ten kilometers of the site range from .70838 to .70853 (average value .70844). This is nearly identical to the mean of the individuals buried in Str. 4A (average value .70841 ± .0002): all individuals have values similar to those found in the Belize River strontium zone (Table 5.14 and Figure 5.43). One value is slightly lower than the baseline values. If it is excluded, the average human value (.70845) nearly equals that of the Belize River faunal baseline. However, the two closest baseline samples have different values. *Jute* shells sampled from Roaring Creek just a few kilometers upstream have a low Central Lowland zone value (.70777) and a high Maya Mountain zone value (.71392). It is important to note that neither of these values represents the strontium isotope average of any Belize River zone human population identified to date. The snail with the high value might easily have washed downstream, but this is a geologically variable area that could results in different average strontium values at sits nearby.

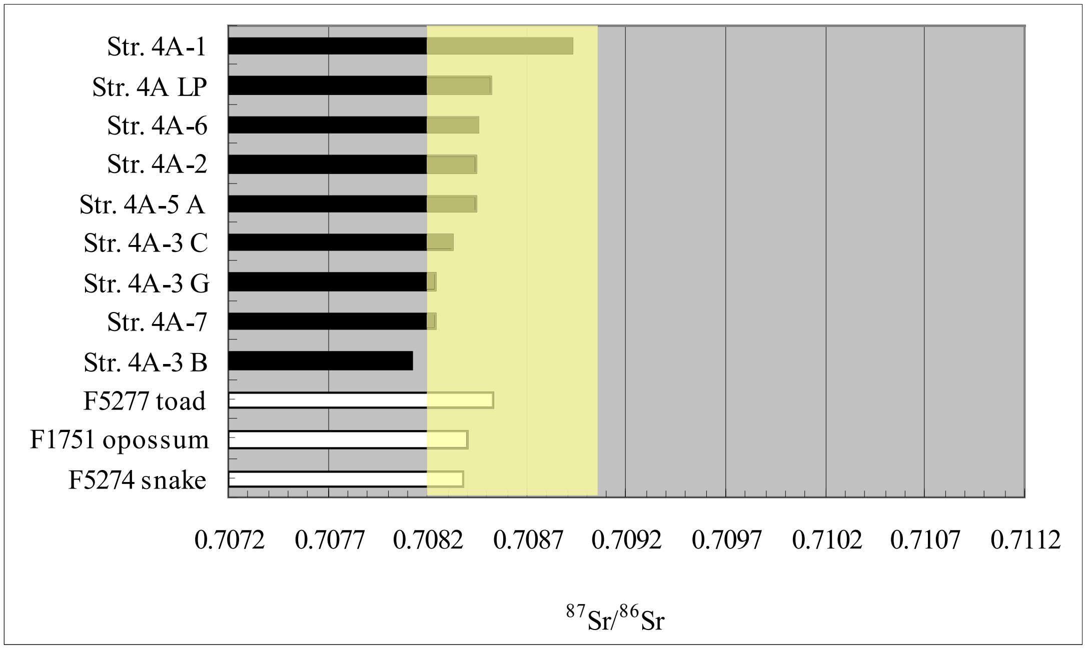

Figure 5.43. Pook's Hill strontium isotope values bar graph: White bars represent $^{87}Sr/^{86}Sr$ baseline values and the shaded area represents the range of values identified along the Belize River. Black bars represent each individual in the study (including marginal values).

The lack of variation within this sample population results in one statistical outlier (Figure 5.44). While this falls within the range of values sampled in the Belize River zone, it is apparent that the individual with the .70893 value had a different childhood diet than the others buried in the same structure. This is reasonable, since this is the latest interment in the sample, and the burial may postdate occupation at the site. The value could indicate food sources near the site as well as elsewhere in the valley or along the coast.

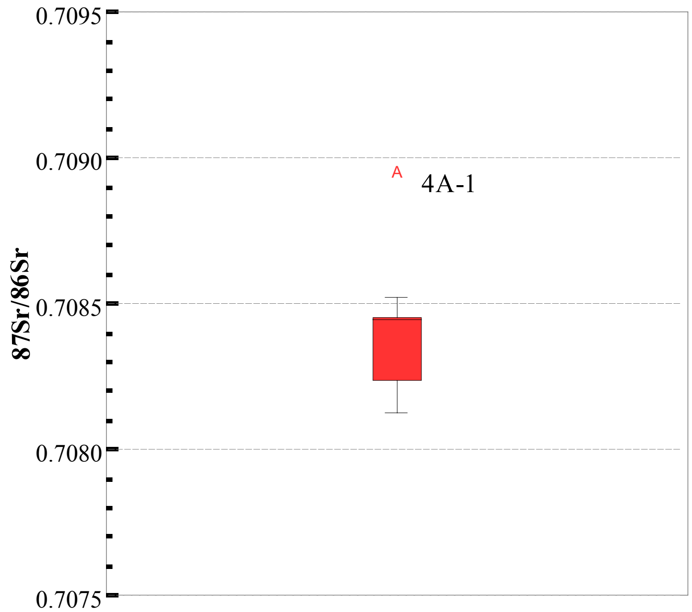

Figure 5.44. Pook's Hill strontium isotope values box plot: One outlier value (IQR) still falls within the range of Belize River strontium zone samples. A second value does not, but is similar to most human values identified at the site.

The .70813 value, however, is lower than the baseline values identified along the Belize River. This marginal value also could represent in-migration, but is not markedly different than the other values. Both or neither of these individuals could have relocated to this residential group. Neither value can be securely interpreted as non-local Pook's Hill.

12b. Burial contexts and population movement

Eleven burials were identified in the plazuela group, and all were single interments with the exception of Str. 4A Burial 3, which contained the partial and complete remains of seven individuals. Four of these individuals were sampled, along with five individuals from other burials in the same structure. Most were primary interments found within a series of plaza floors. Although there are possible associations with nearby caches, most lacked funerary goods, with the exception of personal items like beads or necklaces (Helmke et al. 2006:179).

Burial treatment of the two individuals with the high and low isotope values did not show notable differences. All individuals in the sample were interred with a southern orientation, many in a prone and/or extended position. Eight individuals also faced west (the position of the ninth is unknown). Whether the individuals were oriented to face the plaza, or some other location, it shows uniform treatment. The large capstones on the grave of Burial 4A-1 (the outlier high isotope value), also resembled other construction techniques elsewhere in the Roaring Creek Valley.

Two burials differed from others at the site, and one contained the individual with the low $^{87}Sr/^{86}Sr$ value, Burial 4A-3 Individual B. Burial 4A-3 contained the remains of seven individuals and was located under the core of the terminal outset stair. Six of the individuals lay parallel to the steps and to one another, with some remains close enough to be intermingled. The interments ranged from primary burials of complete skeletons to the secondary deposit of at least one skull. Body position was variable, with both flexed and extended positions visible in the drawing. A large number of burial goods also were present, including multiple vessels, granite, shell, jade, and perishable items (Helmke 2003).

The second burial, Burial 4A-7, had a greater number of burial goods than the others, but the individual also has a Belize River zone strontium isotope value. One other burial merits a brief discussion. The context of Burial 4A LP was reconstructed by archaeologists salvaging materials from a crypt looted long before the excavations. The proximity of human remains and pottery allowed Helmke and colleagues to reconstruct the Looter's Pit (LP) burial, but body position and placement is not certain (Helmke et al. 2000a).

More than half of this sample had some type of dental modification. No cranial or dental modification is noted for Burial 4A-3 Individual B with the marginal low value, and evidence for healed pathology is similar to observations on the rest of the burial population in this study (Piehl personal communication 2010). In contrast, the individual with the high value in Burial 4A-1 has both Romero's (1970) type C-3 and B-7 dental modification (Helmke et al. 2000b). Information on the complete burial population that can be used for comparative purposes is not yet available.

12c. Pook's Hill summary

The Pook's Hill Str. 4A sample burial population provides another example of a single burial location, likely of a lineage or family, where individuals have very similar strontium isotope values. The overwhelmingly local values for the burials are supported by the similarity in orientation and other aspects of burial treatment. Yet one of these individuals obtained food from a different source during early childhood. An origin in the Northern Yucatan is possible: isotope values for the Belize River Valley and the Northern Lowlands are indistinguishable. Individuals in Str. 4A-1 Burial 3 also could have origins in the Northern Lowlands that would not be visible using strontium isotope assays.

None of the nine Pook's Hill interments can be clearly designated migrants to the Belize Valley strontium zone. No aspect of burial treatment is different either for the high value that is a statistical outlier (IQR) from the rest of the values, or the marginal value that is lower than the baseline values. Local isotopic variability within the Belize River strontium zone is explored further in Chapter 6 using nitrogen and carbon bone collagen and apatite assays to compare other aspects of diet. The focus is on sites with documented non-local foods, like the parrotfish reported at Pook's Hill. There does not appear to be a link between strontium isotope variability and long-term dietary differences.

13. Saturday Creek

Saturday Creek is located in the central Belize River valley and is comprised of a site core with ceremonial architecture that includes small temples, a ballcourt, and dispersed settlement north of the Belize River (Figure 5.45). The site has a long occupation history that spans the Preclassic through the Postclassic periods (Lucero 2006). Interaction spheres may differ from sites in the upper Belize Valley. Recent analysis of the ceramic assemblages shows more similarity with centers to the east in the Sibun Valley than the Central Petén (Eleanor Harrison–Buck personal communication 2009).

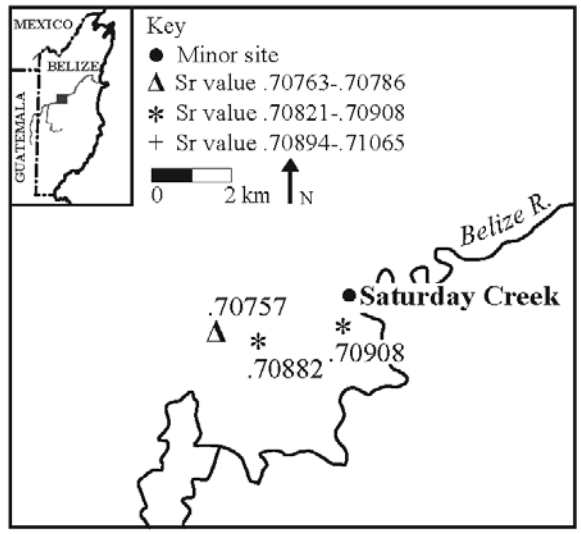

Figure 5.45. Saturday Creek and closest strontium isotope values.

All of the Saturday Creek burials were located in two house mound structures near the site core, including three burials in house mound SC-18 and five burials in SC-85 (Table 5.15). The structures were located less than 150 m from the site core, and less than 250 m from each other. Greater architectural investment and material goods led excavators to attribute a higher socioeconomic status to SC-18, but both are interpreted as commoner residences (Lucero 2006).

Table 5.15. Saturday Creek strontium isotope values and burial information: The sex, age and context of the burial information is derived from Piehl (2002), Sanchez and Chamberlain (2002), and Lucero (2006), which also draws from Sanchez and Piehl (2002).

Burial	$^{87}Sr/^{86}Sr$	Sex	Age in yrs	Burial context and information	Date
Str. SC-18 B2	.70861	M?	14-20	Burial context: residential Seated, legs crossed, facing south	AD 800-900
Str. SC-18 B5	.70912	I	40-50	Burial context: residential Extended position, head to the south	AD 400-600

Str. SC-18 B7	.70902	F	20-30	Burial context: residential Extended position, head to the south	AD 700-800
Str. SC-85 B1	.70927	F	24-30	Burial context: residential Extended, prone position, head to the south and facing east	AD 700-900
Str. SC-85 B3	.70851	I	10-12	Burial context: residential Seated with legs under chin, facing west (also called bundle burial)	AD 600-700
Str. SC-85 B4	.70888	I	1-4	Burial context: residential Extended, prone position, head to the south, face down	AD 800-900
Str. SC-85 B6	.70840	M	18-25	Burial context: residential Extended, prone position, head to the south and facing east or down	AD 400-600
Str. SC-85 B8	.70857	M	24-30	Burial context: residential Extended, supine position, head to the southeast and facing east	AD 700-900

13a. Identifying origin: analysis of the strontium isotope values

Samples collected near Saturday Creek show a higher, and more variable, range of expected strontium isotope values than elsewhere in the valley. The lowest value (.70757) was identified in a terrestrial snail shell. A rabbit bone sampled from the same field has a value of .70882, similar to that of an opossum tooth sampled less than 1 km from the site core (.70908). The low value is a statistical outlier for the Belize Valley floodplain. It may represent an isolated geologic value or microregion due to the small range of the snail, rather than the average biologically available strontium in the catchment of the site. The two higher values have a mean of .70895, while all three samples average .70849, close to the average value for all Belize River zone samples (.70850 $^{87}Sr/^{86}Sr$).

All but two individuals have $^{87}Sr/^{86}Sr$ values with the range of the Belize River strontium zone samples (Figure 5.46 next page). Although one of the highest baseline values identified along the Belize River was collected near Saturday Creek, both .70927 and .70912 values match those of the Macal River strontium zone. Statistically, only the highest value (SC-85 B1) is an outlier, while the second value (SC-18 B5) is a marginal value. The average value for the seven remaining individuals is similar to other sites located along the Belize River, .70869, despite the higher values identified near the site.

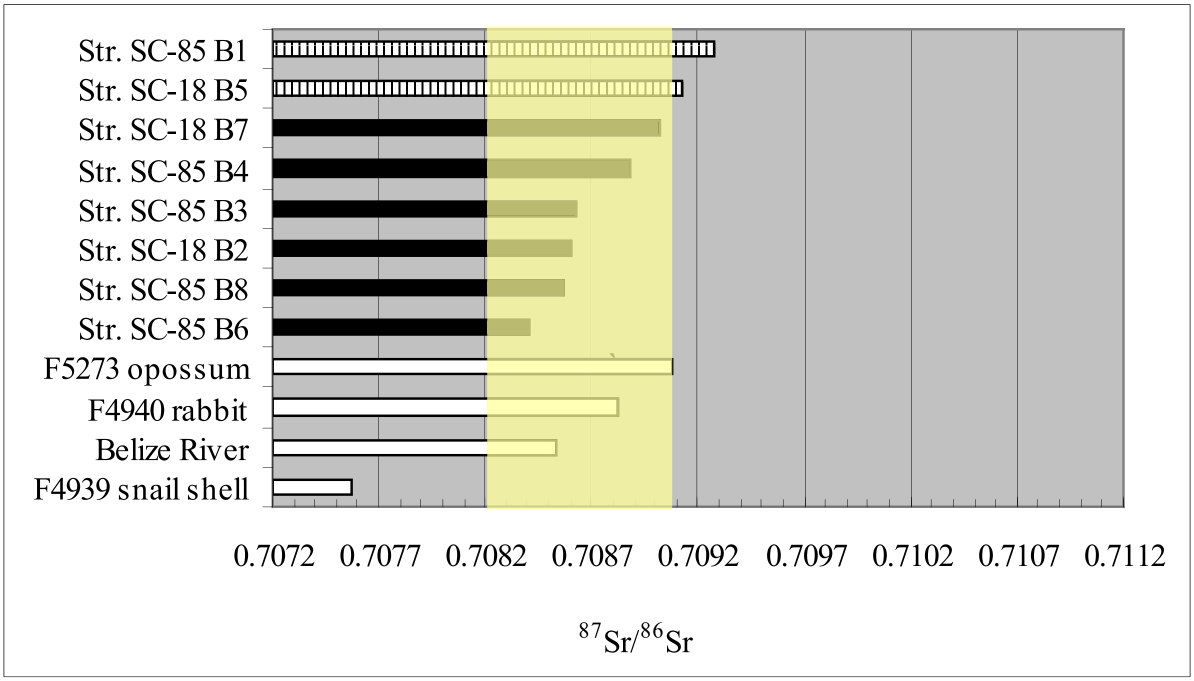

Figure 5.46. Saturday Creek strontium isotope values bar graph: White bars represent $^{87}Sr/^{86}Sr$ baseline values and the shaded area represents the range of values identified along the Belize River. Black bars represent each individual in the study: striped bars are individuals with isotope values not found near the site.

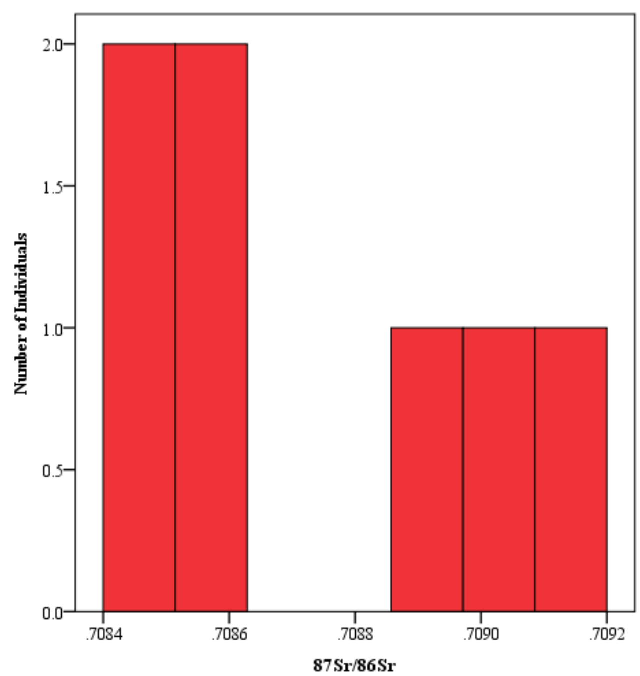

Figure 5.47. Saturday Creek strontium isotope values histogram.

13b. Burial contexts and population movement

Figure 5.47 (previous page) shows a bimodal distribution of values at the site. If each mode corresponded to a house mound, it could suggest use of different catchments within the polity for major food sources. Instead, the individuals buried in each residence have a range of values, and each residence includes the burial of an individual with a Macal River zone value.

All Saturday Creek interments were located in structure floors with limited, if any, grave construction. Most were placed in an extended position, with the head oriented to the south, the norm for the Belize Valley (Piehl 2002; Schwake 2008; Welsh 1988; Willey et al. 1965; Yaeger 2003). Two adolescent individuals, one in each house mound, were buried in a seated position. While one was oriented to the west instead of the south, both have strontium isotope values similar to the Belize River zone average value.

Three individuals in the SC85 house mound have $^{87}Sr/^{86}Sr$ values similar to the mean of the Belize River strontium zone. Two individuals have higher values: one of these is similar to baseline values identified near the site, while the other suggests an origin in the Macal River zone. The latter is a female who was interred without grave goods, as were fewer than half of the burials in the structure (Sanchez and Chamberlain 2002; Lucero 2006).

Two of the three burials in the SC-18 house mound have high values, one that falls within the range of Belize River zone values and one that suggests an origin in the Macal River zone. The third individual, who was buried in a seated position, has a Belize River zone value. This was one of the richest burials at the site, but all individuals interred in SC18 were buried with grave goods (Sanchez and Chamberlain 2002, Lucero 2006).

Piehl's (2002) osteological analysis shows strong similarities between the individuals in each residence. She describes a burial population with a notable number of chronic infections and childhood stresses that may evidence frequent illness or parasitic infections, despite a lack of evidence for increased mortality or malnutrition. Likewise, carbon and nitrogen bone collagen assays (see Chapter 6) show a uniform diet with depleted carbon isotope values relative to other lowland sites and a reliance on terrestrial protein sources (Piehl 2002, 2006). Similar findings are reported from Baking Pot and Barton Ramie (Gerry 1993). Only two individuals had dental decoration, and none had cranial modification (Sanchez and Chamberlain 2002, Piehl 2002). All of these patterns suggest that the individuals came from the same general population.

13c. Saturday Creek summary

Two of the eight individuals of the Saturday Creek sample have $^{87}Sr/^{86}Sr$ values that are not found near the site. One value is higher than baseline values identified along the Belize River zone, but is not a statistical outlier. This results in an estimate of 13 – 25% non-local individuals in the sample population. Each non-local individual was interred in a different house mound, and each was identified as female. Four males have Belize River zone values. There was variability in burial treatment, but this did not correspond to the differences in isotopic signatures. Like those buried in Baking Pot residences, these individuals have variable isotope values.

However, all values identified in the sample population can be found within the Belize Valley, where similar patterns of burial treatment and diet are reported (Gerry 1993; Schwake 2008). Similarities in diet, patterns of health, and burial orientation also are visible in the Saturday Creek population. This supports the assumption that the closest location for each set of strontium values is the most plausible place of origin. In addition, Macal River zone values have not yet been identified elsewhere in the Maya lowlands. Population movement within a region might not leave patterns that are visible without isotopic assays.

14. Franz Harder and Chapat Caves

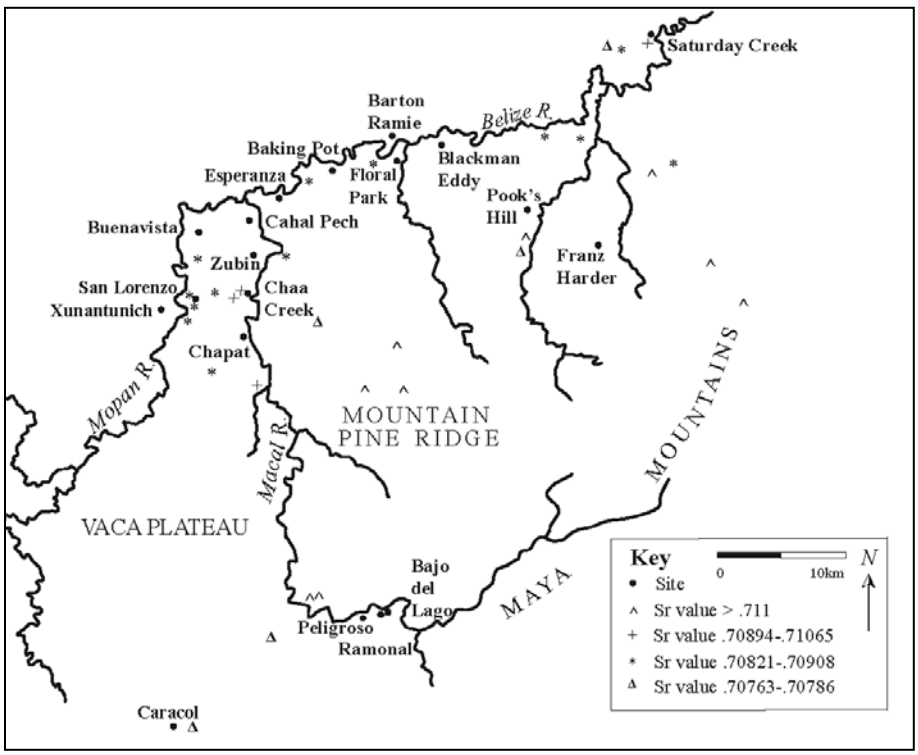

Figure 5.48 Chapat and Franz Harder cave sites and strontium isotope values

Maya use of caves is well-documented, and extensive research on Late and Terminal Classic cave use in the upper and central Belize River valley has resulted in two views on the nature of burials in caves. Evidence in some cave contexts, like Actun Tunichil Muknal in the Roaring Creek Valley, supports the view that cave burials often represent sacrificial contexts (e.g., Gibbs 2000). These interments may include individuals on the margins of society who were perceived as dangerous, or those without a strong support system (Lucero and Gibbs 2007).

Caves also may have served as cemeteries for the broader population, answering a longstanding question about where much of the population was laid to rest (Bonor 2002; Glassman and Bonor 2005; McNatt 1996; Wrobel and Tyler 2006; Yaeger 2000).

In most cases, activities in caves are not clearly associated with a particular site. In other cases, like at Pook's Hill, similar artifacts and probable manuports suggest that the plazuela group's residents used the caves in the Roaring Creek Valley (Helmke et al. 2006). Where no direct association exists between a cave and nearby sites, specific burial contexts may serve as useful comparisons. For example, if burial patterns in residential groups, especially in eastern structures interpreted as family shrines, contrast with those in non-residential monumental architecture, they could serve as analogy for interpreting the cave interments.

This study includes only two individuals from cave burial contexts, but these may serve as an initial point of discussion. Actun Chapat is located in the foothills of the Maya Mountains near the Macal River (Figure 5.48). The cave is not clearly associated with a site. The second individual was found in Franz Harder cave, which is located near the recently discovered site of Tipan Chen Uitz near the Roaring Creek and Caves Branch Valleys, not far from Actun Tunichil Muknal cave (Andres et al. 2010). Both individuals have values that suggest an origin in the Belize River strontium zone, but both require further analysis (Table 5.16).

Table 5.16. Chapat and Franz Harder strontium isotope values and burial information

Burial	$^{87}Sr/^{86}Sr$	Sex	Age in yrs	Burial context and information	Date
Chapat	.70816	I	I	Burial context: other No information available	Not known
Franz Harder	.70824	I	I	Burial context: other No information available	Not known

14a. Identifying origin: analysis of the strontium isotope values

Chapat

The Chapat cave is located near the Macal River approximately 20 km upstream from Cahal Pech and is one of a number of caves in the region. It has extensive architectural features, like walls and raised platforms, and ceramics show that the cave was used for centuries (Ferguson 2000). Cave use intensified in this region during the Late Classic, as it did in elsewhere in the Belize Valley (Helmke et al. 2006). The cave contained a walled burial chamber that was looted, but another individual was identified in separate burial deeper into the cave.

The closest baseline sample has a value of .71065, similar to other values collect along the Macal River near Chaa Creek, as well as near Tipu (Kennedy Thornton personal communication 2009). However, it is not clear where individuals using the cave lived. The nearest large site is Arenal, where a baseline sample showed a Belize Valley strontium zone value of .70834.

The Chapat individual had a value lower than either the values collected along the Belize or Macal Rivers (Figure 5.49). It is a marginal value only slightly lower than Belize River strontium zone values, similar to those identified in a small number of individuals buried at San Lorenzo, Xunantunich, Baking Pot, Buenavista, and Pook's Hill. The values of these individuals could be compared with those of others in the burial populations at those sites, but this is not possible for the Chapat cave burial. However, the value differs from Macal River zone $^{87}Sr/^{86}Sr$ values, which demonstrates use of the cave by individuals living at Belize River zone sites like Cahal Pech.

Franz Harder

This cave is situated in a heterogeneous geologic zone with where distinct strontium isotope values were collected. This includes Maya Mountain zone values near the Hummingbird Highway and Roaring Creek. However, values of humans sampled at Pook's Hill are similar to modern samples collected near Caves Branch and the Belize River. This supports the interpretation of the Franz Harder individual's strontium isotope value as local to the vicinity of the cave. Samples from the closest site, newly discovered Tipan Chen Uitz have been collected, but not processed, and could offer additional insight into the origin of interments in this cave.

At Pook's Hill, objects interred with individuals in Burial 3 in the residential shrine are similar to those found frequently in caves in the region (Helmke 2000b). Future research likely will show additional associations between sites and caves in their vicinity. This suggests that the individual interred in the Franz Harder cave probably lived near the cave. A more general interpretation places the individual's origin in the Belize River strontium zone.

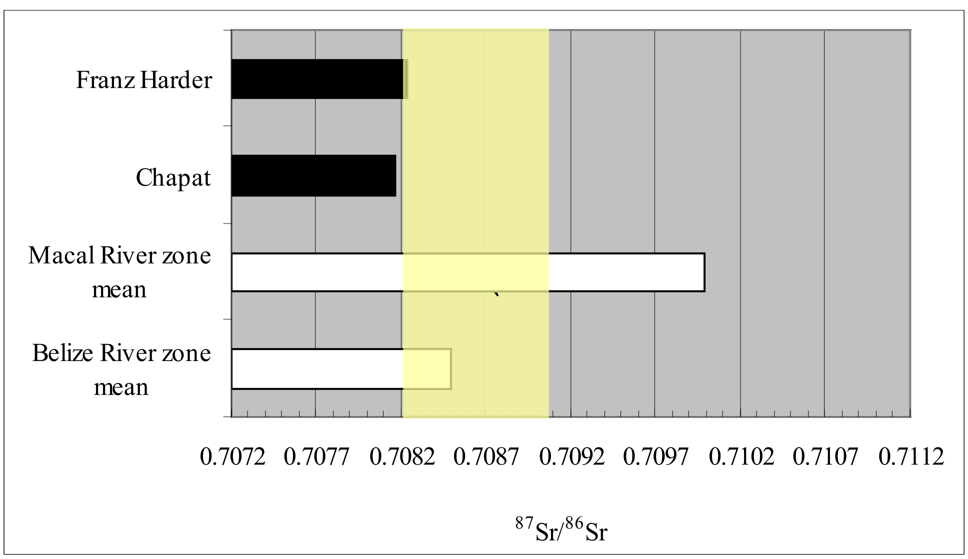

Figure 5.49. Chapat and Franz Harder strontium isotope values bar graph: White bars represent $^{87}Sr/^{86}Sr$ baseline values and the shaded area represents the range of values identified along the Belize River. Black bars represent each individual in the study (including marginal values).

14b. Chapat and Franz Harder summary

The individual interred in the Franz Harder cave spent the earliest years of life in the strontium zone that included the cave. The Chapat individual was buried in a different strontium zone, which does not imply long distance movement, but does show that the cave was not located adjacent to the individual's residence. Both individuals likely had origins in the Belize River strontium zone. The date of the burials is not known, but the most intensive use of caves in the region dates to the Late and Terminal Classic, or AD 600-950 (Helmke et al. 2006).

Future publications should provide more contextual information for the two individuals sampled in this study, which will be helpful in associating use of these caves with a particular site or microregion. Additional baseline data, provided both by human and non-human faunal samples, also will be useful in interpreting the isotope results and will results in a better understanding of cave use in the Belize Valley.

D. Conclusion

The percentage of in-migration identified at each site ranges from 0% – 100%, with the caveat that this includes a number of small samples containing only three individuals: Cahal Pech (n=20) has an in-migration rate of only 5% and Esperanza (n=3) has a rate of in-migration of 100%. The proportion of non-local individuals in the Belize Valley sample, including Mitchell's (2006) samples (n=14), is 20.8% – 26.2%. The low value represents individuals with $^{87}Sr/^{86}Sr$ values distinct from those near the site where they were buried. The higher number includes the marginal values, those that are slightly higher or lower than the baseline values.

Each site provides some insight into the three questions posed in Chapter 2. Migration generally occurs within the region, but instances of interregional relocation are visible at multiple sites. However, migration occurred frequently and in all segments of the population. This is illustrated in a short summary of key trends from each site. Additional lines of evidence are provided in Chapters 6 and 7, including results from oxygen, nitrogen, and carbon isotope assays and evaluation of the relationship between health and body modification and an individual's origin.

Major centers Xunantunich, Cahal Pech, Buenavista, and Baking Pot show different patterns of migration. While almost no in-migration is visible at Cahal Pech, individuals from two or more strontium zones were buried at the other sites. Population movement from within the region is documented at all three sites, but interregional migration patterns differ. It appears that evidence for interaction with the Central Petén site of Naranjo mirrors the high number of individuals with Central Lowland $^{87}Sr/^{86}Sr$ values. However, foreign burial goods did not signal the origin of the individual in the burial, and may instead reflect real or desired individual or family relationships.

The small sample from Blackman Eddy suggests that, like Cahal Pech, this major center also may have low rates of in-migration, or perhaps movement from places with similar $^{87}Sr/^{86}Sr$ values that is not visible isotopically. Individuals in the same burial locations in many cases have very similar strontium isotope values. Saturday Creek, on the other hand, shows a pattern similar to Baking Pot where individuals buried in the same residence have distinct values. It could reflect variability in food sources and the materials used to prepare them or movement within the region. Barton Ramie house mounds also contain burials of both local and non-local individuals, which are indistinguishable without isotopic assays.

Similarity in burial treatment for non-local individuals may be explained by their origins within the valley. Values of individuals at ten of the sites in the study show movement between the Belize and Macal River strontium zones. More than 13.4% of the sample population has a value from another strontium zone in the Belize Valley. In contrast, 7.4% of the sample population has Central Lowlands, Metamorphic, or Maya Mountain values. Most of these are Central Lowland strontium zone values (5.4%), and all but one are values that can be found in adjacent regions.

Two findings come from burials in residential group ancestor shrines. First, individuals with non-local origins are found in nearly all of them. Many of these, like Pook's Hill, are interpreted as burial grounds for a family group. The tight cluster of strontium isotope values may be the result of shared food sources. Second, changing patterns of ancestor veneration are visible isotopically. Burials that predate settlement at both Zubin and Chaa Creek have strontium isotope values that differ from both the baseline values identified near the sites, and from the individuals interred at the sites during later periods.

The strontium isotope values show that social networks were multidirectional, a pattern that is visible even in small samples at Esperanza, San Lorenzo, and Floral Park. Did sites settled earlier, like Cahal Pech, have less measurable in-migration than sites settled later like Xunantunich and Esperanza? The Esperanza and Floral Park samples also show that even highly fragmentary skeletal remains from problematic contexts can provide useful archaeological information. A final pattern relates to cranium and skull-only burials. These individuals are more than twice as likely to have non-local strontium isotope values.

Strontium isotope correlates serve as one indicator of non-local origin, as do some differences in burial treatment. Carbon and oxygen isotope assays provide additional support for these findings in the next chapter. Understanding the connection between origin and key aspects of life, like diet and burial treatment, is crucial not only to identifying migration, but to understanding what it meant to be a migrant during the Late and Terminal Classic in the Belize River Valley.

Chapter 6 Diet and Migration

Chapter Summary

An analysis of childhood and adult diet is based on carbon and oxygen isotope values in tooth enamel, and carbon, nitrogen, and oxygen assays in bone collagen and apatite. This provides basic information on diet in the region, building on studies by Piehl (2006) and Gerry (1993), and presenting new information on childhood diet and how it compares to that of adults.

Isotopic values in humans compare favorably to modern and ancient baseline values in surface and groundwater in Mesoamerica. However, while carbon and nitrogen isotope values in fauna and flora do not vary substantially in different parts of the Maya lowlands, human values do, suggesting that dietary differences reflect real cultural differences rather than environmental variability.

Diet also is discussed in the context of population movement to address key questions on the relationship between an individual's new and old residence. Migrants sometimes maintain distinct diets, and specific aspects of diet have been reported to affect local strontium isotope values. In the Belize Valley, diet appears to relate more to burial location or other factors than to an individual's origin. However, key aspects of the life histories of several migrants can be reconstructed using multiple isotope values, which can offer significant insights into the importance of migration on the individual level.

A. Introduction

Diet and migration are related on both theoretical and methodological levels. Diet forms the basis for isotopic analysis because elements in tooth enamel and bone come from what individuals eat and drink. Variation in strontium isotope ratios stems from the geographic source of the food, though some foods contribute more to the body's strontium reserves than others. Differences in rainfall, elevation, and precipitation, which also vary according to geographic region, form the basis for variability in oxygen ($^{18}O/^{16}O$) isotope ratios. $\delta^{18}O$ values in human tissues will reflect those of the individual's principal water source.

Carbon ($^{13}C/^{12}C$) and nitrogen ($^{15}N/^{14}N$) isotope ratios reflect food choices rather than origin. $^{13}C/^{12}C$ ratios vary in plants that use different photosynthetic pathways, which in Mesoamerica include foods like maize and seafood. $^{15}N/^{14}N$ isotope ratios provide information on the type of proteins consumed because trophic-level fractionation allows researchers to distinguish between diets rich in legumes, herbivores, and carnivores. Spatial and temporal variation in these values generally is smaller than real differences in human populations.

A subset of the sample population in this study is used to reconstruct three basic aspects of Classic Maya diet and its relationship to an individual's origin. First, how did childhood diet vary between centers? Most information on Maya diet is derived from bone collagen formed during adolescence and adulthood. Carbon and oxygen isotope analysis of tooth enamel provides general information on diet during infancy and early childhood. Values from six Belize Valley, one Vaca Plateau, and three Mountain Pine Ridge sites are compared to new and published data from other regions.

Second, variability in oxygen and carbon isotope ratios in tooth enamel provides an additional tool for identifying migrants. Residents of the Belize River Valley generally consumed less maize than residents of Copán and Tikal (Gerry 1993), which means that dietary differences might also serve as a proxy for population movement. It is important to note that similar carbon and oxygen isotope ratios exist in multiple regions to a greater extent than with strontium isotope ratios. However, environmental studies show that spatial variability in oxygen isotope ratios differs from that of δ^{87}Sr values. The large Central Lowlands strontium zone exhibits variation in present day oxygen isotope values that should be reflected in human populations. Variation in δ^{18}O and δ^{13}C also has the potential to identify differences in diet that contribute to variability in local strontium isotope values, or those within a population.

Third, carbon, oxygen, and nitrogen isotope ratios in bone collagen and apatite provide information on dietary differences as an adult. Did migrants maintain different dietary or culinary practices that can be detected isotopically? Strontium isotope values in tooth enamel are available for 92 Belize River Valley individuals who also have values from bone collagen and apatite. These are analyzed in the context of the individual's origin, as identified in $^{87}Sr/^{86}Sr$ values. Information in the Belize Valley now exists for both major centers like Cahal Pech, Baking Pot, and Xunantunich, minor centers like Saturday Creek, and hinterland settlements of Barton Ramie and Pook's Hill. These values also add to knowledge about diet during the Late and Terminal Classic, creating a larger sample useful for comparing differences by site, sex, household, and burial context. This also provides a more robust regional representation of dietary patterns that can be compared with other areas in Mesoamerica.

The chapter begins with a description of the sample population and the theoretical background for carbon, oxygen, and nitrogen isotope analysis. This includes detailed information on sample preparation and baseline isotopic values. The results of tooth enamel assays are used to discuss childhood dietary differences in terms of both diet and migration. The second section uses the results of carbon, oxygen, and nitrogen values in bone apatite and collagen samples to reconstruct the diet of adults with both local and non-local origins. The chapter concludes with a reconstruction of the life histories of some migrants, using a dietary perspective to understand the interplay between diet and place of origin (e.g., Buikstra et al 2004; Price et al. 2010; Sealy et al. 1995; Tourres-Rouff and Knudson 2007).

B. The sample and methods

Dietary analysis includes a subset of the sample population described in Chapter 3. Tooth enamel is sampled from the Xunantunich polity (including the minor center of Chaa Creek and San Lorenzo settlement) and individuals with strontium isotope values from other zones. Tooth enamel samples from other regions provide comparative information (Table 6.1). While this provides baseline information on childhood diet, the main goal is to assess the extent to which childhood food and water sources varied in different strontium zones. Data from Chiapas sites are presented in summary form and will be published in detail separately. Table 6.1 also shows the information available on adult diet derived from bone collagen and apatite, including values from Xunantunich and Pook's Hill in the Belize River Valley and previously published information.

Table 6.1. Number of dietary samples in the study: values include published data from Gerry (1993)[2] and Piehl (2006)[1]. All values except Paso de la Amada, Cantón Corralito, and Chiapa de Corzo are presented in Appendix C (these data are shown only in summary form in this chapter). Some individuals were sampled multiple times, and failed samples are not included in the totals. Strontium zones (see Chapter 4) include the Central Lowlands (CL), Belize River (BR), Maya Mountains (MM), and Pacific Coast (PC).

Site (Sr zone)	**$\delta^{86}Sr$**	**$\delta^{18}O_{PDB}$**	**$\delta^{18}O_{SMOW}$**	**$\delta^{13}C_{ap}$**	**$\delta^{13}C_{ap}$**	**$\delta^{13}C_{co}$**	**$\delta^{15}N$**
Material sampled	Tooth enamel	Tooth enamel	Bone apatite	Bone apatite	Tooth enamel	Bone collagen	Bone collagen
Xunantunich (BR)	19	19	20	20	19	7	7
San Lorenzo (BR)	3	3	-	-	3	-	-
Chaa Creek (BR)	12	12	-	-	12	-	-
Pook's Hill (BR)	9	-	27	27	-	13	13
Barton Ramie (BR)	20	-	4	4, 21[2]	-	3, 39[2]	3, 39[2]
Baking Pot (BR)	29	1	-	4[1]	1	4[1], 9[2]	4[1], 9[2]
Saturday Creek (BR)	8	-	-	5[1]	-	6[1]	6[1]
Cahal Pech (BR)	20	-	-	12[1]	-	16[1]	16[1]
Floral Park (BR)	3	1	-	2[1]	1	6[1]	6[1]
Esperanza (BR)	3	2	-	1[1]	2	1[1]	1[1]
Blackman Eddy (BR)	3	-	-	2[1]	-	5[1]	5[1]
Caracol (CL)	11	7	-	-	7	-	-
Ramonal (MM)	7	5	-	-	5	-	-
Bajo del Lago (MM)	1	1	-	-	1	-	-
Peligroso (MM)	3	2	-	-	2	-	-
Chiapa de Corzo (SL)	8	6	-	-		-	-
Paso de la Amada (PC)	9	10	-	-	10	-	-
Cantón Corralito (PC)	4	4	-	-	4	-	-
Total samples	172	73	47	97	73	109	109
Number of individuals	170	73	24	71	73	107	107

1. Oxygen isotope background

Variation in precipitation, elevation, temperature, and relative humidity result in regional variation in oxygen isotopic values. As with strontium, body tissues like tooth and bone reflect the $^{18}O/^{16}O$ composition of the local environment. Body water mirrors water ingested through drinking, moisture in food, and water vapor in air (Longinelli 1984; Luz and Kolodny 1985; Luz et al. 1984). Oxygen isotope ratios are more variable than those of strontium because they are affected by more factors at the environmental, species, and individual level. Oxygen isotope fractionation must be characterized for each genus and its environment regardless of similarities between ecosystems (Bryant and Froelich 1996; Kohn 1996; Kohn et al. 1996; Longinelli et al. 2003).

A complex set of environmental and behavioral influences complicate interpretation of oxygen isotope signatures. Seasonal fluctuations in precipitation result in distinct wet/dry season temperatures (Balasse et al. 2002, 2003). Evapotranspiration processes during the dry season (or in permanently dry climates) enrich leaves and standing water in ^{18}O as oxygen-16 preferentially evaporates (Kohn et al. 1996). Long term climate changes also result in changing oxygen isotope values in a particular region.

Animal bones often are used for paleoclimate reconstruction because they reflect environmental differences. However, although oxygen isotope values in tissues and environmental values vary at a constant rate, animal behavior results in variable isotope values. Herbivores have values that differ from browsers and carnivores in the same environment because $\delta^{18}O$ values in plant leaves differ from those in roots or stems (Luz et al. 1984; Sponheimer and Lee-Thorp 1999). Researchers generally use species-specific fractionation rates that take into account differences in body temperature, drinking habits, and sweating that occur within a species due to reproductive status, age, sex, and dietary preference (Cormie et al. 1994).

1a. The Maya Region and baseline oxygen isotope values

Background studies of oxygen isotope variation in Guatemala and Belize show patterned regional variation might be reflected in human populations. Lachniet and Patterson (2009) suggest that 84% of the variability in precipitate oxygen isotope values can be explained by distance from the coast and average altitude. In an analysis of 186 water samples, they posit a -1.24‰ change in $^{18}O/^{16}O$ values for each 100 mm increase in rainfall, and an altitude effect of -1.9‰ to -2.4‰ km^{-1}. This produces a continental effect of -0.69‰ per 100 km (corrected for altitude); that is, values decrease by 3‰ from the Caribbean to the Pacific coast.

In Belize, there is variation in rainfall and elevation that could result in measureable oxygen isotope variation. Annual rainfall in Belize increases from 130 cm in the north to 450 cm in the south (Marfia et al 2004; Wright et al. 1959). Rainfall in the upper Belize River valley has a range of 150 - 175 cm annual precipitation (Wright et al. 1959; Yaeger 2000). Annual precipitation in the Mountain Pine Ridge is ~150 cm, and exceeds 200 cm in the Maya Mountains (Wagenseil 1999).

Wet and dry seasons also result in seasonal variation. Precipitation during the rainy season peaks twice annually. In June and July the easterly trade winds bring strong rains, while October and November rain is the result of winds from the north and orographic precipitation on northern edge of the Maya Mountains (Wright et al 1959). The mountains have two main watersheds to the north and east through which water moves into the lowlands. The upper watershed is in the southern Maya Mountains, while the Mountain Pine Ridge forms a regional subwatershed. Most of the Mountain Pine Ridge lies in the shadow of the Maya Mountains, and therefore receives less rain than surrounding regions (Wright et al. 1959). In fact, *northers* during October through January increase this drying effect, despite the increased precipitation of the rainy season, with more than 25 cm falling during the wettest months of September, October, and June. Evaporation likely exceeds precipitation for most of the year (Wright et al. 1959).

The Macal River carries water from both watersheds to the Belize Valley. Fast-moving streams from the southern Maya Mountains overtake slower moving tributaries near the Mountain Pine Ridge to form a single fast-moving channel that floods the valleys below and flows back into the Mopan River (Wagenseil 1999). Tributaries to the Macal River remain dry during the summer months, though the river flows year round downstream.

There also are subregional differences in elevation, temperature, and humidity. Temperatures in the upper Belize River valley normally are <24 degrees Celsius, decreasing in the Mountain Pine Ridge (19-29 degrees), and the Maya Mountains (17-25 degrees). Humidity is relatively high year round (Yaeger 2000). The level of elevation near Belize Valley sites is <100 m, increasing to ~370-700 m in the Vaca Plateau and Mountain Pine Ridge, reaching elevations of > 1000 m in the Maya Mountains (Wright et al. 1959).

River waters are considered to be good representations of rainfall $\delta^{18}O$ values. Isotopic variation that occurs in microregions or results from seasonal changes is not visible (Table 6.2). Lachniet and Patterson (2009) observe that values in Belize collected during the dry season were similar to those collected in Guatemala during the rainy season. Samples collected by the author in Belize after a series of tropical storms are similar to those reported by Marfia and colleagues (2004), who cite a rapid exchange of ground and surface water in the region (but see Lachniet and Patterson 2009). However, lake water in the Yucatan shows significantly more enriched values that than those in nearby surface and groundwater (Curtis and Hodell 1996). This is significant because human water sources can be variable even within a site.

Table 6.2. $\delta^{18}O_{SMOW}$ baseline information for Belize River, Macal River, and Mountain Pine Ridge sources: samples collected by the author during 2008 and processed by White and Longstaffe (n.d.). These are cited with their permission. Belize River Valley samples also include data from Marfia et al. (2004), which is the sole source for Southern Belize values. Yucatan values from Curtis and Hodell (1996b). Mean values expressed in per mil, with sample size (n).

	surface water	**groundwater**	**lake water**
Belize River Valley	-4.41 ± 0.4 (n=10)	-4.10 ± 0.4 (n=7)	
Macal River	-6.83 ± 1.0 (n=2)		
Mountain Pine Ridge streams	-3.34 ± 1.1 (n=4)		
Southern Belize	-3.67 ± 0.4 (n=3)	-4.43 ± 0.2 (n=3)	
Punta Laguna, Yucatan (near Cobá)	-3.91 (rain) (n=4)	-3.92 (n=3)	0.66 to 0.93 (n=15)

Regional differences occur instead over broad areas (Figure 6.1). Values of approximately -7‰ were measured near the Pacific Coast, -11‰ in the Guatemalan mountains, and significantly more positive values in the Central Petén – values also identified during the Late Classic (Curtis and Hodell 1996a, 1996b; Lachniet and Patterson 2009:436). These values can provide a baseline for general trends expected in human values.

These serve as useful guides only on a broad scale. Temporal variability is documented in environmental reconstructions of Classic period climate in the Maya lowlands. Curtis and Hodell (1996a) describe decadal wet and dry cycles within long-term cyclical changes in the Yucatan Peninsula. Fluctuations of ~1.5‰ (-0.05‰ to 1‰ $\delta^{18}O_{PDB}$) are documented at least three times between AD 500-1000. Paleoclimate reconstructions are available for some of the Petén lakes, but represent localized variability that cannot be assumed for the Belize Valley (e.g., Yaeger and Hodell 2008).

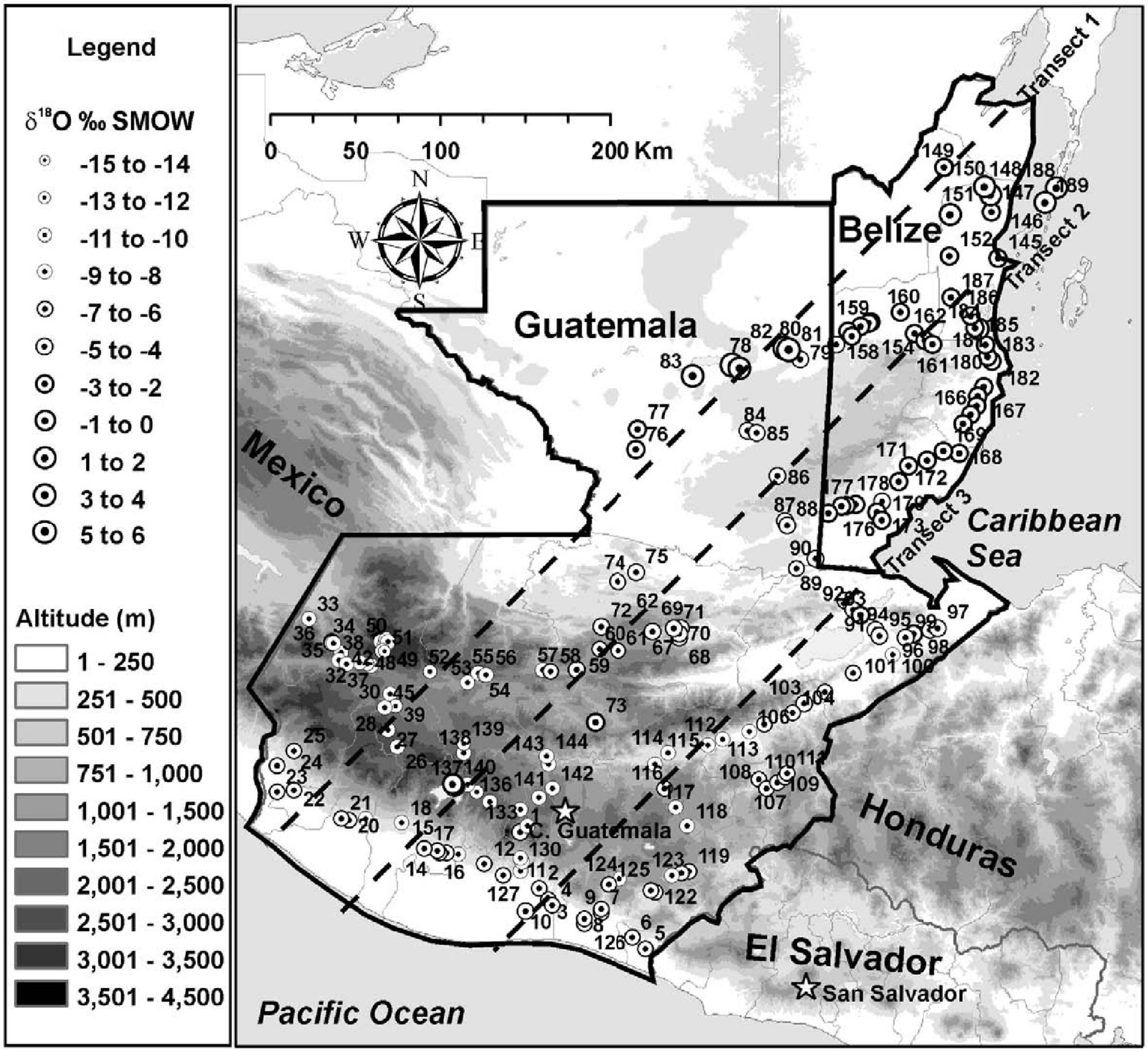

Figure 6.1. Oxygen isotope values from water samples from Lachniet and Patterson (2009:436 Figure 1). Reprinted from *Earth and Planetary Science Letters*, 284, Mathew S. Lachniet and William P. Patterson, Oxygen isotope values of precipitation and surface waters in northern Central America (Belize and Guatemala) are dominated by temperature and amount effects, 435-446. Copyright (2009), with permission from Elsevier.

White and colleagues (1996, 1998, 2000, 2001a, 2001b, 2002, 2004a, 2004b, 2007) have used oxygen isotope values in bone phosphates to identify population movement across Mesoamerica, including sites in Belize (also see Wright 2007). White suggests that changes that exceed 2‰ represent population movement (White et al. 2004a, 2004b). Human bone $\delta^{18}O$

values from Monte Alban, Teotihuacan, Tzintzuntzan, Kaminaljuyú, Altun Ha, and Rio Azul (data from White et al. 2002) increase with precipitation and temperature and decrease with higher elevation.

Regional differences, however, might be obscured by variability in human behavior. Kohn et al. (1996) suggest that physiological and dietary factors can affect oxygen isotope values by as much as 5-10‰. This range is far greater than that suggested by controlled experiments, which posit differences greater than 1-2‰ as signifying separate populations (Luz and Kolodny 1985). Studies on non-human fossil tooth enamel phosphates show ranges of variability of 3.7‰ (Longinelli et al. 2003), and values of 4.2‰ (Balasse 2003) and 4.6‰ within a single tooth (Straight et al. 2004).

There also are differences between tissues sampled. Oxygen isotope values in body water differ at a constant rate from those in phosphates (1.0178 in Luz et al. 1984) and carbonates (1.0263 ± .0014 in Bryant et al. 1996). In addition, bone represents averaging over a time period that may be 10-20x longer than that captured by a microsample of tooth enamel. Teeth in this study also have more enriched $\delta^{18}O$ because the enamel formed while the infant was nursing, which results in a value enamel on average 0.7‰ – 1.6‰ lower (Williams et al. 2005; Wright et al. 2010). Oxygen isotope values are compared to two standards: Standard Mean Ocean Water ($\delta^{18}O_{SMOW}$) and the marine carbonate standard PeeDee Belemnite ($\delta^{18}O_{PDB}$). The human tooth enamel in this study is presented in $\delta^{18}O_{PDB}$, which can be converted to $\delta^{18}O_{SMOW}$ values ($\delta^{18}O_{SMOW}$ 1.03104*$\delta^{18}O_{PDB}$ + 31.04).

Average values in tooth enamel carbonates suggest that measureable differences exist only between some regions and that the differences are generally very small (Table 6.3: average phosphate values also are summarized in Price et al. 2010). Movement between sites as far apart as Campeche, Mexico and Palmajero, Honduras will not result in notable differences in oxygen isotope ratios, and variability within each sample needs to be explored. Comparison also should be made for similar time periods to minimize variability due to cyclical environmental changes (Curtis and Hodell 1996a).

Table 6.3. $\delta^{18}O_{PDB}$ values in human tooth enamel published by Price and colleagues (2010:Table 1): detailed information on sample selection is not provided.

	tooth enamel (‰)
Calakmul (n=12)	-1.2
Campeche (local, n=54)	-2.9
Tikal (n=150 samples)	-3.2
Palmajero Valley (Honduras n=5)	-3.7
Palenque (n=3)	-3.9
Maltrata (Gulf Coast n=3)	-3.9
Copán (n=10)	-4.1
Kaminaljuyú (n=14, from Wright and Schwarcz 1998)	-4.8
Tzintzantzun (central Mexico n=3)	-5.4

These values are not directly comparable to modern water samples; however, similar trends should exist (Bentley and Knipper 2005). The ancient tooth enamel and modern water samples suggest that differences between at least three regions might be identified: between the Caribbean and Pacific coasts, between lowland and mountain areas, and between different parts of the central Petén. These serve as useful distinctions that can complement differences in the distribution of strontium isotope values in the Maya region.

2. Carbon and nitrogen isotope background

Variability in carbon isotope values results from different photosynthetic pathways used by three major groups of plants. Most plants use the temperate C_3 pathway (the Calvin and Benson cycle), resulting in depleted $\delta^{13}C$ values that range from -22‰ to -35‰. C_4 plants (the

Hatch-Slack pathway) developed a different carbon dioxide uptake process that minimizes losses to photorespiration. These plants consist mainly of warm and dry-tolerant tropical grasses, such as maize and amaranth. These values are less variable than C_3 plants, ranging from -9‰ to -19‰ (Ambrose and Norr 1993; Schwarcz 2000). Crasseulean Acid Metabolism (CAM) plants are C_4 plants that separate their C_3 and C_4 cycles by time (day/night) or by leaf structure. The result is a highly variable $\delta^{13}C$ ratio that can resemble either C_3 or C_4 plants.

Carbon isotope values also vary spatially and temporally. A plant growing in an open field may have more enriched $\delta^{13}C$ values than the same species growing in a forest, an effect attributed to the recycling of carbon in closed canopy environments. Temporal differences are caused by use of fossil fuels that result in carbon isotope values 1-2‰ more depleted in modern samples than in archaeological ones (van der Merwe and Medina 1991; Medina and Minchin 1980; Tieszen and Boutton 1989).

Larger differences result from fractionation in $\delta^{13}C$ values as carbon moves through each trophic level. Animals consuming only plants have $\delta^{13}C$ 5‰ higher in bone collagen values, with additional offsets for omnivores and carnivores consuming those animals. The offset between diet and bone apatite values is estimated to be 12‰. Nursing also is reflected in tooth enamel values, but the positive trophic level offset is outweighed by the values of the macronutrients in the mother's milk. Wright and colleagues (2010) report a slight decrease of 0.7‰ to 1.6‰ in the carbon isotope values of nursing infants. This can be complicated by other changes in an infant's diet, like the introduction of solid foods before the child is weaned (Williams et al. 2005; Wright et al. 2010; Wright and Schwarcz 1998).

2a. Baseline carbon and nitrogen isotope values

Dietary reconstructions are based on these estimates, with the goal of comparing proportions of broad categories of food rather than arriving at specific menus. Average estimates of C_3 plant values range from -26‰ to -27.5‰ and -9‰ to -12‰ for C_4 plants (Ambrose and Norr 1993; Krueger and Sullivan 1984). Researchers measure the isotopic values of locally-available plants and animals to determine what the local baseline values should be (Table 6.4). For example, Lambert (1997) describes a study where human bone collagen values in the Amazon approximated those of plants ($\delta^{13}C$ -26‰). An assessment of the plant communities in the region suggests that depleted C_3 plants in the region result in values < -30‰.

Bone collagen is the tissue most frequently sampled because it is considered less subject to diagenesis than apatite and because nitrogen isotope values also can be sampled. These values provide information on key aspects of Maya diet: how much maize and meat did different segments of Maya society consume? While collagen only provides information about the protein component of the diet, bone apatite also is sampled and provides information on total diet.

Table 6.4. Baseline carbon and nitrogen isotope values: select baseline isotope values in flora and fauna in the Maya Lowlands expressed as per mil (‰). An adjustment of ca. -1.5‰ is needed for modern samples.

Baseline samples	**$\delta^{13}C_{ap}$ ‰**	**$\delta^{13}C_{co}$ ‰**	**$\delta^{15}N$ ‰**	**References**
Flores whitetail deer *ancient*		-20.7 (n=5)	4.6 (n=5)	Gerry 1993
Copán whitetail deer *ancient*	-10.5 (n=16)	-21.1 (n=32)	4.2 (n=32)	Gerry 1993
Altun Ha whitetail deer *ancient*		-21.6 (n=7)	3.7 (n=6)	Gerry 1993
Holmul whitetail deer *ancient*		-21.3 (n=2)	6.8 (n=1)	Gerry 1993
Petexbatun whitetail deer *ancient*		-20.6 (n=53)		Emery 2006
Pasión cervids *ancient*			4.4	Wright 2006
Colha, Belize whitetail deer *modern*		-24.3 (n=1)		White et al. 2001
Xunantunich, Belize whitetail deer *ancient*	-12.1 (n=5)	-20.2 (n=18)	5.3 (n=18)	Freiwald, Yaeger and Tykot unpublished

Cuello, Belize whitetail deer *ancient*		-20.5 (n=5)		Tykot et al. 1996
Cuello, Belize fauna *ancient*		-20.8		Tykot et al. 1996
Cuello, Belize fauna *modern*		-22.4		Tykot et al. 1996
Cuello, Belize marine fish *modern*		-7.3	6.8	Tykot et al. 1996
Cuello, Belize other marine *modern*		-13.3	3.5	Tykot et al. 1996
Flores peccaries *ancient*		-22.8 (n=4)		Gerry 1993
Copán peccaries *ancient*	-11.7 (n=11)	-19.8 (n=21)	5.2 (n=21)	Gerry 1993
Altun Ha peccaries *ancient*		-19.9 (n=6)	4.5 (n=2)	Gerry 1993
Cuello, Belize canids *ancient*		-15.6 (n=12)	7.5 (n=12)	Tykot et al. 1996
Copán canids *ancient*	-4.6 (n=5)	-8.8 (n=12)	5.8 (n=9)	Gerry 1993
Altun Ha canids *ancient*		-8.4 (n=3)	8.2 (n=1)	Gerry 1993
Flores canids *ancient*		-9.8 (n=3)	7.1 (n=3)	Gerry 1993
Pasión canids *ancient*		-9.1 (n=5)	6.28 (n=5)	Wright 2006
Colha C_4 plants *modern*		-11.2 (n=1)		Wright 2006
Pasión C_4 plants *modern*		-10.7 (n=3)	0.5- 5.5 (all plants)	Wright 2006
Colha C_3 plants *modern*		-27.9 (n=13)		Wright 2006
Colha C_3 plants *modern deer browse*		-28.8 (n=6)		Wright 2006
Kaminaljuyú C_4 (maize) *modern*		-10.87		Wright et al. 2010
Kaminaljuyú C_3 plants *modern*		-26.35		Wright et al. 2010
Pasión C_3 plants *modern*		-27.9 (n=30)	0.5- 5.5 (all plants)	Wright 2006
Pasión C_3 plants *modern/open field*		-26.3 (n=14)	0.5- 5.5 (all plants)	Wright 2006
Pasión C_3 plants *modern/forest cover*		-28.2 (n=16)	0.5- 5.5 (all plants)	Wright 2006
Pasión CAM plants *modern*		-16.7 (n=1)	0.5- 5.5 (all plants)	Wright 2006

Carbon isotope values in plants establish the baseline for values in the rest of the ecosystem. C_3 plants dominate lowland vegetative communities, though savannah grasses are common in tropical lowlands (Tieszen and Boutton 1989). Depleted carbon isotope values are reported in both modern plants and ancient human populations in Belize. This suggests an environment with more forested areas than fields, but Wright (2006) shows that isotopic differences also are present in different species of maize. Maize is considered to be the main C_4 contribution to diet (e.g., Emery et al. 2000; Gerry 1993; Tykot 2002; White et al. 2001a, 2001b; Wright 2006; van der Merwe et al. 2000).

Consumption of maize also can results in enriched isotopic signatures in wild game. Gerry (1993) and Wright (2006; also see Emery et al. 2000) each sampled more than 100 plants and animals to establish a baseline for the human sample population. They focus on whitetail deer because these are the most frequently identified zooarchaeological remains at most inland sites, and because these were the largest game animals believed to form a significant part of the Maya lowland diet. Consumption of C_4 foods like maize or savannah grass by game animals could result in enriched $\delta^{13}C$ faunal values, resulting in an overestimate of maize consumption in human diets.

Carbon isotope values in the tooth enamel of almost 30% of wild game sampled from upper Belize River valley sites value are more positive than those reported elsewhere (Freiwald 2010; Yaeger and Freiwald 2009). However, although a number of whitetail deer bone collagen values (in different individuals at Xunantunich) also are enriched, there appear to be no significant regional differences in isotopic inputs to Classic Maya diet (e.g., Wright 2006).

Archaeological whitetail deer (*O. virginianus)* sampled in the Central Lowlands have a range of average values (-20.6‰ to -21.3‰) similar to the range reported at sites in Belize (-20.2‰ to -21.6‰), similar to the range of 1.8‰ in studies of animals consuming similar foods in the same habitat (Cormie and Schwarcz 1994). A slightly larger range is reported in northern Belize for whitetail deer sampled from Preclassic contexts (Tykot et al. 1996).

Enriched values are more commonly reported in other fauna, including peccary, paca, and dogs. Interpreting just how much C_4 foods an animal consumed depends on the estimate of carbon isotope baseline values in plants. Upper Belize River valley deer apatite samples were interpreted using an end value of -28‰, an average measure published by White and colleagues (2001a) for deer browse in Belize. If this value is instead -27‰ or -26.5‰, deer interpreted as invasive feeders in *milpas* had diets that may instead reflect occasional consumption of C_4 foods like wild grasses (e.g., Cormie and Schwarcz 1994). In this study, the more depleted end values are appropriate, ranging from -27‰ for C_3 plants to -12.5‰ for C_4 plants. This suggests bone collagen values of -22‰ for a pure C_3 diet and -7.5‰ for a one consisting mostly of C_4 foods. Bone apatite values may range from -15‰ to ~0‰.

Enriched C_4 values also signal consumption of marine foods, so researchers commonly compare carbon and nitrogen isotope values to understand protein sources (Schoeninger and DeNiro 1984). Marine resources are identified in archaeological assemblages, but generally are rare at inland sites. Terrestrial game is more commonly identified. The abundance of whitetail deer in archaeological deposits is perplexing to scholars for ecological and cultural reasons. Could wild game have provided sufficient protein for densely-inhabited regions? This has led to suggestions that large game was managed or even semi-domesticated (Pohl 1991; Dillon 1988; but see Emery 2006).

$^{14}N/^{15}N$ isotopes are used to more specifically identify the type of protein consumed. The type of protein source – plants, terrestrial, or marine – will result in different isotopic values in humans. Nitrogen isotope values are measured against atmospheric ^{15}N, which has a value of zero. Legumes derive their nitrogen from air, so have more depleted values (0-3‰) than animals (3-10‰). Other plants may have slightly more positive values (3‰), and because there is fractionation at each trophic level, herbivores have lower values than carnivores (Ambrose 1991; Schoeninger and DeNiro 1984).

Humans consuming animals are enriched by ~3‰, so diets rich in legumes (4-7‰) will result in values that differ from one that includes terrestrial game (9-16‰) or marine resources (10-20‰) (Ambrose 1991; Lambert 1997). There is variability, as in most isotopic values, in extreme climatic conditions. For example, values in dry coastal areas can mimic terrestrial ones (Lambert 1997). Nutritional stress also can affect isotope ratios. $\delta^{15}N$ values increase during pregnancy and lactation as a function of nutritional stress in many species, include humans (Fuller et al. 2004, 2005).

Wright reported difficulty sampling nitrogen isotope values in plants because too little elemental nitrogen was present. However, values are assumed to be lower than those identified in animals. For the most part, wild game animals have similar values in different areas of the Maya lowlands. Canid values appear to be more variable, but zooarchaeological evidence suggests that dogs were not an important part of Maya diet during the Classic period. More specifically, they are identified only in minimal numbers in faunal assemblages in the Belize Valley (Clowery 2005; Freiwald 2010; Powis et al. 2005; Stanchly 1994, in Piehl 2006; Stein n.d.). Values of marine and riverine resources are variable: freshwater fish may resemble terrestrial game, but crab and turtle values are enriched (Wright 2006:100-101.)

Nitrogen isotope values reflect measureable human behavior to a greater extent than the other isotope values in this discussion. Strontium isotope values in humans are largely determined by the geology of the catchment area(s), assuming most food is local. Oxygen isotope values are affected by behavioral differences, but climate and geographic differences likely are more important. While carbon isotopes reflect broad dietary differences, $^{14}N/^{15}N$ values reflect food choices more than any of the other assays. Protein can be derived from riverine, terrestrial, marine, and plant resources and differences will be visible in the isotope values.

3. Sample treatment and preparation

A large body of literature concerns preparation of samples for isotopic analysis to ensure measurement of biogenic values rather than diagenetic ones (Meiggs 2009). Concerns about diagenesis vary according to the body tissue and the isotope measured. Tooth enamel presents the smallest risk of contamination, but it is still a concern (Gabaordi et al. 2005; Hoppe et al. 2003). However, a comparison of extensively and minimally treated samples suggests that different techniques produce comparable results. This is important because researchers use multiple sample preparation procedures (e.g., Balasse and Ambrose 2005; Bentley and Knipper 2005; Wright et al. 2010). A comparison of 32 treated and untreated enamel values from a subset of the sample population shows no patterned variation for $\delta^{13}C$ values and a small positive shift in $\delta^{18}O$ values. Understanding the reason behind changes in values that result from specific treatments also is important (Koch et al. 1997), so the tooth enamel samples presented in this analysis are minimally treated.

Initial tooth enamel sample preparation is described in Chapter 4: $\delta^{18}O$ and $\delta^{13}C$ values were sampled from the same tooth enamel used for strontium isotope analysis. Approximately 1 mg of the enamel was ground into a fine powder using an agate mortar and pestle. All carbon and oxygen isotope tooth enamel samples were measured in the Environmental Isotope Laboratory at the University of Arizona Department of Geosciences, under the direction of Dr. David Dettman. Samples are measured against $\delta^{18}O$ using reference values from Craig, 1957, with an automated Finnegan Delta S VG602C with analytical precision of 0.11 and 2 s.d.=0.08. Standards include SMOW and VSMOW. $\delta^{18}O$ is measured relative to Standard Mean Ocean Water (SMOW), determined as follows: $\delta^{18}O=1000 \times [((^{18}O/^{16}O)_{sample)}/(^{18}O/^{16}O)_{SMOW}) - 1]$. $\delta^{13}C$ is measured relative to relative to marine carbonate standard PeeDee Belemnite (PDB). Ratios are expressed as $\delta^{13}C=1000 \times [(^{13}C/^{12}C)_{sample} - (^{13}C/^{12}C)_{standard}) / {}^{13}C/^{12}C_{standard}]$. Values for six samples are not considered valid because voltage readings were too low.

Thirty-two samples were processed in duplicate. One set of samples was processed after the minimal treatment described above, and a second set was processed using procedures outlined by Balasse, Ambrose, and colleagues (Balasse et al. 2002; Balasse and Ambrose 2005). This includes pretreatment with bleach and acetic acid to remove organic materials and adsorbed carbonates. Briefly, 1.5 mg Clorox solution was added to a sample of 0.5 - 10 mg powdered tooth enamel. It was then agitated and left overnight. A pipette was used to remove the bleach solution, and then the sample was rinsed three times with distilled water using a vortex and centrifuge with each rinse. A solution of 0.1 M acetic acid was added for each milligram of the original sample weight, and left for four hours. This was followed by a second rinse procedure, and then the samples were desiccated and freeze-dried.

Bone apatite and collagen samples were processed at the University of Illinois at Urbana-Champaign under the direction of Dr. Stan Ambrose following procedures modified from Balasse et al. (2002). The surface of each bone sample was mechanically removed with a carbide drill bit that was cleaned in 1 M HCl between each sample. Bone samples were ground into medium and fine fraction (>0.063 μ). Two sets of samples were treated with a 50% NaClO solution and acetic acid, but the finer fraction underwent more intensive processing meant to remove contaminants from carbonate rich environments. $\delta^{18}O$ and $\delta^{13}C$ isotope values (650-750 μg bone powder fine fraction) were measured in an automated carbonate preparation device (KIEL-III) coupled to a gas-ratio mass spectrometer (Finnigan MAT 252). The isotope ratio measurement is calibrated based on repeated measurements of NBS-19 and NBS-18 and precision is ± 0.1‰ for $\delta^{18}O$ and ± 0.06‰ for $\delta^{13}C$ (1σ).

Bone collagen samples were purified and mineralized in annealed funnel filters using ~50ml 0.2 M HCl, and then rinsed to neutrality. In all but five cases, cortical bone from the mid-shaft of the femur was chosen for the analysis. Bone from the radius, ulna, humerus, and tibia were used in the case of preservation and comingled burials for these individuals. Details are provided in Appendix C. Bones were treated with a 0.125 M NaOH solution, rinsed and treated with HCl, condensed, and freeze-dried. 205-450 μ of each prepared sample was processed using the Finnegan MAT 252 mass spectrometer. Duplicate samples were systematically run. Three samples resulted in C:N ratios outside the acceptable range and were considered to have too little remaining collagen to be used in this analysis.

3a. A comparison of pretreatment procedures

Table 6.5 shows values resulting from both pretreatment protocols applied to 64 tooth enamel samples are from upper Belize Valley sites Xunantunich, Chaa Creek, and San Lorenzo.

Table 6.5. Comparison of treated and untreated tooth enamel samples from Xunantunich, San Lorenzo, and Chaa Creek: Values expressed per mil (‰).

Minimal treatment (M)						Intensive treatment (I)					Difference (M-I)			
sample #	$\delta^{13}C$ VPDB	$\delta^{13}C$ 1σ	$\delta^{18}O$ VPDB	$\delta^{18}O$ 1σ		$\delta^{13}C$ VPDB	$\delta^{13}C$ 1σ	$\delta^{18}O$ VPDB	$\delta^{18}O$ 1σ		$\delta^{13}C$ VPDB	$\delta^{13}C$ 1σ	$\delta^{18}O$ VPDB	$\delta^{18}O$ 1σ
F4528	-2.40	.015	-2.36	.009		-2.02	.029	-2.09	.072		-.38	-.014	-.27	-.063
F4530	-2.85	.009	-0.32	.094		-3.21	.011	-0.41	.086		.36	-.002	.09	.008
F4531	-3.36	.017	-1.73	.098		-3.47	.030	-1.59	.076		.11	-.013	-.14	.022
F4532	-7.71	.061	-3.16	.064		-7.52	.067	-2.93	.065		-.19	-.006	-.23	-.001
F5140	-5.91	.020	-3.41	.031		-6.01	.015	-3.28	.099		.10	.005	-.13	-.068
F5141	-6.99	.029	-2.65	.021		-6.68	.031	-2.28	.068		-.31	-.002	-.37	-.047
F5142	-4.50	.020	-3.98	.047		-4.16	.008	-2.88	.054		-.34	.012	-1.1	-.007
F5143	-4.18	.018	-3.01	.055		-4.16	.028	-2.64	.052		-.02	-.010	-.37	.003
F5144	-5.98	.032	-1.41	.092		-6.22	.042	-1.26	.052		.24	-.010	-.15	.040
F5145	-5.90	.019	-3.47	.030		-6.05	.019	-3.44	.022		.15	0	-.03	.008
F5146	-4.91	.020	-0.60	.067		-5.16	.051	-0.59	.020		.25	-.031	-.01	.047
F5147	-5.36	.032	-2.76	.069		-5.66	.036	-2.92	.021		.30	-.004	.16	.048
F5148	-8.97	.046	-3.10	.035		-8.68	.038	-3.08	.011		-.29	.008	-.02	.024
F5149	-6.05	.033	-3.33	.106		-6.16	.060	-3.16	.037		.11	-.027	-.17	.069
F5150	-6.72	.028	-2.40	.038		-6.42	.047	-2.20	.034		-.30	-.019	-.20	.004
F5151	-5.80	.037	-2.89	.027		-5.74	.032	-2.73	.031		-.06	.005	-.16	-.004
F5152	-4.16	.023	-3.18	.055		-4.27	.026	-2.98	.037		.11	-.003	-.20	.018
F5153	-2.65	.025	-0.91	.050		-2.78	.053	-0.70	.006		.13	-.028	-.21	.044
F5157	-4.66	.014	-4.37	.030		-5.01	.029	-3.89	.080		.35	-.015	-.48	-.050
F5158	-6.05	.008	-2.45	.031		-7.07	.010	-2.22	.059		1.02	-.002	-.23	-.028
F5159	-6.62	.030	-2.92	.032		-7.08	.041	-2.92	.016		.46	-.011	0	.016
F5160	-8.71	.016	-2.79	.025		-8.75	.023	-2.70	.038		.04	-.007	-.09	-.013
F5161	-7.36	.088	-2.90	.089		-7.40	.039	-2.62	.100		.04	.049	-.28	-.011
F5162	-3.58	.017	-4.48	.036		-3.05	.030	-3.85	.016		-.53	-.013	-.63	.020
F5163	-7.89	.019	-3.06	.062		-7.60	.009	-2.15	.031		-.29	.010	-.91	.031
F5164	-4.39	.047	-4.61	.032		-3.30	.043	-4.30	.108		-1.09	.004	-.31	-.076
F5165	-4.88	.023	-3.73	.077		-4.71	.041	-3.23	.052		-.17	-.018	-.50	.025
F5166	-6.58	.021	-3.44	.099		-6.26	.015	-3.07	.061		-.32	.006	-.37	.038
F5167	-7.06	.050	-3.74	.052		-7.20	.019	-3.20	.017		.14	.031	-.54	.035
F5168	-6.07	.018	-2.20	.055		-6.21	.030	-2.19	.020		.14	-.012	-.01	.035
F5169	-5.11	.020	-2.73	.066		-5.40	.034	-2.69	.017		.29	-.014	-.04	.049
F5189	-5.04	.059	-3.15	.038		-4.68	.013	-2.79	.021		-.36	.046	-.36	.017

The carbon isotope ratios of 21 samples are lower after treatment, and in all but a few cases the differences are greater than the standard deviation. These differences are not statistically significant in a two-tailed comparison of means (t = -.147, df = 31, p = 0.884). Mean values are nearly equal for both treated samples (-5.57 ± 1.72) and untreated ones (-5.58 ± 1.68). Median values also are similar (Figure 6.2).

Oxygen isotope values show a different trend than carbon isotope ones (Figures 6.3 and 6.4). Nearly all treated oxygen isotope samples have more positive values, though a number of these are smaller than the standard deviation of the sample mean. A comparison of the oxygen isotope treated and untreated samples does show a significant relationship between treated and untreated samples (t = 5.419 df =31 p = <.000).

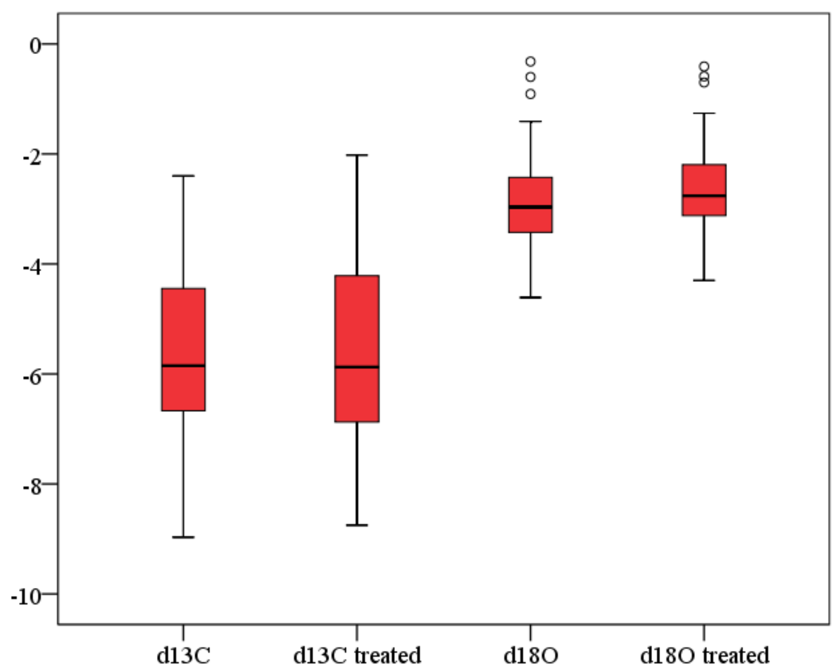

Figure 6.2. Comparison of central tendencies in treated and untreated carbon and oxygen isotope tooth enamel samples using IQR box plots.

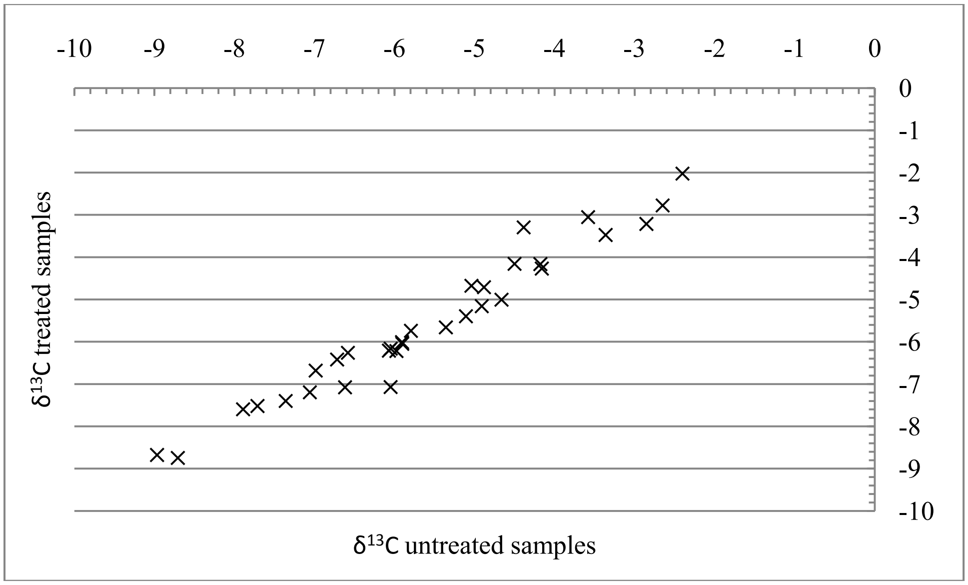

Figure 6.3. Treated and untreated carbon isotope values in tooth enamel using a scatterplot diagram.

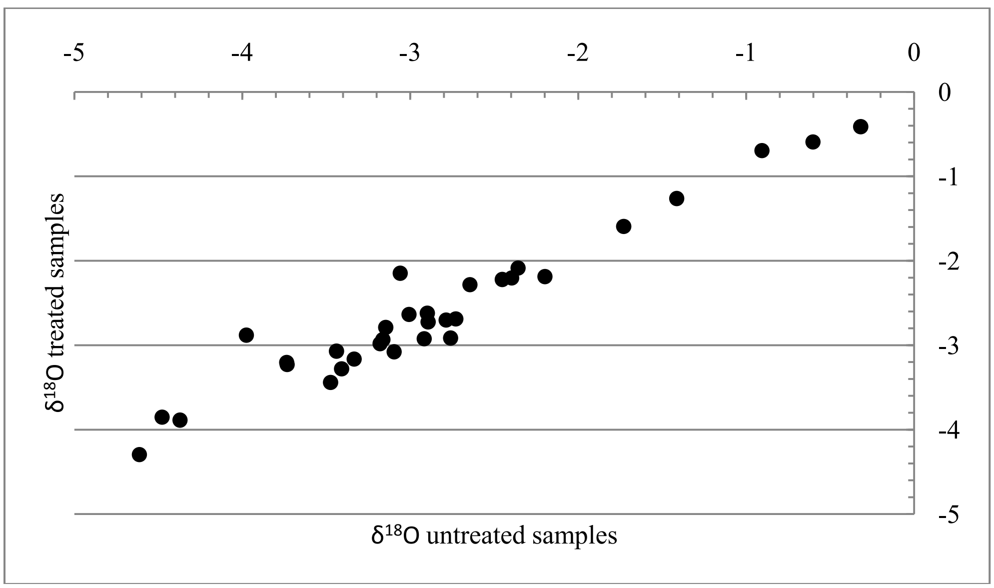

Figure 6.4. Treated and untreated oxygen isotope values in tooth enamel using a scatterplot diagram.

These findings mirror trends identified by Koch and colleagues (1997), although most treatments have a larger impact on bone than tooth enamel. While bleach and peroxide have little effect on tooth enamel, acid treatment results in a shift in positive shift in values for oxygen measures and a negative one for carbon values. This may result from removal of contaminants, but very little organic matter is present in tooth enamel hydroxyapatite. For strontium isotope analysis, most contamination is believed to be in the top layer of the tooth, which was mechanically removed for each of these samples.

Tooth carbonates measured in labs processing Mesoamerican samples generally follow minimal pretreatment procedures, so these values are presented in this analysis. Different treatment procedures may contribute to isotopic variability, but these differences appear to be smaller than those resulting from environmental variation or human behavior, so should not affect interpretation of overall trends.

C. A regional comparison of childhood diet and individual origin

1. Carbon isotope values

Carbon isotope ratios were sampled from the tooth enamel of 73 individuals (Table 6.6 next page). Thirty-eight of these individuals were buried at Belize Valley sites, although six have $\delta^{87}Sr$ values that suggest their childhood home was somewhere else. These values are compared with those from 14 individuals in neighboring regions and 21 from more distant parts of Mesoamerica. Chiapas sites are presented as summary values will be discussed in detail in future publications.

Table 6.6. Carbon isotope tooth enamel values by site location: values are expressed as per mil (‰).

samples by site location	N	range	minimum	maximum	mean	s.d.	median
Belize River sites (Baking Pot, Chaa Creek, Blackman Eddy, Esperanza, Floral Park, San Lorenzo, and Xunantunich)	38	6.57	-8.97	-2.40	-5.56	1.70	-5.82
Chiapa de Corzo	6	2.19	-4.03	-1.84	-3.00	0.97	-3.13
Caracol	7	2.30	-5.56	-3.26	-4.03	0.78	-3.88
Mountain Pine Ridge sites (Peligroso, Bajo del Lago, and Ramonal)	8	2.34	-6.10	-3.76	-4.74	0.75	-4.51
Pacific Coast sites (Paso de la Amada and Cantón Corralito)	14	7.61	-9.74	-2.13	-7.16	1.77	-7.49
Kaminaljuyú Late Classic molars and premolars (Wright et al. 2010)	8	-	-	-	-3.6 (M1) -3.4 (P) -3.2 (M3)	-	-
Cuello (Tykot et al. 1996)	11	-	-	-	-8.4	1.5	-
Altun Ha (White et al. 2001a)	21	-	-	-	-8.4	1.9	-

The most depleted values in the Maya region are found at sites in Belize, a trend also identified by Gerry (1993; also see Piehl 2006). Samples that predate the Classic period also have very negative values, most notably at Paso de la Amada and Cantón Corralito on the Pacific Coast in Chiapas. The assumption that a range of values within a population consuming the same general foods is ~2 per mil is met only in the Caracol and Mountain Pine Ridge sample populations. While some variability in the Belize River Valley samples may relate to temporal difference in diet, only three individuals in the sample predate the Late Classic. The wide range of values instead may be the result of different diets during childhood linked to a non-local place of birth. Individuals buried at these Belize River Valley sites have δ^{87}Sr values that suggest origins in at least four different strontium zones, so this possibility can be evaluated by comparing individuals by their place of birth instead of place of burial.

Table 6.7. $\delta^{13}C$ values separated by strontium isotope zones: one value was reassigned from Caracol to the Southern Lowland zone. Otherwise, only values from Belize Valley sites are placed into strontium zones. Mountain Pine Ridge sites are presented as the Maya Mountain zone. Values expressed per mil (‰).

samples by strontium zone	N	range	minimum	maximum	mean	s.d.	median
Chiapa de Corzo site	6	2.19	-4.03	-1.84	-3.00	0.97	-3.13
Pacific Coast sites	14	7.61	-9.74	-2.13	-7.16	1.77	-7.49
Caracol site	6	2.30	-5.56	-3.26	-4.10	0.83	-4.01
Maya Mountain zone	8	2.34	-6.10	-3.76	-4.74	0.75	-4.51
Southern Lowland zone	2	0.57	-3.64	-3.07	-3.36	0.40	-3.36
Central Lowland zone	5	3.43	-5.83	-2.40	-3.87	1.45	-3.36
Belize River zone	16	5.24	-7.89	-2.65	-5.40	1.49	-5.26
Macal River zone	16	5.39	-8.97	-3.58	-6.41	1.47	-6.31

When the samples are analyzed by strontium zone (Table 6.7), which represents the residence when the tooth enamel formed, the difference between the median and mean is reduced by half and the range of values is greatly reduced. While mean values that correspond to Central and Southern Lowland strontium zones and Chiapa de Corzo are generally similar, some regional and temporal differences are visible (Figure 6.5 next page).

The most basic interpretation is that C_4 foods contributed less to Belize Valley childhood diets than in those in some parts of the Central Lowlands. The values are slightly more negative than those measured in bone samples because of the nursing effect (Witt and Ayliffe 2001; Wright et al. 2010; Wright and Schwarcz 1998), but compare favorably to Gerry (1993) and Piehl's (2006) findings. That is, C_4 foods comprised less than 50% of infants' food, from the mother's milk and/or solid comestibles. In contrast, C_4 foods may have provided more than 60% of an infant's diet in the Central and Southern Lowlands.

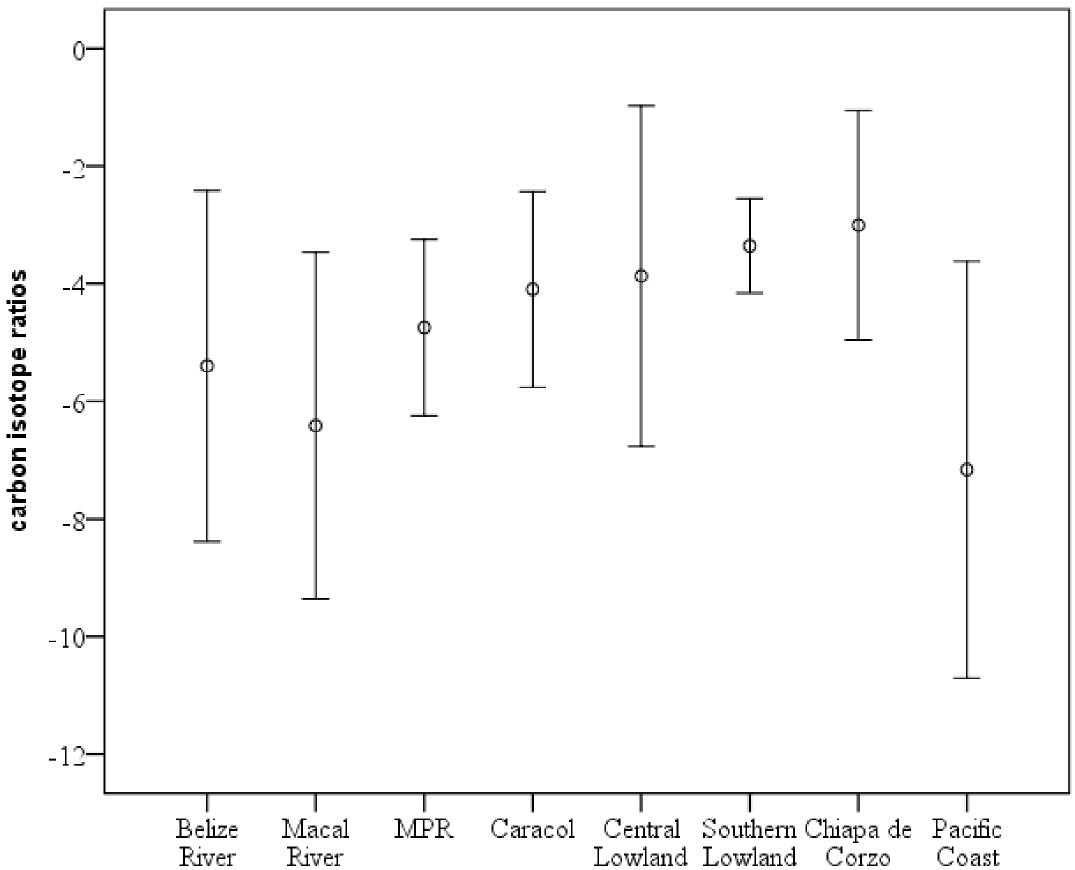

Figure 6.5. Distribution of tooth enamel carbon isotope values by strontium zone: values are presented using the mean value (circle) and two standard deviations (whiskers).

Gerry (1993; Gerry and Krueger 1997) suggests that the availability of more diverse resources that resulted from lower settlement density offers one possible explanation for differences in regional diet, like depleted carbon isotope values at Belize River Valley sites. However, C_4 foods may also have had less importance in childhood diet in other times and places. Apatite values in tooth enamel and bone should be comparable, and depleted bone apatite values also are reported for juveniles at Cuello (-8.4 ± 1.5‰) and children aged 6-9 months to 7 years at Altun Ha (-8.39 ± 1.92‰) (Tykot et al. 1996; White et al. 2001a, 2001b).

In contrast, tooth enamel sampled in Late Classic child interments at Kamanaljuyú (Late Classic) has enriched mean values (Wright et al. 2010). Similar baseline values across multiple regions and disparate environments suggest that instead these differences are cultural rather than environmental.

2. Oxygen isotope values

$\delta^{18}O_{PDB}$ values are available from the same 73 individuals and also demonstrate regional variability that complements strontium and carbon isotope results. Like the carbon isotope values, the variability in the $\delta^{18}O$ values is reduced for Belize Valley sites when compared by strontium zone instead of by site (Tables 6.8 and 6.9). That is, comparing individuals by origin, when the tooth enamel formed, produces different outcomes than a comparing them by burial location. As predicted by the baseline values, regional differences are measureable in limited circumstances.

Table 6.8. $\delta^{18}O_{PDB}$ samples by site location: values expressed per mil (‰).

$\delta^{18}O_{PDB}$ samples by site location	**N**	**range**	**minimum**	**maximum**	**mean**	**s.d.**	**median**
Belize River sites (Baking Pot, Chaa Creek, Blackman Eddy, Esperanza, Floral Park, San Lorenzo, and Xunantunich)	38	4.16	-4.61	-0.32	-2.90	0.99	-3.03
Chiapa de Corzo	6	6.55	-10.78	-4.23	-6.07	2.44	-5.31
Caracol	7	1.80	-4.35	-2.55	-3.41	0.65	-3.27
Mountain Pine Ridge sites (Bajo del Lago, Peligroso, and Ramonal)	8	1.57	-4.44	-2.87	-3.55	1.57	-3.32
Pacific Coast sites (Paso de la Amada and Cantón Corralito)	14	1.76	-6.78	-5.02	-5.91	0.46	-5.92
Kaminaljuyú Late Classic molars and premolars (Wright et al. 2010)	8 8 7	-	-	-	-5.00 (M1) -5.00 (P) -5.50 (M3)	-	-
Altun Ha (White et al. 2001a)	24				-2.05	0.76	

Table 6.9. $\delta^{18}O_{PDB}$ samples by strontium zone: values expressed per mil (‰).

$\delta^{18}O_{PDB}$ samples by strontium zone	**N**	**range**	**minimum**	**maximum**	**mean**	**s.d.**	**median**
Chiapa de Corzo	6	6.55	-10.78	-4.23	-6.07	2.44	-5.31
Pacific Coast	14	1.76	-6.78	-5.02	-5.91	0.46	-5.92
Caracol	6	1.8	-4.35	-2.55	-3.43	0.71	-3.42
Maya Mountain zone	8	1.57	-4.44	-2.87	-3.55	0.58	-3.32
Southern Lowland zone	2	1.00	-4.27	-3.27	-3.77	0.71	-3.77
Central Lowland zone	5	2.04	-2.36	-0.32	-1.37	0.87	-1.73
Belize River zone	16	3.46	-4.37	-0.91	-2.99	0.87	-3.04
Macal River zone	16	2.41	-4.61	-2.20	-3.20	0.65	-3.18

The trends identified by Lachniet and Patterson (2009) are reflected in three basic groups (Figure 6.6). Pacific Coast average human values are more negative than those identified in the Eastern and Central Lowlands. The Chiapa de Corzo mean value is similar once a single depleted outlier value is removed (-5.13‰). The second group likely includes most of the lowland sites (Caracol and Belize River Valley sites). These values are identified as far west as Tikal and south as Palmajero in Honduras (Price et al. 2010 in Table 3). This includes the three Mountain Pine Ridge sites, though river and stream water values in the region are more variable.

The third group of values consists of heavy oxygen isotope values. Lachniet and Patterson (2009) identify these values immediately west of the Belize Valley in Guatemala, a finding Yaeger and Hodell (2008) report, as well in cores from Salpetén and Petén-Itza lakes dated to the Terminal Classic period. Enriched values also are visible in the humans sampled at Calakmul (Price et al. 2010 in Table 3), though not at Tikal, a phenomenon that can only be explained with more information on the sample population. The enriched values in this group were identified in Xunantunich individuals with Central Lowland zone strontium values. If the distribution of these heavy $\delta^{18}O$ values were better known, they could serve to differentiate between individual origins within the Central Lowlands strontium zone.

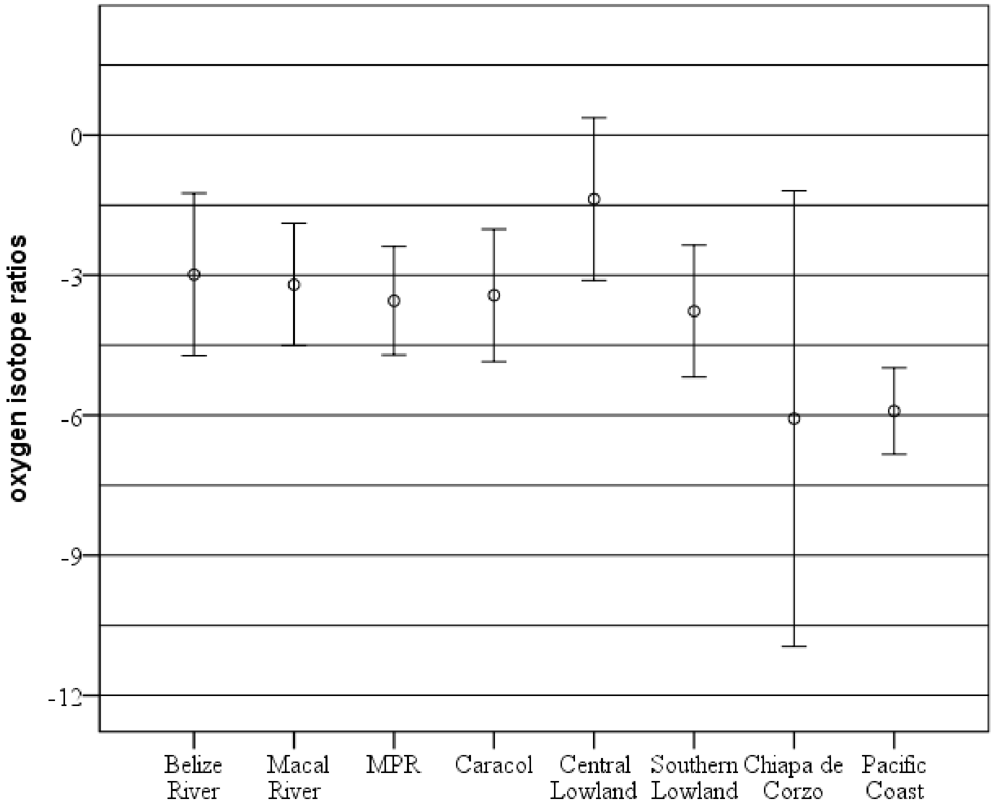

Figure 6.6. The distribution of tooth enamel oxygen isotope values by strontium zone: values are presented using the mean value (circle) and two standard deviations (whiskers).

Distance from the coast appears to explain some differences in mean human values, but elevation and rainfall have little measureable effect (or are offset by other factors). Mountain Pine Ridge, Caracol, and Belize Valley samples show a similar average value. While elevation is not significantly different at Caracol (~475 m) and Mountain Pine Ridge sites (~450 m), Xunantunich, Chaa Creek, San Lorenzo, Esperanza, and Floral Park, have an average elevation of ~60 - 120 m. Differences in rainfall also produce less variability than expected. Water values from the Belize Valley and the Mountain Pine Ridge are similar to those reported by Marfia et al. (2004) for southern Belize, which has markedly higher rainfall.

3. Childhood diet and origin

The main goal of this analysis is to explore the relationship between diet and origin, so this serves as a framework for a preliminary discussion of childhood diet. Carbon and oxygen isotopes show two aspects of diet important in the Maya lowlands during the Classic era. Unlike strontium isotope ratios, specific values cannot differentiate individuals living in one region from another. However, general dietary trends are visible that can be used to differentiate individuals and groups in certain parts of Mesoamerica.

The main finding is that like adult diet, childhood diet in the Belize Valley consisted of proportionately fewer C_4 foods than in other parts of the Maya lowlands (see Gerry 1993). The broader implication, however, is that osteological studies all likely include teeth of individuals with different childhood residences. A re-assessment of dental hypoplasias demonstrates how this can alter interpretations of weaning age and childhood diet in the Xunantunich polity (see Chapter 6).

Most water sources utilized by Belize Valley residents have oxygen isotope values similar to those used by other Maya lowland residents (Figure 6.7). However, individuals from the Pacific Coast and mountain sites will have distinct oxygen isotope values. A more important difference is the presence of enriched values in both the Central Lowlands immediately adjacent to the Belize Valley and at Calakmul. Identifying heavy oxygen isotope values in Belize River Valley individuals with Central Lowland strontium isotope ratios supports an interpretation of these individuals as migrants.

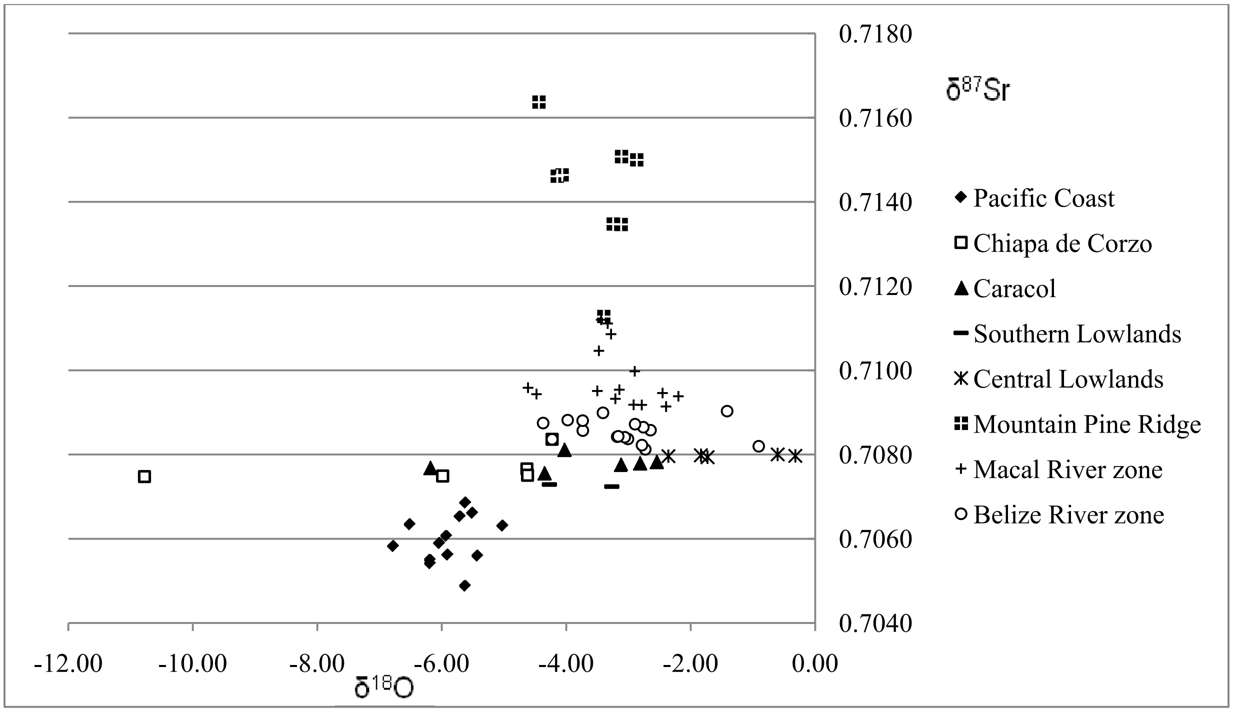

Figure 6.7. Strontium and oxygen isotope values in tooth enamel: values include two Pacific Coast sites, Chiapa de Corzo, Caracol, and the three Mountain Pine Ridge/Maya Mountain sites. Belize River Valley sites are plotted by strontium zone.

While initial analysis shows a moderately strong correlation between oxygen and strontium isotope values, it disappears when outlier values are removed from the strontium isotope dataset (greater than two standard deviations from the mean). This relationship may stem from the extreme difference between Mountain Pine Ridge and Pacific Coast strontium values. In fact, all three isotope values identified at Pacific Coast sites are distinct. When strontium and oxygen isotope values are compared for only Maya lowland sites, the only difference is visible in the small number of Central Lowland values (Figure 6.8).

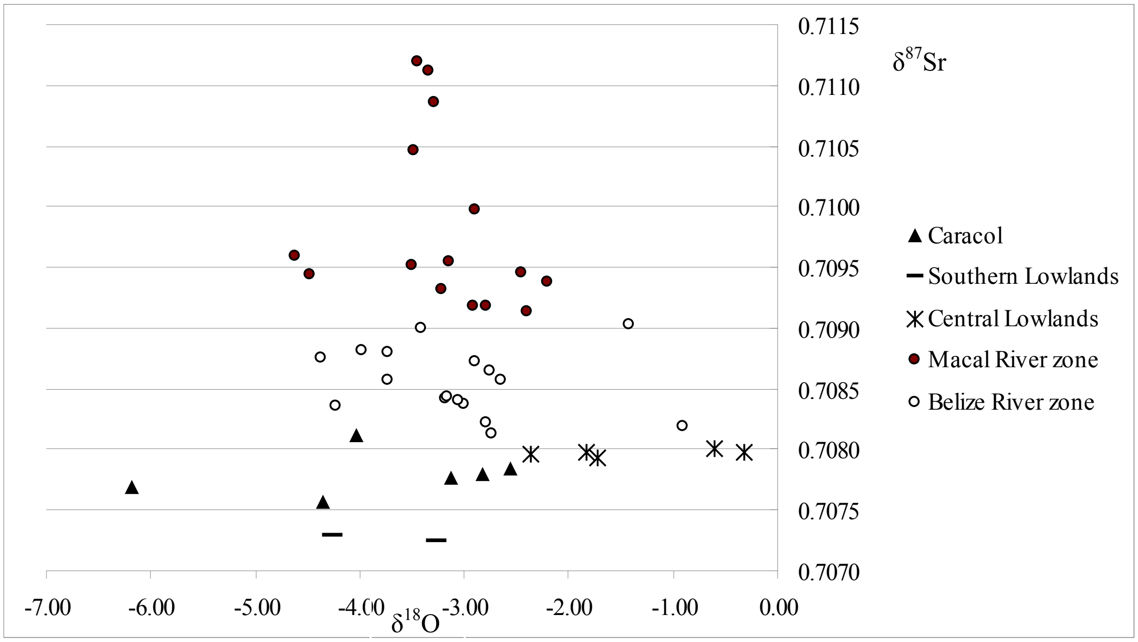

Figure 6.8. Strontium and oxygen isotope values for Maya lowland sites: Belize River Valley sites are plotted by strontium zone.

Carbon and strontium isotope values also show no relationship when values from all regions are compared (Figure 6.9). There is reason to assess the relationship between strontium and carbon isotope values. Researchers believe that the poor soils of the Mountain Pine Ridge and lack of settlement in the Maya Mountains relate to poor agricultural potential (e.g., Wright et al. 1959). However, individuals from sites located in the Mountain Pine Ridge instead have enriched values similar to those at Caracol. The possibility that basic foodstuffs were imported, or that local soils are more variable than previously reported, merits additional investigation.

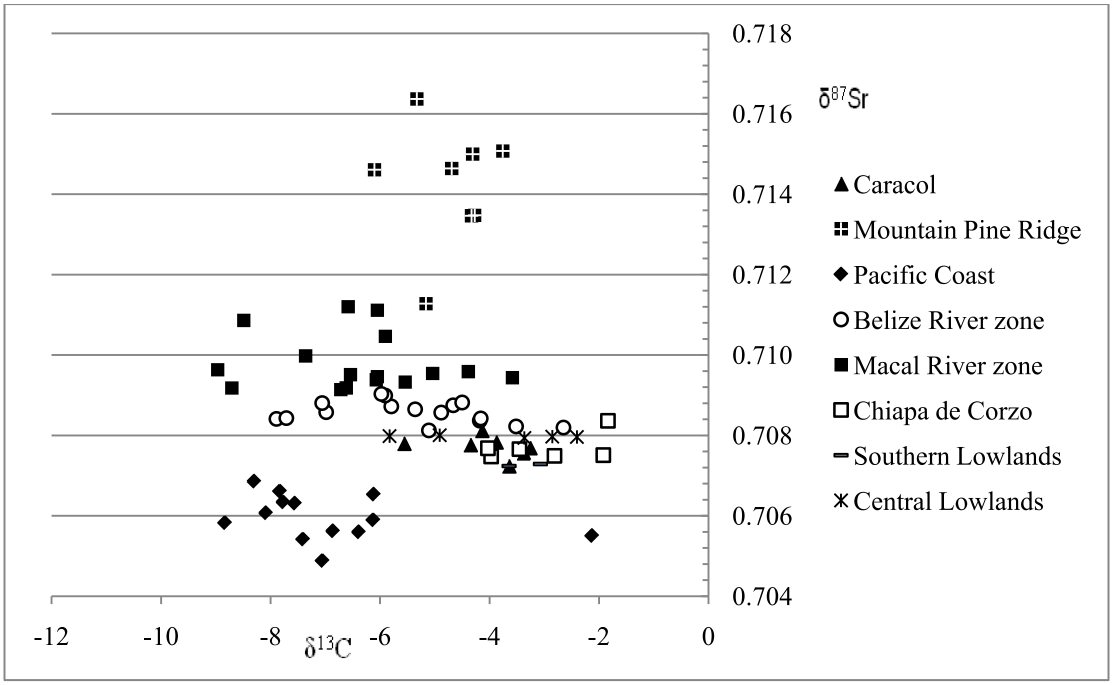

Figure 6.9. Strontium and carbon isotope values by strontium zone: values for two Pacific Coast sites, Chiapa de Corzo, Caracol, and the three Mountain Pine Ridge/Maya Mountain sites. Belize River Valley sites are plotted by strontium zone.

When sites with strontium values that are outliers from the rest of the dataset are removed (Pacific Coast and Mountain Pine Ridge sites), the correlation is moderately strong (*r* = -63 n = 51). In lowland sites, there is an inverse relationship between decreasing strontium isotope values and increasing C_4 food consumption (Figure 6.10). While there is substantial overlap in the values, use of all three isotope assays – in conjunction with archaeological evidence – may provide substantial insight into the origins of individuals at a site or regional basis.

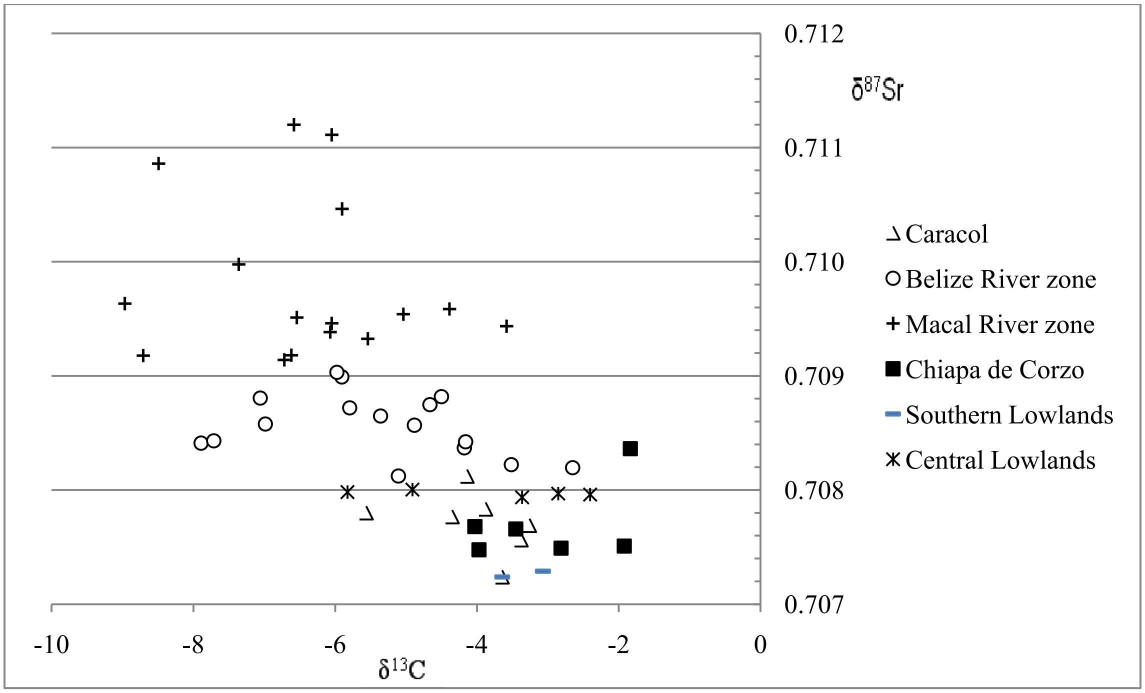

Figure 6.10. Strontium and carbon isotope values in tooth enamel: scatterplot excludes the Mountain Pine Ridge and Pacific Coast sites. Belize River Valley sites are plotted by strontium zone.

Carbon and oxygen isotope assays prove useful in explaining some of the more perplexing strontium isotope values. Four individuals have values that are outliers (IQR) in the Belize and Macal River zone oxygen isotope datasets. The first is a female in an elite residential burial in Group B at Xunantunich. Her strontium isotope ratio is slightly lower than the lowest baseline faunal value and is one of the marginal values that cannot be clearly identified as local or non-local. However, her oxygen isotope ratio shifts the evidence toward a non-local origin because it fits better with the enriched Central Lowlands values, suggesting that she may share a similar origin (Figure 6.11).

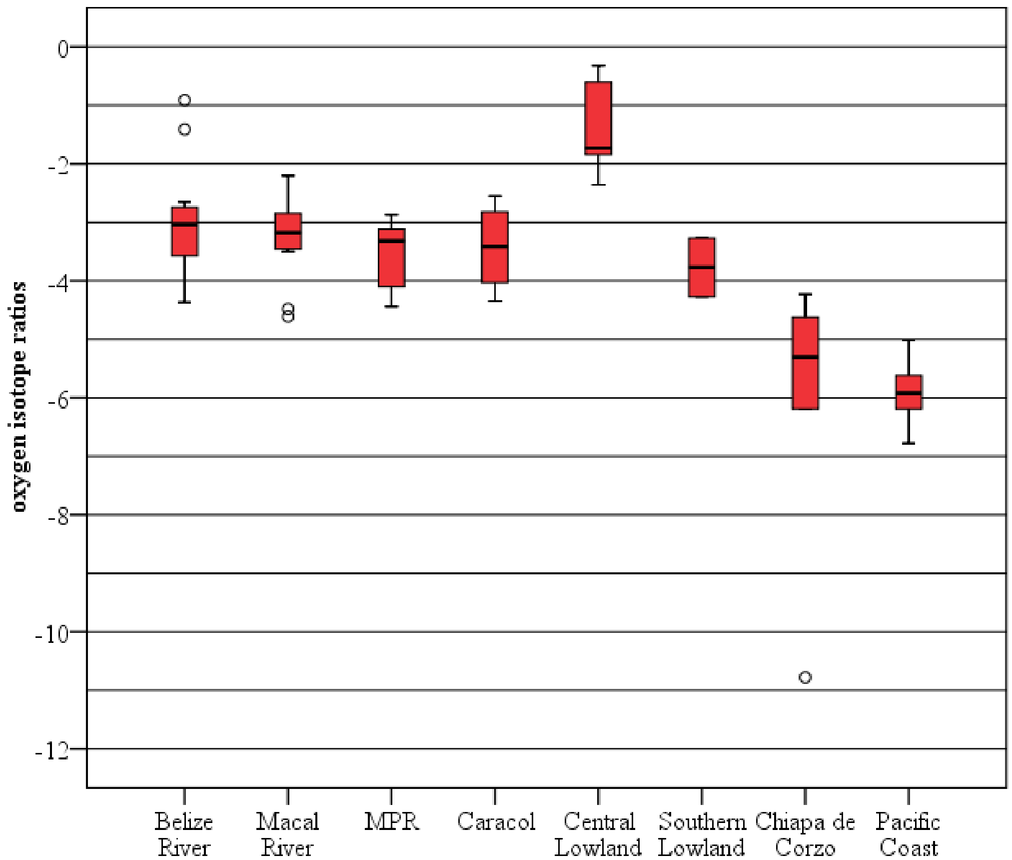

Figure 6.11. IQR Box plots comparing tooth enamel samples plotted by site: Caracol, Chiapa de Corzo, Pacific Coast and Mountain Pine Ridge values plotted by site and by strontium zone for Belize River Valley burials in the sample.

The second individual with an anomalous oxygen isotope value was buried in another elite residential group at Xunantunich. The Group D individual designated Burial Op. 21 C1 #1 has one of the highest strontium isotope values in the Belize River zone. While the value is conservatively interpreted as local, both the strontium and oxygen isotope values could indicate a coastal origin (see summary of values in Price et al. 2010).

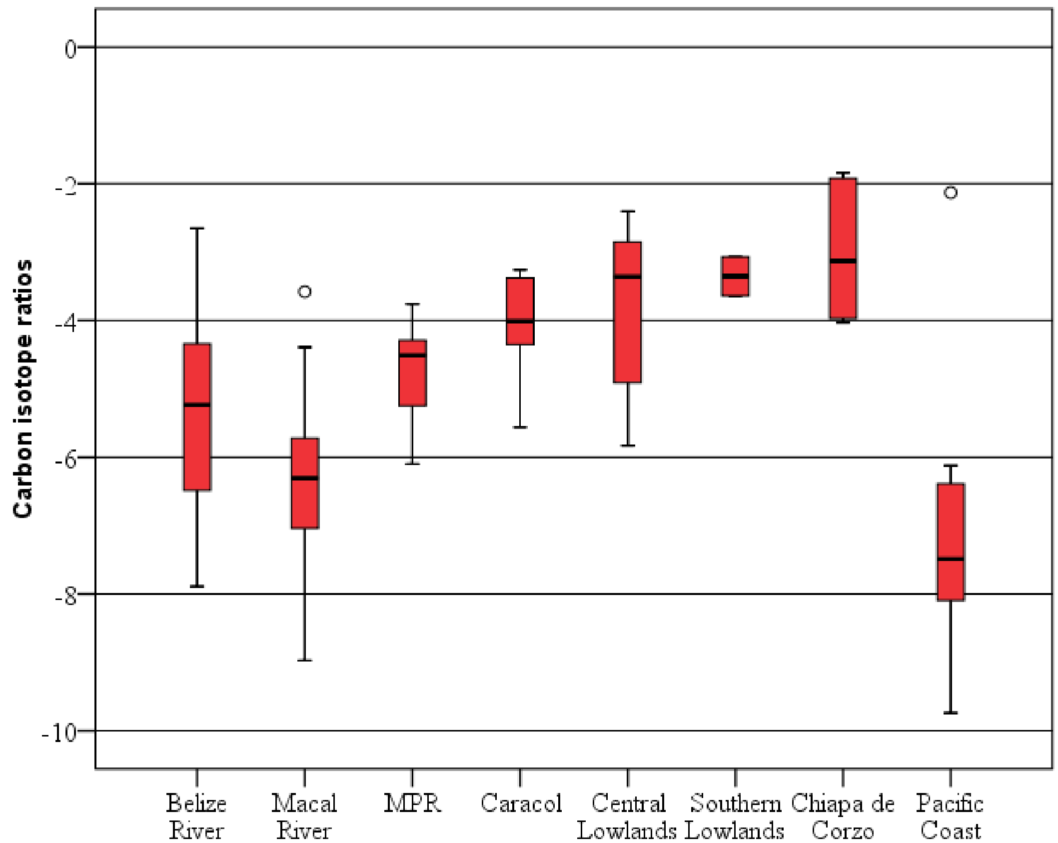

Figure 6.12. IQR Box plots comparing carbon isotope values in tooth enamel samples: The interquartile range shows 50% of the data (shaded box) with the median value (line). The depleted values of Pacific Coast and Belize Valley strontium zones contrast with more enriched values in the Central Lowlands and Mountain Pine Ridge.

Two individuals with Macal River strontium zone values have depleted oxygen isotope ratios that are outliers (IQR), along with more positive carbon isotope values than the rest of the site's burial population (Figures 6.11 and 6.12). Chaa Creek individuals interred in Op. 161 #173 and the chultun did not share the same childhood C_4 diet as the individuals with Macal River zone strontium isotope values. This is the only area where similar $^{87}Sr/^{86}Sr$ values are identified, which suggests either a distinct, but local origin, or that these differences result from another aspect of behavior.

D. Belize River Valley diet and origin in a regional context

Did migrants maintain different culinary practices that can be detected isotopically? More than half of the 102 Belize Valley individuals with bone collagen and/or apatite values also have strontium isotope values (Table 6.1). This includes 24 individuals from three sites sampled as part of this study, along with 34 individuals sampled as part of Gerry's (1993) and Piehl's (2006) studies. This provides an opportunity to assess the relationship between an individual's origin and diet. Information in the Belize Valley now exists for both major centers like Cahal Pech, Baking Pot, and Xunantunich, minor centers like Saturday Creek, and hinterland settlements Barton Ramie and Pook's Hill. On the most basic level, these values provide deeper insight into dietary diversity in the Belize Valley. Dietary practices during the Late Classic often were highly variable at sites within the same region (Wright 2006).

It also creates a larger sample for an improved understanding of regional diet during the Late and Terminal Classic that can be compared with other areas in Mesoamerica. Belize Valley dietary patterns differed from those identified elsewhere in the Maya lowlands for reasons that still are not fully understood (Freiwald 2010; Gerry 1993; Wright 2006). Piehl (2006) did not identify patterns by site, sex, or burial context that might be visible in a larger sample twice, which also presents the opportunity to compare patterns by residential group.

The second section uses the results of carbon, oxygen, and nitrogen values in bone apatite and collagen samples to reconstruct the diet of adults with both local and non-local origins. The chapter concludes with a reconstruction of the life histories of some migrants, using a dietary perspective to understand the interplay between diet and origin.

1. Diet and origin in the Belize River Valley

Migrants in many societies maintain distinctive culinary traditions that can range from specific recipes or a favorite food, to the dietary regime of an entire household. Multiple regional dietary differences existed in the Maya lowlands (Figure 6.13). For example, Gerry and Krueger (1997) estimate that maize consumption comprised nearly 66% of the diet at Petén and Copán Valley sites, but less than half the diet in the Belize Valley. Differences in protein sources were less marked. Petén populations consumed more terrestrial animal protein than those in the Belize River valley, and diet in both regions included more animal protein than at Copán (Gerry and Krueger 1997; Reed 1999).

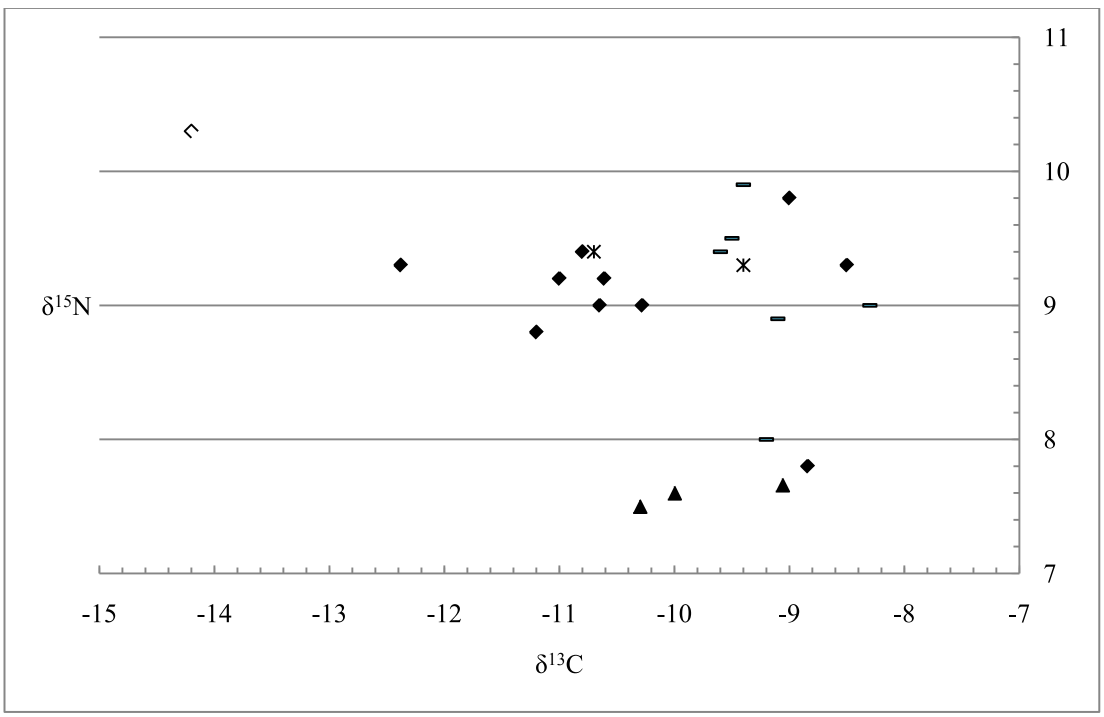

Figure 6.13. Average C and N isotope values from 22 Late Classic sites: The Belize Valley ◆, Lamanai ◇, the Southern Lowlands ▬, the Central Lowlands *, and Copán ▲ (data from Gerry and Krueger 1997; Piehl 2006; Wright 1997; White 1997).

However, differences also are reported by status, sex, and age (Chase et al. 2001; Coyston et al. 1999; Reed 1999; White 1997; Whittington and Reed 1997). It is not likely that a single individual's attempt to maintain non-local dietary practices would be discernible isotopically. However, migration is not an isolated phenomenon. It may include multi-generational movement, or the relocation of more than one individual. Connections between communities and regions likely existed at the household rather than the individual level. This suggests that differences might exist among residential groups, and that this may be visible archaeologically.

Sample

Samples were chosen in part to supplement studies by Piehl (2006) and Gerry (1993), which include carbon and nitrogen isotope assays of bone collagen for 86 individuals from seven Belize Valley sites. Values for twenty-one additional individuals from Xunantunich, Pook's Hill, and Barton Ramie bring the total number of individuals sampled to 107. In addition, carbon and oxygen isotope values in bone apatite are available for 24 additional individuals, bringing the total number in the region to 71 (see Table 6.1).

Samples also were intentionally selected to explore potential dietary differences at sites with different migration patterns. Both interregional migration and within-region migration are identified at Xunantunich, a pattern that presents a sharp contrast with the local and/or regional variability identified at Pook's Hill. Imported foods are documented at both sites, including parrotfish at Pook's Hill (Stanchly 2006) and wild game at Xunantunich (Freiwald 2010; Yaeger and Freiwald 2009). Most of the sample population from Xunantunich is described in Chapters 5, but one additional individual is included. A cranium labeled "skull 2" is associated with the adolescent female interred in the Str. A4 burial with a child and several skulls and/or crania (Jennifer Piehl personal communication 2010). Five additional individuals from Pook's Hill include Str. A4 Individuals E and A, and individuals designated Burials 1, 2, and 3 in Str. 2A. This structure is located on the western side of the plaza across from burial shrine Str. 4A and its use likely included public activities (Helmke 2000b).

The results of bone collagen assays for Xunantunich and Pook's Hill are discussed separately and in the context of dietary patterns in the Valley and the Maya lowlands. Carbon isotope values in bone apatite provide complementary data, as do oxygen isotope assays. While there is not a strong relationship between dietary differences and an individual's non-local origin, some isotopic distinctions are visible in different residential groups that may relate to population movement between communities.

2. Carbon and nitrogen isotope values

The Belize River Valley burial population is included in two dissertations that use bone collagen and apatite assays to reconstruct dietary patterns. Gerry (1993) concludes that the isotope values of Baking Pot and Barton Ramie individuals indicated a reliance on maize agriculture and terrestrial game. This fits well with zooarchaeological assemblages in the region that consist primarily of predominantly whitetail deer and other wild game (Clowery 2005; Freiwald 2010; Powis et al. 2005; Stanchly 1994, 1999, 2005, 2006). Piehl (2006:587) finds similar results in the five sites in her study, which also includes a number of individuals from Baking Pot.

This general diet also is identified in studies across the lowlands, but Belize Valley isotopic signatures are notable in two ways: first, carbon isotope values are depleted, suggesting that the diet included a diverse mix of resources (Gerry 1993; Piehl 2006). In contrast, residents of Copán relied more on plant proteins with a significant input from C_4 plants that also is identified in the Petén. Second, reasons for the region's distinct diet are not well-understood. Possible explanations include environmental heterogeneity, diverse food choices, low settlement density, or use of diverse catchments, each of which are interrelated (Freiwald 2010; Gerry 1993; Gerry and Krueger 1997).

Another possibility stems from sample selection. Wright (2006) finds unique trends at each of the Pasión region sites in her study, where understanding the relationship between diet, status, and gender of diet was complicated by temporal change as well. In contrast, Piehl (2006) notes more similarities than differences within the Belize Valley, which she describes by site, burial context, and sex. With the exception of the enriched values at Blackman Eddy, which indicate a diet with significantly more C_4 resources than all sites in the valley but Pacbitun, she finds little distinction in dietary strategies or access to food resources (Piehl 2006:612). The goal of this study is not to re-analyze the same questions, but to explore one aspect of dietary diversity: differences that may relate to individual and household migration histories.

Tables 6.10, 6.11, and 6.12 show $\delta^{13}C_{co}$, $\delta^{13}C_{ap}$, and $\delta^{15}N$ summary values for each Belize Valley site in this section: the mean $\delta^{13}C_{co}$ value for all sites is 10.63 ± 2.5‰. This is slightly more enriched than the value reported by Gerry (1993) ca. -11‰, and not substantially different from the mean value for Copán ~10.2 ± 0.9‰ or Petén sites -9.5 ±1‰. If Blackman Eddy values are removed, the mean is more negative (-10.8). Xunantunich has the most negative average value, while Pook's Hill is near the valley mean.

Table 6.10. $\delta^{13}C_{co}$ samples by site location: only one value is available for Esperanza – it is not listed. Data includes values from Gerry (1993) and Piehl (2006). See Table 6.1 for details. Values are expressed as per mil (‰).

site	N	range	Minimum	maximum	mean	s.d.	median
Xunantunich	7	3.7	-12.8	-9.1	-11.3	1.6	-12.1
Pook's Hill	13	3.1	-11.9	-8.8	-10.7	0.9	-10.9
Barton Ramie	42	5.4	-13.3	-7.9	-11.2	1.4	-11.1
Cahal Pech	16	4.4	-13.0	-8.6	-10.6	1.4	-10.5
Blackman Eddy	5	1.1	-9.4	-8.3	-8.8	0.5	-9.0
Baking Pot	13	3.5	-12.4	-8.9	-10.9	1.1	-11.4
Saturday Creek	6	2.5	-11.4	-8.9	-10.0	0.8	-10.2
Floral Park	6	4.2	-13.6	-9.4	-10.7	1.5	-10.1

The mean value for all sites is 8.8 ± 0.8‰. Four values are outliers (more than two standard deviations from the mean), but there are no significant changes in the mean and standard deviation if these and low Blackman Eddy values are removed. The highest values also are those with the largest range in values at Cahal Pech and Baking Pot. However, Piehl (2006) notes more cohesion than difference between sites in her study with the exception of Blackman Eddy, which she interprets as a more limited low (animal) protein diet. Xunantunich and Pook's Hill values are lower than all mean values except those at Barton Ramie, but generally fall within one standard deviation from the mean.

Table 6.11. $\delta^{15}N$ samples by site location: only one value is available for Esperanza – it is not listed. Data includes values from Gerry (1993) and Piehl (2006): see Appendix C for details. Values are expressed as per mil (‰).

site	N	range	minimum	maximum	Mean	s.d.	median
Xunantunich	7	2.2	6.8	9.0	8.3	0.8	8.6
Pook's Hill	13	2.2	6.4	8.6	7.9	0.6	8.2
Barton Ramie	41	1.7	8.1	9.8	8.8	0.4	8.8
Cahal Pech	16	4.0	7.2	11.2	9.2	1.0	9.4
Blackman Eddy	5	0.6	7.4	8.0	7.8	0.2	7.9
Baking Pot	13	4.3	7.0	11.3	9.2	1.1	9.3
Saturday Creek	7	0.7	8.5	9.2	8.9	0.2	9.0
Floral Park	6	1.0	8.5	9.5	8.9	0.4	8.9

The relationship between carbon isotope values in bone apatite and collagen should generally follow a linear relationship, but apatite is a reflection of total diet rather than just protein sources reflected in bone collagen. Mean apatite values, like the other isotope values, are similar to those identified by Gerry (1993), though slightly more enriched. Petén sites and Copán have lower average apatite values, ca. -5.5‰, which reflect the greater C_4 contribution to diet (Gerry 1993).

Collagen-apatite spacing is nearly identical for all sites (3.8 – 4.6‰), though this range of average values begins to blur the regional distinctions that Gerry (1993) identified. Petén site mean collagen-apatite spacing is 3.8‰, which is that of both Pook's Hill and Cahal Pech. Since this is used to indicate lower meat consumption (but see Hedges 2003), it suggests that there is variability within the Belize Valley sites – in addition to that identified at Blackman Eddy and Pacbitun (Coyston et al. 1999) – that is worthy of further exploration.

Table 6.12. $\delta^{13}C_{ap}$ samples by site location: only one value is available for Esperanza – it is not listed. Data includes values from Gerry (1993) and Piehl (2006): see Appendix C for details. Duplicate values are included for Barton Ramie, Xunantunich, and Pook's Hill. Values are expressed as per mil (‰).

site	N	range	minimum	maximum	mean	s.d.	Median
Xunantunich	20	-5.1	-9.7	-4.6	-7.0	1.9	-6.8
Pook's Hill	28	2.6	-8.2	-5.5	-6.9	0.9	-7.1
Barton Ramie	37	2.0	-8.1	-6.1	-7.1	0.6	-6.9
Cahal Pech	12	3.5	-8.8	-5.2	-6.1	1.9	-6.3
Blackman Eddy	2	1.5	-6.7	-5.2	-6.6	0.1	-6.5
Baking Pot	6	3.7	-8.9	-5.2	-6.3	0.7	-6.9
Saturday Creek	6	1.6	-7.0	-5.4	-6.4	0.6	-6.6
Floral Park	2	0.1	-6.3	-6.2	-6.3	0.1	-6.3

To sum up dietary findings for Xunantunich and Pook's Hill, both sites show a large range of bone apatite and collagen values. At Xunantunich, estimates of C_4 foods in the protein component of the diet range from 25 - 81%, and from 47 - 83% of total diet. At Pook's Hill, C_4 sources in protein range from 62 - 83%, and from 59 - 79% of total diet. Significantly less variability is visible in nitrogen isotope values, but some variation in collagen-apatite spacing suggests a different mix of foods in the diet. It is possible that these differences relate to origin: burial location has some relationship to dietary values at these two sites, though this is not the case for the valley as a whole.

Neither Gerry (1993) nor Piehl (1997) identify patterned variation within Belize Valley sites. Gerry's main focus was on status, which does have significant associations with diet in his sample, a finding echoed by Wright (2006) in the Pasión at the regional level. A key finding in both studies was that if dietary differences exist between males and females, they are obscured by other variables. Neither Gerry (1993) nor Piehl (2006) identify differences by sex. Piehl (2006) notes that the burial contexts were not directly comparable in her small sample (n = 16). A comparison of 65 values from Floral Park, Esperanza, Cahal Pech, and Blackman Eddy (Piehl 2006), Barton Ramie (Gerry 1993 and this study), Baking Pot (Gerry 1993; Piehl 2006), and Xunantunich and Pook's Hill show the same results as Piehl (2006). There is no statistically significant difference in male and female diet. The sex determination of the individual in Burial 6 from Floral Park was changed from probably female to indeterminate (see Appendix A).

Females have more depleted collagen isotope values than males. Twenty-two individuals identified as female or probable female have an average $\delta^{13}C$ value of -11.18 ± 1.53. In contrast, the mean value for 42 males (and probable males) is -10.44 ± 3.58. However, the difference is not statistically significant for either collagen isotope results (equal variances assumed $t = 0.916$ $df = 62$, p = 0.363 and equal variances not assumed t = 1.14 $df = 60.27$, p = 0.257 in a two-tailed comparison). Nitrogen isotope results are similar (equal variances assumed $t = -0.47$ $df = 62$, $p = 0.643$ and equal variances not assumed $t = -.536$ $df = 59.81$, $p = 0.594$).

Piehl (2006) also compared public and residential burial contexts, with specific attention to burial shrines in residential groups. She described a great deal of diversity in burials in Cahal Pech residential groups, but noted that the diets of individuals buried in public contexts did not measurably differ from those of individuals in residential burials. However, there do appear to be dietary differences between burial locations in the Pook's Hill and Xunantunich samples.

Individuals buried in the Xunantunich Group D residence (n = 4) have more depleted carbon isotope values than those interred in the Group B residence (n = 1) and in Group A monumental architecture (n = 2). The sample sizes are very small in part because poor bone preservation resulted in low C:N ratios for three individuals because insufficient collagen was preserved for the analysis (Appendix C). Individuals were sampled from two structures in the Pook's Hill residential group: sampling additional individuals in Str. 2A would show whether or not values also cluster by burial location. However, Pook's Hill values only partially overlap those in the two groups at Xunantunich with the main differences in the carbon isotope values (Figure 6.14).

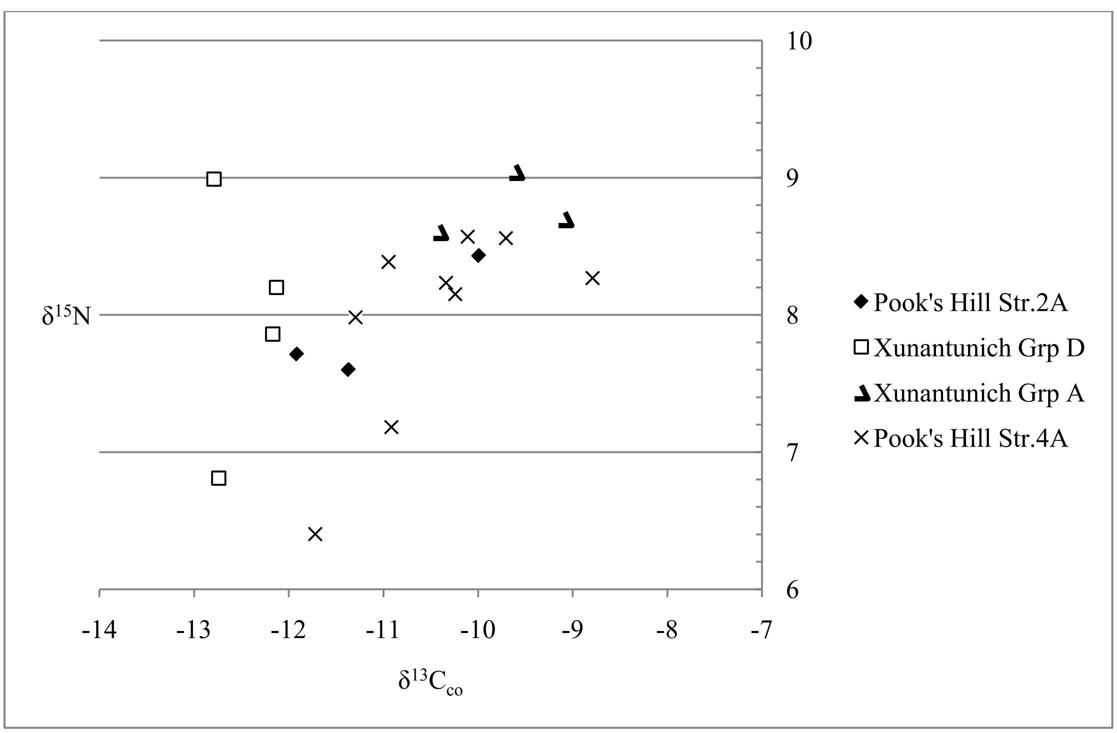

Figure 6.14. Carbon and nitrogen isotope values by burial location: individuals interred in Pook's Hill and Xunantunich residential groups.

Piehl's (2006) observations on the diversity present in burial shrines also are visible in the larger sample. Figure 6.15 shows values in burial shrines, including four sites sampled by Piehl (2006), Mound G sampled by Gerry (1993), and the Pook's Hill burial structures. While most sample sizes are small, Ricketson's (1931) excavations at Baking Pot Mound G show a burial population with a great deal of dietary diversity. In contrast, the burial population at Blackman Eddy does not.

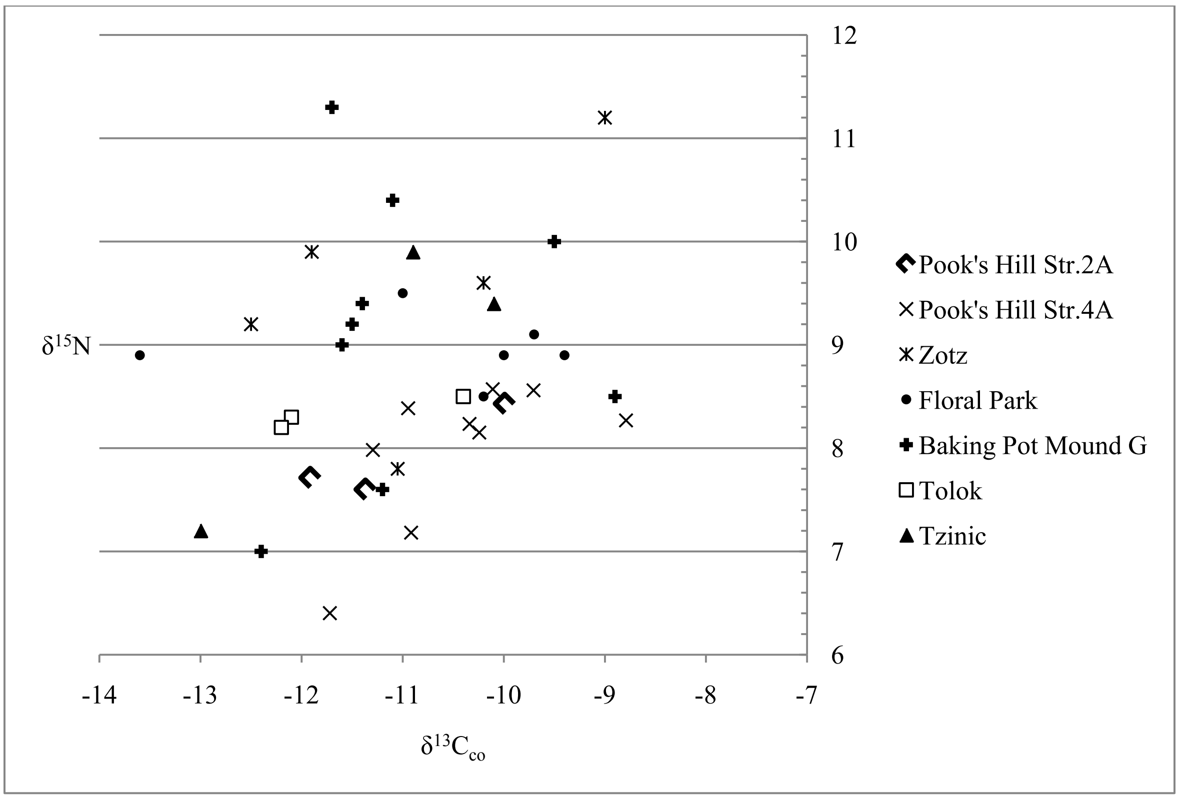

Figure 6.15. Individuals interred in residential shrines: includes data from Gerry (1993) and Piehl (2006).

The values of individuals buried in residential groups tend to form groups, but these loose clusters only show marked differences in a few cases (Figure 6.16). The small number of samples in BR-155 and Xunantunich Group D show depleted carbon isotope values, which will be explored in the context of origin and strontium isotope values in the next section. However, there clearly is less diversity in isotope distribution than in the burial shrines, especially in the distribution of nitrogen isotope values.

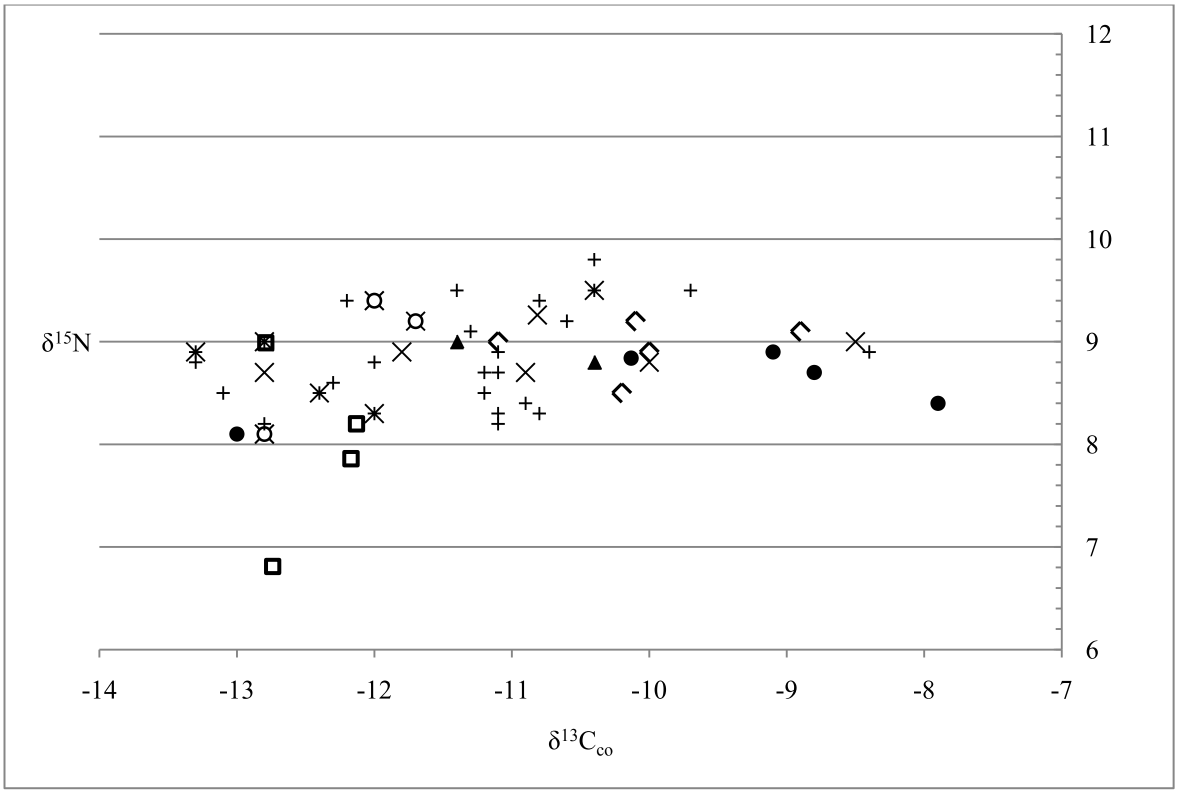

Figure 6.16. Carbon and nitrogen isotope values for Belize Valley residential groups: values for individuals interred in residential groups, including data from Gerry (1993) and Piehl (2006).

3. Oxygen isotope values

Mean average oxygen isotope values are more depleted than anywhere yet reported in the Maya Lowlands when compare to a summary of published samples in Price et al. (2010). Fifty-one values from 24 individuals at Xunantunich (samples = 20), Pook's Hill (samples = 27), and Barton Ramie (samples = 4) represent 24 individuals. Mean values for the region are $\delta^{18}O_{SMOW}$ 27.64 ± .49‰ (median value 27.69‰) and range from 26.56‰ – 58.54‰. The range of 1.98‰ for the values does suggest a population sharing the same basic water sources. No difference is apparent in values by site or burial location (Table 6.13).

Table 6.13. Oxygen isotope values in tooth enamel: values expressed per mil (‰).

Site	Samples	individuals	$\delta^{18}O_{SMOW}$	minimum	maximum
Xunantunich Group D	12	6	27.26	25.71	27.92
Xunantunich Groups A and B	8	4	27.59	26.67	28.11
Pook's Hill Str. 2A	9	3	27.76	27.54	28.19
Pook's Hill Str. 4A	18	9	27.93	27.51	28.54
Barton Ramie	4	2	27.31	25.55	27.85

Oxygen isotope values from tooth enamel also are available for seven Xunantunich individuals. When the $\delta^{18}O_{PDB}$ values are converted to $\delta^{18}O_{SMOW,}$ the values should be slightly more depleted as a result of the offset for nursing. However, a more interesting pattern emerges. Four of these individuals have strontium isotope values that suggest a non-local origin. The difference between their tooth enamel and bone oxygen isotope values exceeds what -0.7 to -1.6‰ nursing offset. The anomalous carbon and oxygen isotope values for Group D Op. 21 C Individual #1 also show a larger offset than would occur using a similar water source, which supports the suggestion that this individual relocated from a coastal area with similar strontium isotope values (Table 6.14).

Table 6.14. Xunantunich oxygen isotope values in tooth enamel and bone: bold values show offsets likely caused by factors other than nursing. Values higher or lower than Belize River strontium zone values also are highlighted. The tooth enamel values are those treated with the minimal treatment protocol, while the bone apatite values were intensively treated. The average difference between intensively and minimally treated tooth enamel samples is -0.25‰, though change for many values did not exceed the standard deviation for the sample.
.

Xunantunich	sample # tooth	Tooth sampled	$\delta^{18}O_{PDB}$ tooth enamel	$\delta^{18}O_{SMOW}$ bone	Offset	$\delta^{87}Sr$
Group D Burial Op. 74JJ	F5140	LLM1	-3.41	27.26	-0.11	.708991
Group D Op. 21B	F5143	P	-3.01	27.36	-0.66	.708369
Group D Op. 21C#1	F5144	UP	-1.41	27.35	**-2.21**	.709031
Group D Op. 21C #2	F5145	LRM1	-3.47	27.76	**0.13**	**.710463**
Group D Op. 21D	F5149	P	-3.33	26.13	**-1.05**	**.711112**
Group D Op. 74	F5147	LLM1	-2.76	27.72	-0.39	.708648
Str. A-32 Op. 247	F5146	LRM1	-0.60	27.67	**-2.78**	**.708004**
Group B Op. 211	F5153	LLM1	-0.91	27.99	**-1.99**	**.708196**
Str. A-4 Skull 2 and mandible D	F6070 F5420	LLP3	-1.84	27.68	**-1.46**	**.707982**

This provides another line of evidence that individuals with non-local strontium isotope values relocated sometime after childhood to a Belize Valley site. It also appears that sufficient time passed after the move for their bone tissues to remodel to the local oxygen isotope value. No significant differences are visible in $\delta^{18}O$ values in bone apatite, implying that individuals used similar water sources during their last years of life. The next section explores relationships between origin and other aspects of diet that may be visible in isotope values.

4. Diet and Origin

A total of 58 individuals have isotopic values that can be used to explore the relationship between diet and origin. These are used to discuss two interrelated topics. The first is the potential connection between non-local strontium isotope values and atypical diet, which leads to the related topic of isotopic variation within the site and region. Can dietary differences lead to variability in local strontium isotope ratios?

Differences would be hard to detect for a number of reasons. While Gerry (1993) identified broad regional dietary differences, there remains substantial overlap in individual isotope values. In addition, most non-local individuals in the Belize Valley sample moved only a short distance, likely relocating within the region. Differences that did exist also may be masked by myriad other factors, like sex, status, or occupation. Wright (2007) explored this relationship at Mayapán and did not identify dietary differences, despite isotopic and ethnohistoric evidence for migration at the site.

The individuals in Table 6.15 can be divided into four groups: individuals with strontium values lower than those found in the Belize Valley, and Belize River, Macal River, and Maya Mountain zone values. All individuals were buried at Belize River zone sites and are listed in order of strontium isotope value. The mean value is presented for individuals with multiple isotopic assays.

Table 6.15. Carbon, oxygen, nitrogen, and strontium isotope values for 58 individuals: data in italics reprinted from (Piehl 2006) and Gerry (1993): values that fall outside two standard deviations from the mean are bolded.

Burial detail		$\delta^{13}C_{co}$	$\delta^{13}C_{ap}$	$\delta\ ^{15}N$	$\delta^{87}Sr$
Barton Ramie N8857.22	Probable male adult	-10.79	-8.34	9.31	.707650
Esperanza Str. A4 2c-1 B2	Adult	-12.40	-6.30	9.30	.707961
Xunantunich Str. A4 skull 2and mandible D	Female adolescent	-10.43	-5.91	8.61	.707982
Xunantunich Op. 247JJ	Probable male adult	-9.60	-5.40	9.04	.708004
Xunantunich Op. 211K	Female adult	-9.07	-4.57	8.70	.708196
Baking Pot Mound G B7	Male adult	-11.6	-	9.0	.708201
Pook's Hill 4A-7	Indeterminate	-10.24	-6.63	8.15	.708237
Pook's Hill 4A-3 #G	Male adult	-10.34	-7.53	8.23	.708238
Baking Pot Str. 102 B1	Adult	-11.40	-5.20	9.30	.708246
Barton Ramie N8857.84	Probable female adult	-12.80	-7.40	8.20	.708262
Cahal Pech Tolok 4	Adult	-12.20	-7.90	8.20	.708311
Cahal Pech Tolok 2-92	Adult	-10.40	-7.00	8.50	.708311
Pook's Hill 4A-3 #C	Male adult	-8.79	-7.12	8.27	.708325
Xunantunich Op. 21B	Adult	-12.13	-8.35	8.20	.708369
Saturday Creek SC-85 B6	Male adult	-10.00	-6.60	8.90	.708402
Baking Pot Mound G B3	Old adult	-11.7	-7.0	11.3	.708425
Pook's Hill 4A-5	Male adult	-10.11	-7.11	8.57	.708443
Pook's Hill 4A-2	Adult	-10.92	-6.57	7.18	.708448
Pook's Hill 4A-6	Probable male adult	-10.95	-8.13	8.39	.708456
Floral Park Str. 2A B2	Indeterminate	-9.40	-	8.90	.708470
Barton Ramie N8857.134	Adult	-12.30	-7.60	8.60	.708481
Blackman Eddy BME-2C-B1	Adult	-9.00	-	7.90	.708483
Cahal Pech Str. A2 B1	Adult	-8.60	-5.20	8.40	.708505
Baking Pot Mound G B15	Indeterminate	-9.5	-6.5	10	.708510
Barton Ramie N8857.42	Probable male adolescent	-10.60	-6.50	9.20	.708560
Saturday Creek SC-85 B8	Male adult	-10.20	-6.40	8.50	.708567
Barton Ramie N8857.36	Probable adult	-13.00	-	8.10	.708575
Blackman Eddy BME-2C-B3	Adolescent/adult	-8.30	-6.70	7.40	.708581
Floral Park Str. 2A B6	Adult	-11.00	-	9.50	.708582
Barton Ramie N8857.127	Probable male adult	-10.00	-6.10	8.80	.708601
Blackman Eddy BME-2C-B2	Child	-8.40	-6.50	7.90	.708612
Saturday Creek SC-85 B3	Adolescent	-8.90	-6.70	9.10	.708629
Barton Ramie N8857.141	Male adult	-10.13	-6.91	8.84	.708641
Xunantunich Op. 74R	Adult	-12.79	-6.75	8.99	.708648
Cahal Pech Str. B2-2	Adult	-9.30	-	9.80	.708649
Baking Pot Mound G B9	Probable female adult	-8.9	-	8.5	.708674
Barton Ramie N8857.137	Male adult	-12.00	-6.90	9.40	.708675

Barton Ramie N8857.32	Male adult	*-13.30*	*-7.20*	*8.90*	.708699
Xunantunich Str. A4 cist	Indeterminate	-	-4.97	-	.708720
Cahal Pech Zotz 2/B3	Male adult	*-9.00*	***-2.40***	***11.20***	.708726
Cahal Pech Zotz 2/B1	Male adult	*-12.50*	*-8.20*	*9.20*	.708731
Barton Ramie N8857.55	Male adult	*-11.10*	*-7.70*	*8.90*	.708733
Barton Ramie N8857.23	Male adult	*-11.80*	-	*8.90*	.708753
Baking Pot Mound G B11	Male adult	*-11.5*	-	*9.2*	.708836
Cahal Pech Zotz 2/B5	Indeterminate	*-10.20*	*-5.80*	*9.60*	.708892
Pook's Hill 4A-1	Probable male adult	-11.72	-6.85	**6.40**	.708929
Barton Ramie N8857.90	Female adult	*-11.10*	*-6.80*	*8.70*	.708958
Xunantunich Str. D-6 Op. 74	Adult		-8.50		.708891
Saturday Creek SC-18 B7	Female adult	*-11.40*	*-6.50*	*9.00*	.709024
Xunantunich Op. 21C Ind.#1	Male adult	-12.17	-9.56	7.86	.709031
Saturday Creek SC-18 B5	Adult	*-10.40*	*-7.00*	*8.80*	.709123
Barton Ramie N8857-7	Probable male adult	-11.4	-7.00	9.50	.709160
Baking Pot Atalaya B1B	Probable female adult	*-11.20*	*-6.30*	*9.00*	.709259
Saturday Creek SC-85 B1	Female adult	*-11.10*	-	*9.00*	.709273
Barton Ramie N8857.33	Female adult	*-13.30*	*-7.90*	*8.80*	.709584
Floral Park Str. 2A B9	Female adult	*-13.60*	-	*8.90*	.710286
Xunantunich Op. 21C Ind. #2	Male adult	-12.74	-9.08	**6.81**	.710463
Xunantunich Op. 21D	Probable male adult	-	-6.39	-	.711112

There is no relationship between strontium isotope values in tooth enamel and carbon or nitrogen bone collagen and apatite values. Neither is there any relationship visible by burial location for strontium and carbon or nitrogen isotope values (Figure 6.17 and 6.18). Some of the clusters previously described are visible, such as the depleted carbon isotope values in some Xunantunich Group D individuals. Multiple individuals buried in this residential group have high strontium isotope values, but there is not a strong relationship between the variables in these samples to form general conclusions. However, individual anomalous values suggest such a correlation might be identified with a larger dataset.

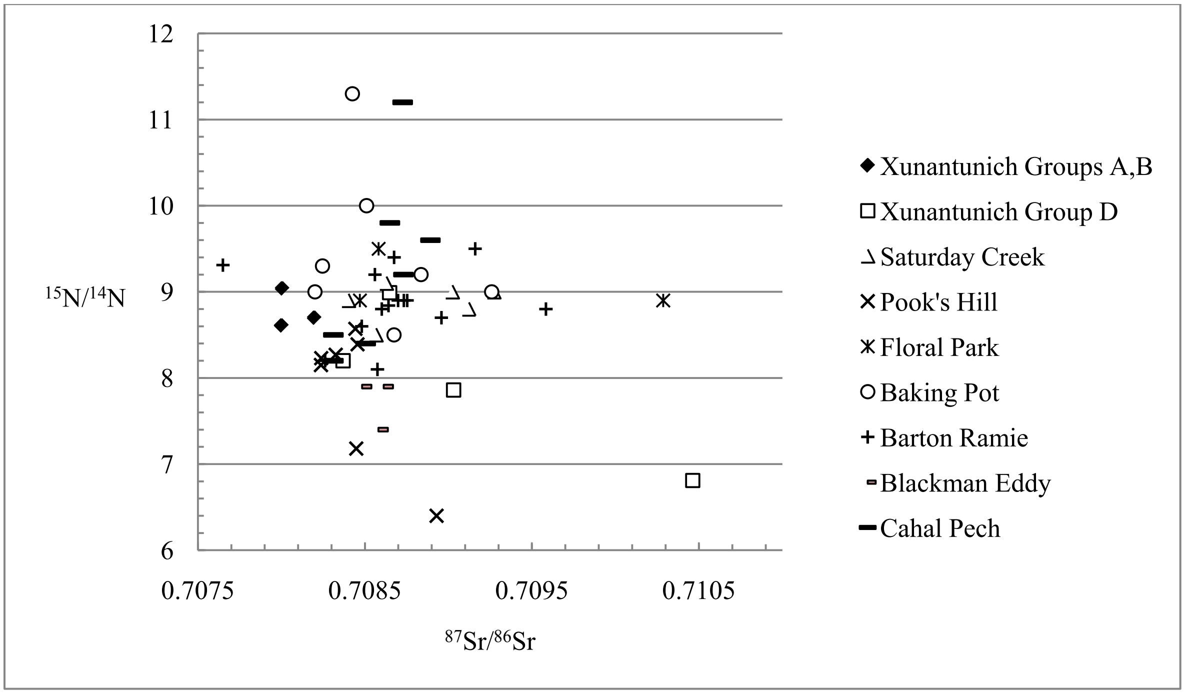

Figure 6.17. Strontium and nitrogen isotope values: includes data from Piehl (2006) and Gerry (1993).

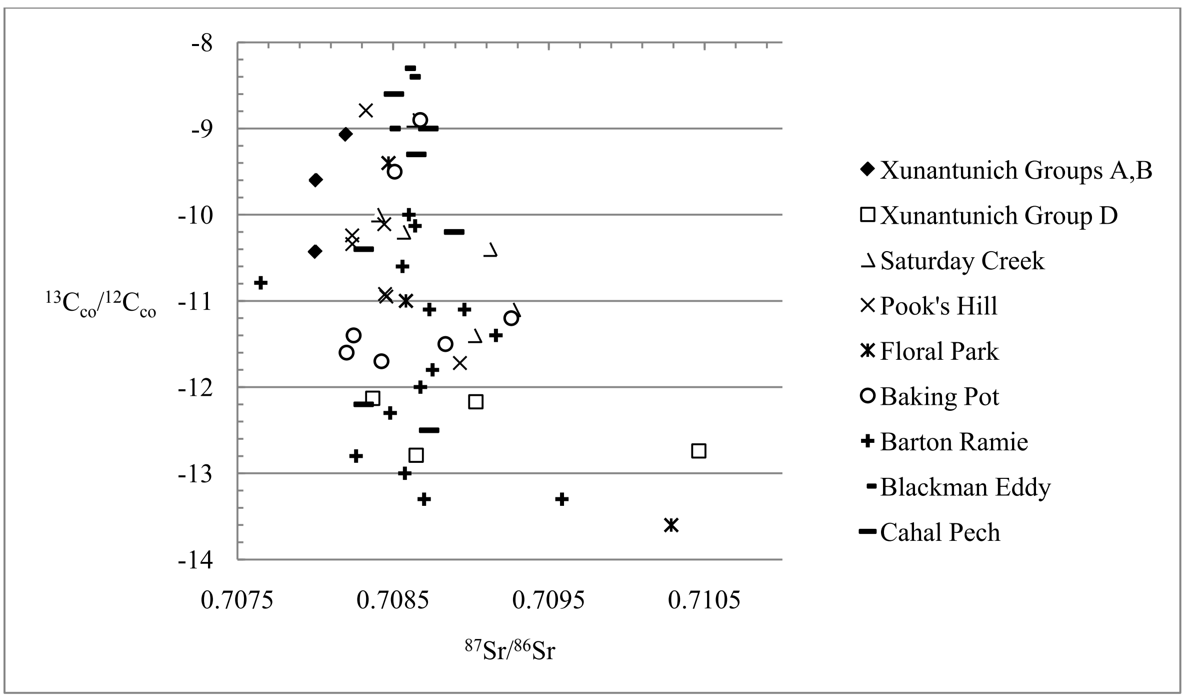

Figure 6.18. Carbon and strontium isotope values: includes data from Piehl (2006) and Gerry (1993).

Only six individuals have isotope values that are higher or lower than two standard deviations from the mean. Four are identified in nitrogen isotope values and three in bone apatite carbon samples. Baking Pot Mound G Burial 3 and (Cahal Pech) Zotz Burial 3 individuals have $\delta^{15}N$ values that suggest a larger marine contribution to the diet than found in other individuals (>11‰). The Zotz individual also has very enriched carbon apatite and collagen values, while the Baking Pot individual shows a low C_4 contribution, which suggests a different combination of foods. For example, some freshwater fish and turtle have depleted carbon isotope values and heavy nitrogen ones. Both of these individuals have strontium isotope values local to the Belize River zone.

Three individuals from Xunantunich have anomalous isotope values, two of whom were buried together. Group D Op. 21C individual #1 has a very low nitrogen isotope value (6‰, which is more than two standard deviations from the mean). Individual #2 also has a low nitrogen isotope value (7‰), but the carbon isotope value instead is an outlier. Both of these individuals had a diet low in C4 foods and animal proteins. Their diet differed with that of the female in Group B burial Op. 211, whose diet is sufficiently enriched in C_4 diet that the bone apatite value is a high statistical outlier. These are more extreme examples of general trends identified at Xunantunich, where dietary distinctions are visible in architectural groups with different patterns of local and interregional migration.

4a. Dietary differences do not explain strontium isotope variability

The sixth individual with an anomalous isotope value was interred at Pook's Hill. The low nitrogen isotope value of the individual designated Burial 4A-1 indicates a lower contribution of animal proteins than other individuals at Belize valley sites, including in the other burials sampled in the same residential group. The strontium isotope value also was higher than most values identified in the Belize River strontium zone. Archaeological evidence supports a separate history for this individual: the burial postdated most of the others at the site (see Chapter 5).

Multiple isotopic values show dietary differences for individual in Burial 4A-1: could dietary differences contribute to δ^{87}Sr variability, especially in the case of marginal values? Wright (2005b) suggests that strontium isotope values at Tikal are elevated as a result of non-local foods (specifically, salt). Parrotfish were identified in the faunal remains at Pook's Hill, but this would have resulted in the exact opposite pattern than that identified for Burial 4A-1: elevated δ^{13}C and δ^{15}N values. While it is uncommon to find a connection between a single food source and an isotope value, it is necessary to show that marginal strontium isotope values reflect movement of people rather than food.

Two assumptions are required to explore this question. First, there must be some similarity in major food sources of infants, children, and adults. While nursing children will receive nutrients from the mother, additional support comes from the depleted mean carbon isotope values for Xunantunich tooth enamel and bones samples. A second assumption is the rate of bone replacement, given in all Mesoamerican dietary studies as during the final years of life. It is well known that age, sex, pregnancy, and physical activity all are factors that can affect the rate of bone growth and absorption. However, Hedges and colleagues (2007) suggest a significantly longer period of turnover where the femur of a 35-year old female might still retain 40-50% of collagen formed during adolescence. A 50-year old would still retain nearly half of bone collagen formed in early adulthood.

In the small Pook's Hill sample of seven individuals with multiple isotope values, there is a moderately strong correlation between carbon and nitrogen dietary values and strontium ones.

However, this appears to stem from the single individual with outlier values just discussed. Variance in strontium isotope values (σ^2 = <0.000) is not on the same scale as that identified in the other isotope values ($\delta^{15}N$ σ^2 = 0.30 and $\delta^{13}C$ σ^2 = 0.86). It does not appear that imported foods at the site have a relationship to individual origin. In fact, no individual appears to have a heavy marine component in the diet given the combination of collagen and apatite values.

There is no correlation between strontium isotope values and the other isotope signatures for the Belize River strontium zone values. In fact, the variance for each of the values, even with outlier values included in the dataset, is ½ that of the strontium isotope values. It does not appear that this set of samples will provide useful information in understanding the variability in strontium isotope values. This may be the result of using an indirect comparison of two difference time periods, or the composition of the dataset, which includes only a few marginal values.

For example, the dietary diversity Piehl (2006) identifies in the Zotz group at Cahal Pech is not visible in strontium isotope values, which cluster tightly together. The individuals clearly had differences in their diets, but the main contribution to strontium isotope values was a local food source. Different strontium isotope values most likely represent distinct places on the local or regional landscape making small-scale movement visible within the valley.

4b. Diet, origin, and individual life histories

Floral Park Str. 2A Burial 9

The isotopic values of this individual may provide the stereotypical example of residential mobility on a regional scale (Table 6.16). This probable female relocated from the southern part of the Belize Valley, as indicated by both oxygen and strontium isotope values, to a community that likely had strong cultural similarities to her childhood home, inferred by burial practices and material culture of each part of the valley.

Her diet throughout life consisted of less maize than other Belize Valley and Maya lowland residents, and it likely included a consistent source of animal protein. Growth defects on some premolars attest to childhood health stresses, and she suffered loss of one or more teeth before her death in mid-life. Years earlier, she had some of her front teeth filed. Although she was buried with no goods, she and/or her family had some standing in the community as she was interred in a cist in the burial shrine for the residential group, with her body placed in the orientation and position typical of the region (e.g., Schwake 2008).

Table 6.16. Multiple isotope values for Floral Park Str. 2A Burial 9

δ^{87}Sr enamel	*δ^{13}C enamel*	*δ^{18}O enamel*	*δCco bone*	*δ^{15}N bone*
.710286	-8.49	-3.28	*-13.6*	*8.9*

Xunantunich Str. A-32 Op. 247 Burial 1

This individual was not born in the Belize Valley, but instead relocated to the site sometime after infancy (Table 6.17). The most likely place of origin, based on both strontium and oxygen isotope values, is the Central Lowland strontium zone. Similar values are identified just a few kilometers away in the central Petén. The absence of hypoplasias indicates a childhood relatively free of major health stresses, and robust musculature suggests physical activity (Adams 1998). The individual was probably male, and he consumed a diet rich in C_4 plants throughout life, with regular access to animal proteins as an adult. He also filed his teeth, though like the individual in Floral Park Burial 9, the filing was not prominent. Calculus build-up was observed, but only two caries and limited tooth wear was observed by the time he died (Adams 1998).

This individual lived in the region long enough for his bones to adjust to local oxygen isotope values. His social status in the community is unclear, but he may have retained a lifetime association with his place of birth. His body was oriented to the west instead of the typical southern direction, and placed on its side against the wall of a room before the structure was remodeled. He was buried in one of the structures on the Castillo, the most prominent building at Xunantunich. However, there was no prepared grave, and although an awl was located close by, no grave goods were noted.

Table 6.17. Multiple isotope values for Xunantunich Str. A-32 Op. 247 Burial 1

δ^{87}*Sr enamel*	δ^{13}*C enamel*	δ^{18}*O enamel*	δ^{13}*Cco bone*	δ^{15}*N bone*	δ^{18}*O bone*	δ^{13}*Cap bone*
.708004	-4.91	-0.60	-9.60	9.04	27.66	-5.40

Xunantunich Group B Op. 211 Burial 1

This individual also may have spent infancy or childhood in the Central Lowlands (Table 6.18). While the strontium isotope value can be interpreted as local to the Belize River zone, the oxygen isotope values in the water source resemble those in the Central Lowlands. The diet of this individual, probably a female, also contained a substantial amount of maize from childhood until her death as a young adult: >80% C_4 food contribution to total diet. In her later years, wild game proteins also were available, but multiple hypoplasias between the ages of 3 - 4 years show some health or dietary stress (e.g., weaning). She had additional dental health issues as an adult, including an abscessed tooth, and was missing two lower incisors in what would have been a very visible congenital defect (Adams 1998).

She was buried in a low platform that demarcated the edge of the residential group near at least two other individuals, one of whom was elderly (based on the presence of a mandible with nearly complete alveolar resorption). While she may not have been born in the Belize valley, she lived there long enough for her bone apatite oxygen isotope values to adjust to the local mean. She was buried with a southern orientation, in the same manner as the locally-born population.

Table 6.18. Multiple isotope values for Xunantunich Group B Op. 211 Burial 1

δ^{87}*Sr enamel*	δ^{13}*C enamel*	δ^{18}*O enamel*	δ^{13}*Cco bone*	δ^{15}*N bone*	δ^{18}*O bone*	δ^{13}*Cap bone*
.708196	-2.65	-0.91	-9.07	8.70	27.99	-4.58

Str. A-4 Burial 1 skull 2

The death, or burial treatment, of this young adolescent female may be more intriguing than the aspects of her life that can be reconstructed isotopically. Her infancy and/or childhood likely was spent in the Central Lowlands, and her enriched oxygen isotope values are similar to other Group A individuals buried with Central Lowland strontium zone values. Her childhood diet also included a heavy C_4 component, though not to the extent of the other Group A individuals.

She lived long enough in the Belize Valley region for her bone to reflect local oxygen isotope values, which are different than those identified in her tooth enamel (see Table 6.19). She consumed fewer C_4 foods during adolescence than childhood, and had access to terrestrial game as an important protein source. Her burial treatment was atypical: she was interred in a floor deposit that was not sealed in the eastern temples structure in the main plaza. She was buried with a child and the skulls and/or crania of three adults with diverse origins in and around the valley.

There were no burial goods, but this was common at Xunantunich. The possible association between this burial and political change at the site poses intriguing questions about the relationship between with central Petén politics, local power, and non-local origin. The overall picture of migration at Xunantunich is a center with substantial in-migration on multiple levels, and one where basic dietary patterns differ within the site and may relate to the origin of the individuals at the site.

Table 6.19. Multiple isotope values for Str. A-4 Burial 1 skull 2

δ^{87}*Sr enamel*	δ^{13}*C enamel*	δ^{18}*O enamel*	δ^{13}*Cco bone*	δ^{15}*N bone*	δ^{18}*O bone*	δ^{13}*Cap bone*
.707982	-5.83	-1.84	-10.43	8.61	27.68	-5.91

E. Conclusion

Isotopic analysis can provide a wealth of information about the origin, weaning age, and basic dietary patterns of both children and adults. Oxygen isotope values provide information about water sources, which can be used to identify an individual's likely place of origin. Carbon and nitrogen isotope values show differences in major plant and animal resources consumed, while strontium isotope values identify where some foods were obtained. The record of an individual's childhood is recorded in tooth enamel, while bone tissues retain the history of adult dietary patterns.

Gerry (1993) and Piehl (2006) identify significant differences in both protein and plant contributions to diet based on geographic region, rather than by burial context, sex, or status. Oxygen isotope values also vary by region. Although there is less overall variability in oxygen isotope values Mesoamerica useful for identifying population movement, there are differences that can be used to differentiate populations within the Central Lowlands strontium zone based on differences in δ^{18}O in river and ground water sources (Lachniet and Patterson 2009; Marfia et al. 2004; Price et al. 2010).

Regional differences also are visible in childhood diet in the Belize River Valley. This includes depleted carbon and oxygen isotope values similar to those identified in adults. The regional variation complements that identified in strontium isotope values, and in a number of cases can be used to identify additional individuals who relocated to Belize River Valley sites.

While no patterned variability relates origin to diet later in life, analysis of multiple isotope values can be used to reconstruct individual biographies, which can be sewn together to construct a picture of migration at the site and the regional level.

Chapter 7 Modeling Migration: Belize River Valley and the Maya Lowlands

Chapter Summary

This chapter brings together all lines of evidence to reconstruct patterns of population movement in the Belize River Valley, including strontium, carbon, and oxygen isotope values, burial treatment, and osteological observations. These patterns include the overall rate of migration, the demographic profile of the migrant population, and examples from Belize Valley sites that characterize Late and Terminal Classic population movement in the region.

There are no measurable differences between migrants and the locally born population in aspects of health or perimortem violence. No patterns are visible in the very small sample of individuals with modified crania, but dental decoration may have some relationship with origin in the Belize Valley region. Body position and orientation have a strong correlation with origin, suggesting that it did play some role in an individual's identity throughout life.

Understanding migration also is critical for regional osteological studies. An analysis of linear enamel hypoplasias showed differences in childhood health at Xunantunich and Chaa Creek: the differences are no longer significant when individuals are compared by place of birth (strontium isotope zone) instead of the site where the individual was buried.

Population movement also is identified in neighboring regions, including the site of Caracol and three sites located in the Mountain Pine Ridge. While in-migration from multiple origins is identified at Caracol, none is visible in the Mountain Pine Ridge, posing interesting questions for future analysis. These results are compared to patterns identified elsewhere in the Maya lowlands. It appears that most movement occurred between neighboring regions, resulting in interconnecting networks of population movement across the Maya region.

A. Migration patterns in the Belize River Valley

Strontium, carbon, and oxygen isotope values serve as the main line of evidence to reconstruct patterns of population movement in the Belize River Valley during the Late and Terminal Classic. A summary of the estimated rate and direction of migration, and temporal trends at different sites in the region, highlight patterns of population movement. The next section presents the reconstruction of the demographic profile of the migrant population, including age, sex, and some aspects of status. These analyses show that migration was common and was not limited to a single segment of the population. Finally, a comparison of burial treatment, health, and body modification show ways that the relationship between non-local origin and identity might be expressed, addressing the social context of migration.

1. Summary information

1a. The rate of migration

Individuals with non-local strontium isotope values are identified at nearly all of the 15 sites sampled in the Belize River Valley: between 14 – 26% of the sample population relocated at least once between birth and burial. The lower value represents a conservative estimate of migration. It includes only those strontium isotope values that fall outside two standard deviations of the mean of the baseline fauna used to establish local values. The higher value represents a conservative estimate of the local population. It includes only values that fall within the range of the baseline fauna in each of the two Belize Valley strontium zones. Choosing the high or low rate of migration hinges on interpretation of marginal values. Even the higher estimate underestimates population movement, as immigrants from communities, polities, or even distant regions with similar strontium isotope values cannot be identified.

Most of the individuals with low marginal values have either anomalous burial treatment or a distinct childhood diet, which supports an inference of non-local origin. This includes five of eight individuals identified at six sites. No dietary or burial information is available for two of these individuals. The individuals in the Group B Op. 211 and Str. A-32 burials at Xunantunich have oxygen and carbon isotope values that suggest a childhood origin in the Central Lowlands, and the latter also is buried in an atypical orientation and location. The San Lorenzo Op. 71 and Buenavista Op. 350 individuals also have atypical orientations, though the latter burial may predate standardization of burial treatment in the region that occurred during the Late Classic (Willey et al. 1965). Baking Pot Str. 190 Burial 5 consists of a cranium-only interment in a non-residential structure, which also represents atypical burial treatment. Anomalous burials often are interpreted as those of non-local individuals, and this provides support for that assumption in non-residential burial contexts.

High marginal values show fewer differences in burial treatment, which could reflect movement over short distances, from the Macal River strontium zone to the Belize River zone. Both zones form part of the Belize Valley. No stark contrasts in diet or burial treatment support a non-local origin for these individuals, but four of five fit within the distinct cluster of Macal River zone values formed by individuals buried at Chaa Creek. If the four Chaa Creek individuals with non-Macal River strontium zone values are included, thirty-five individuals have non-local origins. This results in an estimated 23% population movement in the Belize Valley.

Figure 7.1 (next page) shows the strontium isotope ratios for each Belize Valley site in the study using the median value and interquartile range to illustrate the distribution of values within each site. The median value of the human population at most sites is similar to the mean (.7085) and median (.7084) of the baseline fauna that are used to determine the local value. Human values are slightly elevated, but most lie within the range of the Belize River zone faunal baseline. In-migration from other strontium zones is represented by the outlier and extreme values, as well as the spread within the whiskers of the box plots for some of the sites. This illustrates different patterns of population movement at each site. These values include Mitchell’s (2006) Cahal Pech and Buenavista data.

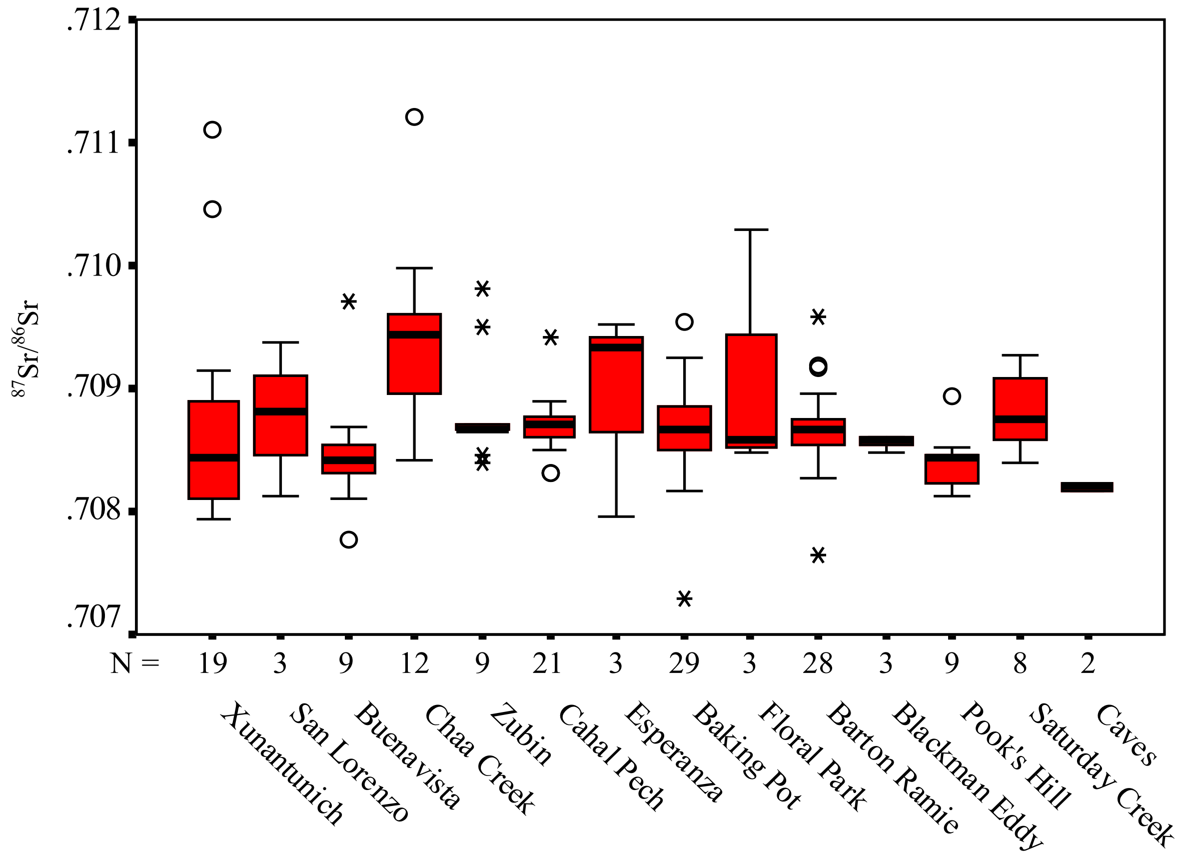

Figure 7.1. Strontium isotope values for Belize River Valley sites: The graphs shows the median value (black line), interquartile range (box), the highest and lowest values that are not outliers (whiskers), and outlier (circle) and extreme (asterisk) values. Sites are displayed according in order of location in the Belize Valley, with the exception of the two caves.

1b. Temporal trends

Eighteen individuals were interred during the Preclassic (n = 5), Protoclassic (n = 4), or Early Classic (n = 9). Eight additional individuals are not securely associated with a specific time period, but may date to the Classic period. The rate of population movement for these individuals is approximately 27%, slightly higher than the sample as a whole. Interpretation of marginal values may shift this value, but not significantly.

The estimate for the small number of individuals with undated burials (25%) is similar to the estimate for the total sample, so should not affect the overall findings. Population movement may have been higher during earlier periods, as ~39% of the 18 samples that predate the Late Classic from Baking Pot, Buenavista, Cahal Pech, Chaa Creek, Saturday Creek, and Zubin have non-local values. However, this must be viewed with caution as removing only one value in this small sample results in a 5% change in the total. Additional research on burials that predate the Late Classic in residential settlement near Buenavista is underway and should provide some insight into this question (John Spotts personal communication 2010).

Samples from earlier time periods illustrate two key aspects of population movement in the region. First, Preclassic burial treatment may not reflect the southern orientation that would later become the norm in the valley (Willey et al. 1965; Yaeger 2003). While the burial orientation for some Preclassic burials is not known, a northern orientation was observed for the individuals in Str. C9 Burial 1, and a possible western one for the child in the Buenavista Op. 350 Burial 1.

Second, strontium values of individuals interred during the Protoclassic and Early Classic show the potentially great time depth of migration patterns, especially in the direction of the movement. Individuals in Early Classic burials have either local Belize River values or marginal ones that most likely show movement from the Macal River zone. Individuals buried during the Protoclassic at Chaa Creek (in the Macal River zone) also had origins in neighboring zones, including the Maya Mountain and Belize River zones. Most population movement during the Late and Terminal Classic occurred within the region as well, showing that movement between areas in the valley was not just a Late Classic phenomenon. Additional research is needed to address critical questions about the earliest Preclassic settlement in the Belize Valley, which has been posited as multi-ethnic in nature (Ball and Taschek 2003).

A change in patterns between the Late and Terminal Classic might provide insight into the demographic changes that occurred during the Maya collapse. Only 18 individuals are securely dated to the Terminal Classic, and only two of these have non-local strontium isotope values. Both individuals were buried at Xunantunich and have values associated with the Macal River and Maya Mountain strontium zones. Temporal resolution is not sufficiently precise to differentiate Late and Terminal Classic burials in many cases. This is unfortunate because most of the depopulation of sites in the valley occurred during the Terminal Classic.

1c. Each site shows a different aspect of migration in the Belize Valley

Several aspects of population movement in the Belize Valley can be used to reconstruct broader patterns of migration and address the three questions that frame the model presented in Chapter 2. The first two questions suggest that most population movement should occur within a region, but that it should reflect the unique historic trajectory of the political entities in the study. Isotopic assays show that most population did occur within the Belize Valley; that is, within the region (question one), and that patterns vary by site and polity (question two). The third question posited that migration should differ according to age, sex or social status; that is, that it did not occur evenly across the population. There were no statistically significant differences in the Belize Valley burial population. It appears that population movement was widespread.

Table 7.1 shows the origins of the 35 individuals interpreted as migrants based on the combination of carbon, oxygen, and strontium isotope values in tooth enamel and archaeological evidence. Most population movement occurred within the Belize Valley, but in-migration is identified from other strontium zones, including the Southern Lowlands, which represents long distance movement. Nearly 60% of the population movement is within the Macal and Belize

Table 7.1. Individuals with non-local strontium isotope values: Values from other strontium zones and marginal values interpreted as non-local to the strontium zones. Buenavista values in italics come from Mitchell (2006).

Total (%)	**# values**	**Strontium isotope values**	**Closest strontium zone**	**Burials**
Belize River zone sites (excludes Chaa Creek)				
2.9%	1	.70729	Southern Lowlands	Baking Pot (Excavation 9 61663)
23.5%	8	.70765 - .70800	Central Lowlands	Barton Ramie (BR-144 B2) *Buenavista (BV-88-B4-2)* Xunantunich (Op. 302 B1, Str. A-4 B1 skull 4, head 1, and mandible D, and Str. A-32 Op. 247 B1) Esperanza (Str. A4 2c1 B2)
8.8%*	3*	.70811 - .70819	Unknown / Central Lowlands (marginal values)	San Lorenzo (Op. 71 B1) Baking Pot (Op. 190 B5) Xunantunich (Group B 211) (*21% if 5 additional low marginal values are included)
50.0%	17	.70912 - .71046	Macal River	Saturday Creek (SC-18 B5 and SC-85 B1) Baking Pot (Str. 112-1-1, Atalaya B1B, Str. 215 B4) Barton Ramie (BR-123 B18 and B9) Esperanza (Str.A4 2b-4-B2?, Str.A4 2d-1 B3) Xunantunich (Op. 21C B1 #1 and Str. A-4 B1 mandible A) San Lorenzo (Op. 243B1) Zubin (Str. A1-B6 and B3 #3) Floral Park (Str. 2A B9) *Buenavista* (*BV-88-B13-1)* Cahal Pech (Zopilote Tomb 1 B2)
5.9%	1	> .711	Maya Mountain	Xunantunich (Op. 21D B1)
Macal River zone site Chaa Creek				
8.8%	3	.70820 - .70909	Belize River	Chaa Creek (Op. 161 XX/31, Op. 190O B1, Op. 190P B1disturbed)
(see above: 5.9%)	1	> .711	Maya Mountain	Chaa Creek (Op. 190P B1 intrusive)

River strontium zones. Nearly all other identified in-migration came from neighboring regions, including the Central Lowland and Maya Mountain zones, but it is possible that some individuals relocated over longer distances. The Northern Lowlands have strontium isotope values similar to those of the Belize River zone, as does a small part of the Western Lowlands near Palenque.

Central Lowland values are found < 20 km away, but also hundreds of kilometers away in Chiapas. There also is overlap between the Central and Southern Lowland zones, so it is possible that additional individuals had origins within the Southern Lowlands.

Only a single value comes from a zone that is not adjacent to the Belize River Valley. Other than the Southern Lowlands zone value, there are none from the Pacific Coast and Volcanic Highlands or the Metamorphic zone near Copán. This supports the interpretation of values from large strontium zones, like the Central Lowlands, as most likely representing short and medium distance movement. That is, that most individuals with Central Lowland values came from centers near the Belize River Valley.

There also is a small amount of overlap between faunal and geologic baseline values ~.709 in the Macal River zone and coastal regions (Gilli et al. 2009; Hodell et al. 2004). However, the individuals identified in Table 7.1 have values exceeding .7091 that have only been identified along the lower Macal River. It is possible that zones with similar values exist elsewhere near the Maya Mountains, but samples collected north and west of the mountains show an immediate, rather than a gradual, transition. This suggests that movement within the Belize Valley occurred over very short distances.

There are broad similarities in the patterns of population movement at sites in the valley. In-migration is identified at nearly every site, and often from more than one strontium zone. However, there are differences. At Xunantunich, higher levels of population movement from the Central Lowlands show that the political and social ties suggested by ceramics and architecture were constructed in part by population movement. The combination of strontium and oxygen isotope values suggests that these individuals came from the Central Petén, the area closest to the Belize Valley, rather than a more distant area within the Central Lowlands strontium zone.

In-migration from multiple regions, including the Central Lowland zone, also is identified by Mitchell (2006) at Buenavista. This individual is buried in a residential group associated with the ruling family. Individuals with Central or Southern Lowland zone values also are identified at Barton Ramie, Baking Pot, and Esperanza, showing that residents of the Belize Valley participated in broader interaction networks. However, these are isolated findings rather than the patterned isotopic and archaeological associations at Xunantunich.

In contrast, population movement at the major center Cahal Pech is was substantially different. No in-migration is identified from outside the Belize Valley, and the only individual with a non-local value is a young male with a Macal River zone value represented only by a cranium. It is interesting that that no individuals with signatures consistent with Caracol have been identified at Cahal Pech, given the similarities in architecture and ritual practices identified by Awe and Helmke (in press).

In-migration at Baking Pot also came from multiple, but distinct locations. Although one individual has a Southern Lowlands value, most movement was within the Belize Valley. This pattern of mostly regional movement also is reflected at minor centers, regardless of polity affiliation, like Zubin, Chaa Creek, and Saturday Creek. Chaa Creek households with close ties to Xunantunich (Connell 2000) did not contain burials of individuals with Central Lowland values. However, when only individuals in residential burials are compared, Xunantunich Group D interments and those at Chaa Creek reflect the same patterns of movement between the Belize and Macal River zones.

1d. Where are migrants found?

Population movement occurred in all levels of settlement within the Belize Valley. The sample of cave burials is too small to generalize, but one individual did not reside in the same strontium zone as the cave where he or she was buried. There are differences between centers, but Table 7.2 shows that these are not significantly different ($x^2 = 2.539$, $df = 3$, $p = .468$).

Table 7.2. Non-local strontium isotope values by site size

	Major centers	**Minor centers**	**Rural settlement**	**Cave burials**
Number of samples	80	35	32	2
Number of migrants	18 (23%)	12 (34%)	5 (16%)	1 (50%)
Total range (with marginal values)	12 - 25 (15 - 31%)	8 - 12 (23 - 34%)	3 - 6 (9 - 19%)	1 - 2 (0 - 100%)

If the origin of the individuals is considered, there are some notable differences. Ten of the non-local values (56%) at major centers are from strontium zones that are not in the Belize River Valley. In contrast, only two are identified at minor centers (17%) and two in rural settlements (40%). More non-residential contexts were sampled at major centers, and the relationship between burial context and non-local origin is explored in the next section. However, these differences (including the cave burials) are not statistically significant different ($x^2 = 3.925$, $df = 3$, $p = .269$).

2. Demographic profile: who were the migrants?

Question two in the model suggests that patterns of population movement will vary in different subgroups of Maya society. Historic evidence from the Classic period shows population movement among elite individuals, while Colonial era records document substantial commoner movement. While there are no stark contrasts among segments of the burial population, which poses interesting questions about the ability of commoners to move and postmarital relocation practices in the region.

2a. Demography: sex

Although more males are included in the sample population than females, a higher proportion of females are identified as migrants than males. Table 7.3 Shows that difference is not statistically significant (Fisher's exact test, p = 0.4324). It seems that either post marital residence practices were flexible, or that people moved for reasons other than marriage (or both).

Table 7.3. Fisher's exact test for male and female migrants.

	Males (includes probable males)	Females (includes probable females)	Total
Non-local $^{87}Sr/^{86}Sr$ value	15	9	24
Belize Valley $^{87}Sr/^{86}Sr$ value	39	15	54
Total Individuals	54	24	
Fisher's exact test (two-tail) *p*= 0.4324			

Sex is assigned for 16 female and 40 male individuals, which increases to 24 females and 54 males when probable sex estimations are included. Nine females and fifteen males have non-local strontium values, including marginal values (Figure 7.2).

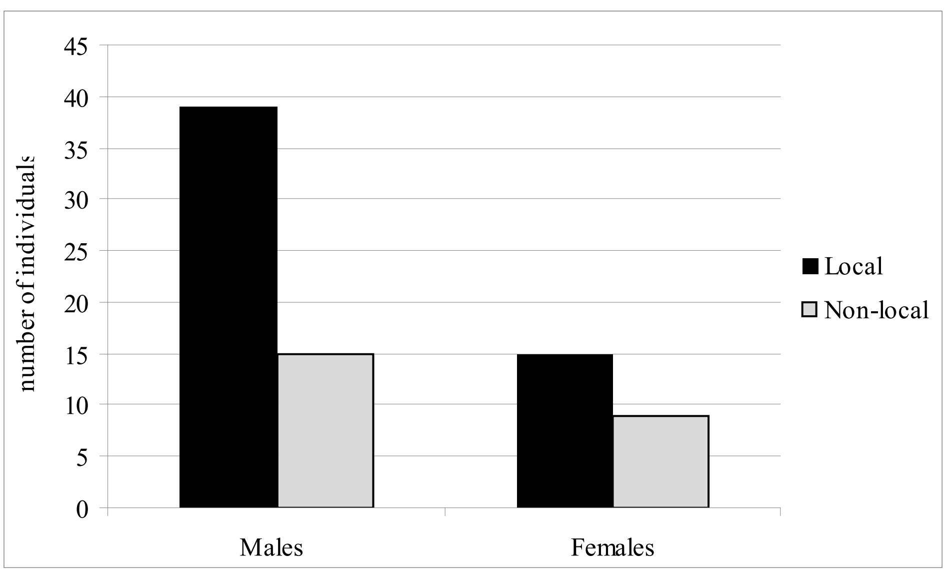

Figure 7.2. Male and female population movement.

The same results are identified in house mound and burial shrine burials. Nineteen males and eleven females were identified in residential burials (including probable sex assignments), and non-locals are distributed evenly: five of ten individuals are male and five are female. This difference is not statistically significant (two-tailed Fisher's exact test, $p = 0.4253$). Almost all of these non-local individuals have Macal River zone values, indicating movement within the Belize Valley.

Sex was identified for 17 individuals interred in eastern structures interpreted as residential ancestor shrines. Three quarters of these individuals were male, and 3 of 4 of the non-local individuals also were male. Statistical analysis of all residential burial contexts shows that the difference between male and female residential mobility is not significant (two-tailed Fisher's exact test $p = 0.3903$.)

There is no simple connection between identifying the sex of the migrant individuals and post-marital residence patterns. Colonial records suggest a great deal of variability within post-marital residence patterns. Farriss (1984) and Restall (1997) document Colonial-era cases where the newly married couple might reside for a year or more in the household of either family before moving to a permanent location. In addition, multiple factors underlie these customs and norms, including availability of land and work opportunities, or the myriad reasons that people relocate in modern societies.

Mobility does seem to follow one broad trend identified in modern studies that shows differences between male and female population movement. With just one exception, females relocated almost exclusively *within* the Belize Valley region. In contrast, strontium isotope values of males suggest more instances of potentially long distance migration. Only one female has a strontium isotope value from a strontium zone outside the Belize Valley; in contrast, five males do. However, neither sex nor age is known for the only individual who can be securely identified as a long-distance migrant.

2b. Demography: age

Age estimates of non-local individuals provide insight into when migration occurred. While most individuals died as adults (n = 99), six non-local individuals died during childhood and adolescence, providing a shorter timeframe for the period in which migration occurred. Examples at multiple sites show that movement in some instances predated the transition to adulthood, and may show cases where it occurred during that phase. For example, Xunantunich Str. A-4 Burial 1 included a 10-12 year old child and a 16-18 year old adolescent female. Both values suggest an origin in the Central Lowland strontium zone, or another more distant region with similar values (Figure 7.3).

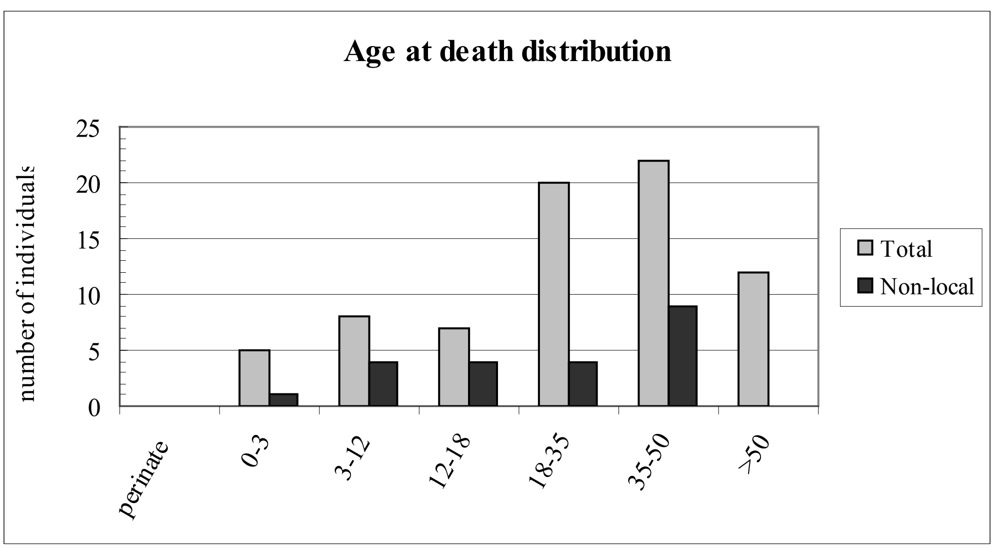

Figure 7.3. Age at death distribution of local and non-local values.

Movement within the region is demonstrated by the values of a 3-5 year old child interred at Chaa Creek and a 13 year old buried at Buenavista (Mitchell 2006). Another child (4 ± 1 years) buried at Buenavista, a young adolescent male buried at Baking Pot, and a 14-20 year old male interred at Saturday Creek have marginal strontium isotope values that suggest in-migration from unknown areas. Not only are these values lower than baseline values identified in the valley, and different from those of others buried at the sites, but two were interred in atypical burial positions (see discussion in Chapter 5).

The proportion of juveniles with non-local signatures (24.1% of 29 individuals) is similar to that of all adults (28.6% of 98 individuals), and both are similar to the total range of population movement in the region. These individuals were identified at major centers and minor ones, and were interred in elite contexts and commoner house mound burials. However, comparing the age at death does not compare the age of migration. At least some of these adults – perhaps the majority - moved as infants, children, or adolescents.

3. How is origin reflected in burial treatment?

3a. Burial context

Burial location and context provide important information on how migration was structured. Migrants buried in house mounds and residential burial shrines were more likely integrated into society than if they were than only identified in ball courts or other public architecture. In the Belize River Valley, Table 7.4 shows no statistically significant difference in the number of non-local individuals interred in the different types of burial contexts in (x^2 = 5.527, df = 4, p = .237).

Table 7.4. Strontium isotope values sorted by burial context: Additional information on individuals identified as migrant at each site is provided in Table 7.1 and is discussed in detail in Chapter 5 for each site and individual.

	Public architecture: royals and rulers	**House mounds and residential groups**	**Residential burial shrines**	**Public architecture: other**	**Unknown**	**Caves**
Xunantunich	0/1	3/7	0/2	6/9	-	-
San Lorenzo	-	1/1	-	1/2	-	-
Chaa Creek	-	0/1	4/10	-	0/1	-
Buenavista	1/4	0/1	1/4	-	-	-
Cahal Pech	0/8	-	0/6	1/4	0/2	-
Zubin	-	-	2/9	-	-	-
Esperanza	-	-	3/3	-	-	-
Baking Pot	0/3	2/9	1/9	1/7	1/1	-
Floral Park	-	-	1/3	-	-	-
Barton Ramie	-	3/20	-	-	-	-
Blackman Eddy	0/1	-	-	0/2	-	-
Pook's Hill	-	-	0/9	-	-	-
Saturday Creek	-	2/8	-	-	-	-
Caves	-	-	-	-	-	½
Total	**1/17 (5.9%)**	**11/47 (23.4%)**	**12/55 (21.8%)**	**9/24 (37.5%)**	**1/4 (25%)**	**½ (50%)**

There are significantly fewer non-local individuals who are interpreted as royal or noble: only one non-local ruler is identified at Buenavista (Freiwald et al. 2011). This is a statistically significant difference as well when burials in public architecture are compared (Table 7.5).

Table 7.5. Burial statistics for public architecture.

	Burials of royals and rulers	**Other burials**	**Total**
Non-local $^{87}Sr/^{86}Sr$ value	1	9	10
Belize Valley $^{87}Sr/^{86}Sr$ value	16	15	31
Total individuals	17	24	

Fisher's exact test (two-tail) ***p*= 0.0281**

There are fewer non-locals individuals in royal and elite burials in monumental architecture than in other burial contexts, but the number of non-local individuals buried in house mounds and residential shrines is similar. This shows that non-local individuals were included in each type of burial context, and the next section shows that more often than not, they were interred in the same grave as individuals who were born locally.

3b. Burial treatment: Body orientation and position

The body position or orientation is described for 100 individuals, and there is a close relationship between an individual's strontium isotope value and burial orientation: 89% of the individuals with Belize Valley strontium isotope values local are buried with their heads oriented to the south. Individuals represented by partial remains (e.g., only a cranium or skull) are not included in this discussion, even if a southern orientation might be presumed. Research by Schwake (2008), Welsh (1988), Yaeger (2003), and Willey and colleagues (1965) shows that by the Late Classic, a pattern emerges where individuals are buried in a prone, extended position with the head oriented to the south. Forty individuals with Belize River zone strontium isotope values were interred in this manner, along with 13 others interred in an extended position and southern orientation, 12 buried in a prone position with a southern orientation, and 9 individuals described simply as oriented to the south.

This also is true for 15 individuals whose strontium isotope values differ from the site where they were buried, but still suggest a place of birth in the other strontium zone in the Belize Valley, the Macal River strontium zone. This includes ten individuals buried in a prone, extended position with a southern orientation, three interred in a prone position and a southern orientation, one placed in an extended position and southern orientation, and one oriented to the south. There is variability in body position described by excavators, which is not always described in detail, but the common variable is a southern orientation.

Nine individuals have Belize Valley strontium isotope signatures and distinct body positions or orientations. These include four individuals in seated interments in house mounds (two at Barton Ramie and two at Saturday Creek), three individuals with northern orientations, and one with a western orientation. One of the northern orientations predated the Late Classic, so this, too, may be an earlier local norm. The child in the Op. 350 Buenavista burial was interred with a possible western orientation, but the burial dates to the Preclassic, before the southern orientation became common (Willey et al. 1965).

Unfortunately, information on body position and orientation for individuals with strontium values from other regions is limited. No data are available for three of four individuals with signatures in the .707 range, with the exception of the Barton Ramie individual (BR-144 B2). This individual was interred in the same manner as individuals with Belize River values. Non-local origin may have been less important than other aspects of identity, at least in this aspect of burial treatment, or the individual may be from a community in another strontium zone where a southern orientation is also the norm.

Body positions are known for three individuals with Central Lowland zone signatures. Two males were placed in semi-flexed positions in atypical burials at Xunantunich, with one oriented to the north (Op. 302 B1) and the other to the west (Op. 247 B1). An adolescent female was in a seated or fully flexed position, also in an atypical context. Overall, body position and orientation present a strong pattern useful in identifying origin; however, mobility within the region and in many residential contexts may not be visible without isotopic assays.

3c. Single v. multiple interments

Individuals with non-local strontium isotope values are more than twice as likely to be interred in burials that contain more than one individual than those born locally. This pattern is present at multiple sites in both residential and non-residential burial contexts (Table 7.6).

Table 7.6. Burials with multiple and single individuals and origin

	Burials with one individual: Non-local Sr values/ total values	**Burials with multiple individuals**	**Unknown**
Xunantunich	2/10	7/9	-
San Lorenzo	2/3	-	-
Chaa Creek	1/3	3/9	-
Buenavista	1/4	1/5	-
Cahal Pech	0/16	1/2	-
Zubin	0/7	2/2	-
Esperanza	-	3/3	-
Baking Pot	2/20	2/3	-
Floral Park	1/2	-	-
Barton Ramie	3/20	-	-
Blackman Eddy	-	0/3	-
Pook's Hill	0/4	0/4	-
Saturday Creek	2/8	-	-
Franz Harder and Chapat caves	-	-	0/2
Total	**14 non-local / 97 total values 14.4%**	**19 non-local / 41 total values 46.3%**	**1 non-local / 8 total values 12.5%**

Individuals in separate graves that are located in close proximity, or multiple burials in the same structure are not included in this discussion. Only two of these burials contain one or more individuals interred with the partial remains (cranium or skull) or another individual. It appears that this pattern is more widespread. Temporal changes in burial practices may explain part of this pattern, but there is insufficient temporal resolution to explore this possibility. Schwake (2008) notes that although burials with multiple individuals are uncommon in the Belize River Valley (10%), this practice increases over time and may relate to re-use and ancestor veneration (e.g., Novotny and Kosakowsky 2009).

3d. Burial treatment: grave goods

Analysis of the relationship of grave goods to non-local origin is problematic. First, some individuals have a single item, while others have large quantities of goods. Second, it is difficult to assign value to funerary objects. Is jade more meaningful as a non-local item than multiple ceramic vessels? Even assigning goods to a particular burial or individual is nearly impossible. In some instances, items were found in structural fill that may or may not have been intentionally included as burial offerings. At Zubin, Chaa Creek, and Pook's Hill, burials of multiple individuals contained goods that may have been associated with one or all of the individuals. It is also possible that one or more of the individuals were considered a grave good for the others.

Variation also occurs over time and space. At Chaa Creek and Xunantunich, most individuals did not have grave goods (e.g., Audet 2006; Braswell 1998; Connell 2000; Yaeger 2000). However, some interments were located near caches that may or may not have been directly associated with one or more burials. At Saturday Creek, differential wealth items in graves are viewed as indicators of household economic status (Lucero 2006), which complicates interpretations of individual status. The increasing occurrence of multiple graves during the Terminal Classic at some centers also complicates interpretation of grave goods as it is not possible to reconstruct associations with one or more individuals.

For these reasons, presence or absence of grave goods serves as a simple assessment of whether there may be a relationship between non-local origin and interment with one or more grave goods. Unfortunately, data for many individuals at Baking Pot, Cahal Pech, Pook's Hill, and the two cave sites are not available, so will not be included in the analysis at this time.

Table 7.7. Strontium isotope values and grave goods: A comparison of individuals with non-local strontium isotope values in burials with grave goods to total burials with grave goods, and a comparison of isotope values of individuals buried without grave goods.

	Non-local values with grave goods / total grave goods	**Non-local values without /total without**	**Comment**	**References**
Xunantunich	1/7	8/10		Braswell 1998; Connell 2000; Yaeger 2000; also see summary in Adams 1998
San Lorenzo	-	2/3		Yaeger 2000
Chaa Creek	3/7	1/4	Multiple individuals in interment with goods	Connell 2000
Buenavista	1/5	1/4		Peuramaki-Brown 2009
Zubin	2/9	-	Multiple individuals in interment with goods	Iannone 1996
Esperanza	1/1	2/2		Schubert et al. 2001; Driver and Garber 2004
Floral Park	-	1/3		Brown et al. 1996; Driver and Garber 2004
Barton Ramie	1/10	2/10		Willey et al. 1965
Blackman Eddy	-	0/3		Garber et al. 2004
Saturday Creek	1/5	1/3		Lucero 2006
Total	**10/44 22.7%**	**17/42 40.5%**		

There were more individuals with non-local strontium isotope values who lacked grave goods than those who were buried with one or more items (Table 7.7). However, the relationship is not statistically significant ($x^2 = 2.152$, $df = 1$, $p = .1424$).

Two other trends are visible. Burial goods are not described for any of the eight individuals with Central Lowland strontium isotope values in residential and public burial contexts. Other individuals were buried with grave goods of Central Lowland origin, but these are not good indicators of origin. Individuals at Baking Pot and Buenavista interred with vessels from Central Lowland polities have Belize River zone strontium isotope values. Individuals with non-local origins are less likely to be buried with grave goods, especially those from the Central

Lowlands. However, the difference is not statistically significant and grave goods appear to be a relatively weak indicator of an individual's origin.

3e. Burial treatment: partial remains

Individuals in six cranium or skull only burials were sampled from three sites, and more than 67% have non-local strontium isotope values. Three of these individuals are from the Xunantunich Str. A-4 Burial 1 deposit. Two have Central Lowland zone values, one of which may have associated cervical vertebrae, and one has Macal River zone values. A fourth skull was buried with another individual in the Zopilote non-residential shrine associated with Cahal Pech. This also is a Macal River zone value.

The final two skull-only burials were identified at Baking Pot. One individual has a local value and the other a value slightly lower than baseline values, which suggests a non-local origin. Two other burials where the skull and postcranial skeleton were separated are identified in Cahal Pech Preclassic burials. In the first, one burial in a plaza contained the postcranial remains while a second contained a skull interpreted as that of the same individual (Garber et al. 2007; Garber and Awe 2008). The skull was not sampled, but bone from the skeleton has a local strontium isotope value. In the second burial, the postcranial remains were separated from cranial ones, which were placed on a bowl. Both individuals are interpreted as remains of venerated ancestors and both have Belize River zone strontium isotope values.

The question central to this analysis relates to the potential for any of these remains to represent involuntary migration, or postmortem movement of remains that does not represent migration at all. The Cahal Pech skull (Plaza B burial) was buried with jade beads, and may be associated with other skeletal remains in a separate burial nearby (Garber et al. 2007; Garber and

Awe 2008). The Zopilote skull (Tomb 1 Burial 2) was associated with two halves of a bowl, but a burial context nearby contains war iconography that Cheetham (2004) relates to this burial.

No grave goods are associated with the remainder of the skulls. Three of these are males, one of whom was an adolescent and another was a young adult at the time of death. Piehl describes perimortem damage on the skulls of two males interred at Baking Pot (Piehl and Awe 2009), both of whom also were buried in a terminus structure at the site (Str. 190 Burials 3 and 5). Partial human remains, including teeth and/or phalanges, are identified in each structure. These patterns have some sacrificial connotations (e.g., Berryman 2007, Tiesler 2007).

The Xunantunich Str. A-4 burial also contains multiple skulls and no grave goods, though sex or secure age estimates are not available. Insufficient information exists to determine whether or not the individuals all were interred at one time, though several likely were. An adolescent female buried with the skulls relocated from another region, but then resided in the Belize Valley for a number of years before her death (see Chapter 6). Whether the individuals represented by skull only remains also resided at the site for a time before death is not known.

Isotope values do not provide direct evidence for interpretation of sacrifice in most burial contexts. Nor can they directly associate a burial context with a particular type of population movement. However, in this region, individuals represented only by skulls or crania are more likely to have non-local strontium isotope values. It is important to note that contexts interpreted as shrines to venerated ancestors at Chaa Creek and other residential shrines also contained the burials of individuals with non-local strontium isotope values (Connell 2000), but most of these are Macal river zone values that are found in that part of the Belize River Valley.

4. How do health and body modification relate to origin?

4a. Health and population movement

The relationship between health and population movement is not a straightforward one. However, three preliminary comparisons between locally-born individuals and migrants reveal important patterns for paleodemographic studies: health as children, health as adults, and perimortem trauma. There are no notable differences between the migrant and local population in any of these categories. However, comparing occurrences of linear enamel hypoplasias (LEH) by place of birth, rather than place of burial, results a very different picture of childhood health. This has broader implications for other studies.

Adult health

Detailed osteological observations are only available for a subset of the study population in this analysis. Assessments of general health, pathology, and trauma for five sites in the sample include 52 individuals from Saturday Creek (n = 8), Pook's Hill (n = 8), Xunantunich (n = 19), Chaa Creek (n = 12), and San Lorenzo (n = 3). Piehl (2002, personal communication 2010) analyzed Pook's Hill and Saturday Creek burials, while Xunantunich, Chaa Creek, and San Lorenzo information is reported by Adams (1998) and is supplemented observations by the author. More pathologies are described in Piehl's analysis than at Xunantunich polity sites, a fact that may relate to both preservation and inter-observer differences. Therefore, a comparison of migrant and locally-born individuals is limited to individuals within each site and to general qualitative observations.

Health indicators at Pook's Hill and Saturday Creek show no general differences between individuals born locally and those who relocated to the site. Pathology or trauma can only be assigned to general time frames in an individual's life, but Piehl (personal communication 2010) notes both healed and active infections and other ailments in the bone of eight individuals sampled from Str. 4A, the residential shrine at Pook's Hill. Approximately half the population had healed infections or cranial porosity, while the rest had active or healing lesions. Piehl identified both localized and systemic infections, as well as caries and antemortem tooth loss in nearly half the sample population. Evidence for linear enamel hypoplasias (LEHs) also were present in more than 50% of the population, which shows that stresses began during childhood.

The individuals appear to have come from a population where bouts of illness or nutritional stress were frequent, but where survival rates were high (e.g., Piehl 2002). The two individuals with anomalous strontium isotope values share this pattern, which is not surprising as both values are interpreted as local to the Belize River strontium zone. It is more likely that health differences relate to age or occupation. Caries, for example, are identified in all middle age or older individuals, but not in either of the young adults.

Extensive pathologies also were observed in the remains of eight individuals buried in the two house mounds sampled at Saturday Creek. The age and sex structure of the burial population is different, but a similar general pattern is visible (Piehl personal communication 2010). Six of eight individuals had healed or active periosteal reactions in bone, and four individuals had one or more LEH episodes. Even though $^{87}Sr/^{86}Sr$ values suggest relocation by at least one individual in each residence, the entire sample seems to form a single population where health indicators are concerned (Piehl 2002).

It is no surprise that the skeletal remains of individuals sharing the same residence and many basic food sources would reflect similar stresses and maladies. Nor is it particularly notable that individuals who moved fit within the same population those who did not, since all are likely from the same regional population. That is, all strontium isotope values identified at Pook's Hill and Saturday Creek are from the Belize or Macal River zones in the vicinity of the Belize Valley. However, it is important to demonstrate that immigrants share the same health indicators as the locally-born population.

Results are similar at sites in the Xunantunich polity, where patterns of adult health, perimortem trauma, and childhood health are compared. A better overall picture of health with fewer pathologies and minimal trauma is visible at Xunantunich, Chaa Creek, and San Lorenzo (Adams 1998). Only two pathologies, in addition to dental caries and other defects, are identified in 30 individuals (Adams 1998). Preservation was highly variable, ranging from nearly perfectly preserved bone surfaces to those cemented with matrix or fragmented into hundreds of tiny pieces. In addition, the remains of more than 1/3 of the individuals were intermingled or incomplete, limiting observations.

Two individuals had traumatic, healed injury, including the healed rib of an elderly woman who was not sampled due to a lack of dentition (Group D, Op. 21E) and the healed mid-shaft right fracture of a tibia and fibula of a mid-age adult male (Chaa Creek Op. 254). The latter injury resulted in permanent misalignment and significant shortening of the lower limb. Adams (1998) notes caries or tooth loss on more than half of the individuals interred at Xunantunich and San Lorenzo. However, the observations do not indicate any patterned differences between individuals with Belize River and other strontium zone values.

Perimortem trauma

Adams (1998) makes no note of perimortem trauma at Xunantunich polity sites excavated by the Xunantunich Archaeological Project. This is a particularly problematic area, as researchers make strikingly different observations about the same individuals based on differences in experience and research goals. This is shown by a re-analysis of Str. A-4 burials excavated by the Tourism Development Project (TDP). Notations by an unknown researcher placed with the remains document a cut mark on the humerus of one of the individuals in the Str. A-4 Burial 1. Independent reanalysis of the same context by Piehl (personal communication 2010) and the author offer a different interpretation: that poor preservation of bone surfaces precludes taphonomic observations for many of the elements, and that marks on the limb bones were modern. No perimortem trauma was observed macroscopically.

Re-examination of burial contexts with multiple individuals at Chaa Creek and Xunantunich in this study finds the same results as Adams (1998). Chaa Creek Op. 161XX contained the scattered remains of at least six individuals whose burial location was associated with a rich assemblage and the end of occupation at the structure (Connell 2000). None of the individuals have observable perimortem trauma or evidence of postmortem processing, like chop or cut marks. There also was no observable perimortem damage on the remains in the Str. A-4 Burial 1 deposit.

Perimortem damage is one of the key lines of evidence used to interpret a burial context as a sacrifice. There are a number of anomalous burial contexts at Xunantunich that suggest an unnatural death for one or more individuals, including a child at the center of a ballcourt, skull-only interments, and burials associated with termination events. Tiesler and Cucina (2006b) describe cut marks on the remains of individuals interred with the Red Queen of Palenque, but suggest that this evidence may be uncommon because most sacrificial acts might fail to leave obvious marks. Some of these individuals have non-local isotope values, which are frequently identified in sacrificial contexts at Teotihuacan (White et al. 2002) and Mayapán (Wright 2007).

Only three instances of perimortem trauma have been observed in this sample, and two of these are in burials at Baking Pot. Piehl (Piehl and Awe 2009) describes a periosteal reaction on the crania deposited in Burials 3 and 5 at Baking Pot terminus structure 190 that she relates to trauma near the time of death. In Xunantunich Str. A-4 Burial 1, extra cervical vertebrae suggest that at least one of the skulls was separated from the body not long after death. The final observation is of a number of cut marks on the proximal femur of an isolated human bone in a Group B deposit that also contained the remains of more than a dozen animals.

Each of these observations is made on partial human remains rather than typical burials. Is it possible that sacrificial remains were more common in non-standard burial deposits? Helmke suggests that Maya lexicon links captives' bones to artifacts or fragmentary remains rather than burials (Christophe Helmke personal communication 2010). Skulls, for example, are depicted especially frequently in art and iconography. A disproportionately high number of skull or cranium-only interments are of individuals with non-local strontium isotope values (see previous discussion). However, neither of the remains with perimortem trauma have clearly non-local strontium isotope values. Baking Pot Str. 190 B5 has a local strontium isotope value, and Str. 190 B3 has a value only slightly lower than Belize River zone values. Str. A-4 head 1 has a Central Lowland strontium isotope value, but the extra cervical vertebrae are not unequivocally associated with the cranium. The lack of evidence for perimortem damage in burials with only partial human remains cannot clearly associate sacrifice with non-local origin in this burial population.

Childhood health

The third comparison assesses the general childhood health of individuals with different origins. Linear enamel hypoplasias (LEH) provide evidence of non-specific childhood stressors, such as weaning, and they are reported for Xunantunich and Chaa Creek individuals by both Adams (1998) and Scopa Kelso (2005). When individuals are compared by place of burial, Scopa Kelso's (2005) analysis of dental hypoplasias suggests that weaning age differed at the urban center of Xunantunich and the rural center of Chaa Creek (no LEH were observed at San Lorenzo). The following discussion shows that when the comparison is made instead by the individual's place of origin (strontium zone), there is no measureable difference. This suggests that an assumption of a stable population with little to no measurable migration for osteological analyses may not be reliable in the Maya region.

Adams (1998:42) comparison of 49 linear enamel hypoplasias (LEH) shows a significant difference between the larger site of Xunantunich and the smaller one of Chaa Creek (p = .00, t = -4.86). This could result from differences in weaning age, even considering the small sample size. In a second study on the same sample population, Scopa Kelso (2005) found that LEH occurred later on burials from Xunantunich than those at Chaa Creek. Occurrences were most frequent at Xunantunich between three and four years of age, with a peak between 3.5-4 years. At Chaa Creek, most hypoplasias occurred between two and three years of age, most frequently between 2-2.5 years. She infers that weaning occurred later in urban centers due to status or occupational differences, and that rural centers seem to have a slightly lower mean of LEH occurrence.

Re-analysis of Adams' data suggests that residential mobility might have a significant impact on studies with small sample sizes. When the data are recalculated using strontium isotope zones to indicate childhood residence (in contrast to burial location), the differences between hinterland settlements and urban centers are greatly diminished. All individuals in the Xunantunich and Chaa Creek analysis have either Belize or Macal River zone values. The average age of hypoplasia occurrence for Belize River zone values changes from 3.56 to 3.98 years and from 4.45 to 4.19 years for Macal River zone values. There is essentially no difference in childhood stressors between the two zones.

Evaluating Adams' (1998) observations by frequency of occurrence in particular age classes - rather than using the mean value - results in a similar finding. It is interesting to observe that while measurable hypoplasias were observed on a nearly equal number of individuals from each Belize Valley strontium zone, twice as many incidences were observed for individuals with Macal River zone values. This trend needs additional analysis and would benefit from a larger sample size, perhaps including the broader Belize Valley burial population.

These findings suggest that origin did not play an important role in an individual's health, but the sample composition and size preclude applying these findings too broadly. Danforth (1997) notes the difficulty in comparing and assessing the health of paleopopulations where there are an infinite number of variables to consider - time period, burial context, status, age, and sex - and far too few samples of adequate size and composition. The comparison made here includes observations on adult health in 17 individuals at two sites and a re-analysis of childhood health for 32 individuals buried at two sites. This preliminary assessment includes almost no individuals with strontium isotope values from outside the Belize Valley, but no marked differences are identified within the region. This includes no significant differences when childhood health indicators are compared by place of birth rather than place of burial a different finding than previously reported at Xunantunich polity sites.

4b. Body modification and dental decoration

Cranial and dental modification are important markers of an individual's identity. They are immediately visible, and unlike dress, hairstyle, body paint, and other forms of decoration, they remain permanent signals of an individual's identity for life. These are especially important for archaeologists, as unlike tattoos or scarification, they are preserved in the archaeological record. The timing of migration also affects the likelihood of finding patterns of cranial modification or dental decoration. Crania were necessarily shaped during early infancy, so will reflect traditions practiced in an individual's household or community, with a particularly strong role played by the mother reported in ethnohistoric accounts (Dingwall 1931; Tiesler 1998, 2009). In contrast, teeth were generally modified during adolescence or later, so mobility during this period could incorporate practices in the new residence or the old one (Tiesler 2009).

Relating body modification to origin is complicated by other factors. Females have a higher incidence of dental modification (65.8%) than males (58.0%). Tiesler (1999) noted that females also have more A-type modifications, one of seven basic type of filing of the occlusal tooth surface noted by Romero (1970), and that incrustations are more common in males (Tiesler 1999). However, it is not clear whether these variables relate to status, occupation, lineage, or personal choice, which each change over time. While dental modification is documented at most sites in the Belize Valley, observations of cranial modification are less frequent there than in other parts of the Maya Lowlands (Tiesler 1998, 1999).

Both practices carry some risk to an individual's health. While bioarchaeologists believe that no long term decrease in brain capacity occurred as a result of most cranial modification, there was risk of increased mortality (Schijman 2005), and Tiesler (1999) describes ethnohistoric accounts that children suffered at least some discomfort during the process. Dental decoration carried increased risk for caries, breakage, and other dental pathology.

Analysis is incomplete or partially published for many of the burials in this analysis. The following section presents a preliminary summary of information on cranial and dental modification in a preliminary attempt to identify patterns that may relate to origin. It almost certainly will be modified as more information becomes available.

Cranial modification

Cranial modification can be compared for individuals at Buenavista and Xunantunich polity sites (Adams 1998; Mitchell 2006; Jennifer Piehl personal communication 2010), with observations on additional individuals at Barton Ramie (Vera Tiesler personal communication 2009). First, identification of only four individuals with modified crania provides support for Tiesler's (1998, personal communication 2009) conclusion that the practice was not common in the Belize Valley. Fewer than half of the 1,515 crania in her sample were modified, while she observed more 88% in other regions.

Cranial modification was observed in only three individuals buried at Xunantunich polity sites, and none have Belize River strontium isotope values. Adams (1998) observed a form of tabular erect cranial modification in a female and male in the Op. Q11/12 burial: all three individuals in the burial have Macal River zone strontium isotope values found locally near the Chaa Creek site. The third individual is the young male in the atypical burial in Str. A-11 with the Central Lowland-like strontium, carbon, and oxygen isotope values. Tabular oblique cranial modification like his also is common in that region, among others (Tiesler 1999). However, an elite individual interred at Buenavista with a similar cranial modification has a local strontium isotope value (Mitchell 2006).

The other individuals with strontium values that suggest in-migration from other regions provide no additional information. Crania were too poorly preserved in Esperanza burials to identify modification, and Tiesler (personal communication 2009) did not observe it in Barton Ramie individuals with non-local strontium isotope values. No information is available for the single Baking Pot long distance migrant.

While this provides little insight into population movement within the Belize Valley, it does show that cranial modification is present on individuals with both Belize and Macal River strontium isotope values. This type of analysis may work better in an area with more interregional population movement than the local or regional relocation observed in this study.

Dental modification

Observations on the presence, absence, and type of dental decoration are available for eight sites in this study, including 64 individuals with osteological and isotopic data that may be compared. These are drawn from eight sites described by four analysts, each of whom used Romero's 1958 and 1970 classification system (Adams 1998; Mitchell 2006; Piehl 2002; Willey et al. 1965). An exploratory analysis of these data suggests that patterns may exist within the Belize Valley that merit more in-depth analysis.

Modifications include filing, notching and inlay of precious and semi-precious materials, like jade, hematite, quartz and turquoise in one or all of an individual's upper and/or lower incisors, canines and premolars. Both recent and decades-old studies suggest that there is no direct relationship between dental decoration and status or sex (e.g., Willey et al. 1965; Tiesler 1999). However, filing and incrustations usually were done after age 15 (Tiesler 1999). There are very limited examples of dental modification of children's teeth (e.g., Braswell and Pitcavage 2009), but filing of teeth occurred throughout life (Tiesler 1999).

Most studies show that there was a substantial amount of variability in dental modification at Classic Maya centers that could relate to occupation, individual preference, temporal change, or other factors, but Tiesler's (in press) inter-regional study of more than 1,515 individuals suggests that variation may relate to family or lineage associations. Further, studies described at Copán suggest that patterns differ by household, and that this variation can be used to identify groups of non-local individuals.

If an individual's origin and dental modification are related, timing is important. An individual might relocate during childhood or adolescence, before teeth are modified. The move might also occur during adolescence or later, after dental decoration is complete. Additional modifications might occur later, meaning that alterations to the dentition can represent both an individual's place of birth and burial location. Therefore, if dental modification is patterned according to childhood residence, individuals 1) modified teeth largely before relocation or 2) origin continued to play a visible role in identity signaling throughout life. If the patterns instead reflect place of burial (and presumed residence during life), dental decoration probably reflected other aspects of a person's family or individual identity.

The results suggest that there is a relationship between burial location and dental decoration. A disproportionate number of individuals with modified teeth who were buried at sites along the Belize River share an origin in the Macal River strontium zone. Dental modification was observed in individuals interred at most sites in the region, but information is available information for individuals buried at Saturday Creek (n = 8), Blackman Eddy (n = 3), Floral Park (n = 3), Esperanza (n = 3), Barton Ramie (n = 20), Xunantunich (n = 13), and San Lorenzo (n = 3). Each of these sites is located in the Belize River zone. Chaa Creek (n = 11), located in the Macal River strontium zone, also is included. Twenty of these individuals have strontium isotope values from a different zone. This preliminary analysis presents only the type of modification observed for each tooth, not the pattern of the dentition as a whole, in order to explore the relationship between an individual's origin and this aspect of identity.

A disproportionate number of individuals with non-local strontium isotope values have modified teeth. Sixty-six percent of the individuals with dental modification have non-local strontium isotope values, as compared to 33% non-local values in the sample. Inlays or filing of one or more teeth are observed in 15 individuals, 10 of whom relocated at least once during life (Table 7.8). Figure 7.4 shows that more migrants with modified teeth have Macal River zone values than Belize River ones. Thirteen of the individuals with dental modification were interred at sites located in the Belize River strontium zone, but only the three Barton Ramie individuals have Belize River strontium zone values. Instead, 46.7% of individuals buried at Belize River sites with modified dentition have Macal River zone values. Two individuals have Central Lowland values (20%) and one has a Maya Mountain strontium zone value. The final individual has a value slightly lower than Belize River baseline values and is interpreted as non-local.

Table 7.8. Individuals with non-local strontium isotope values and modified dentition: B4 modification is also noted in loose dentition at San Lorenzo and C2 at Xunantunich (Adams 1998). Other types noted at Barton Ramie include: A1, A2, B2, B4, B5, C3, F8, F9, and G (Willey et al. 1965). Mitchell (2006) reports E1, B2, and A1 modifications in five Buenavista individuals.

Site	Burial	Sex/Age	Sr value	Romero's filing type (1970)
Barton Ramie	BR-1 B6	Adult	.70858	A1 (Willey et al. 1965)
Barton Ramie	BR-1 B25	Adolescent	.70875	B4 (Willey et al. 1965)
Barton Ramie	BR-155 B3	Male Adult	.70868	F9 (Willey et al. 1965)
Chaa Creek	Op. 161XX	Adult	.70918 .70998	B4 and C4 (2 individuals in Adams 1998)
Esperanza	Str. A4 2d-1 B3	Male? Adult	.70951	B4
Esperanza	Str. A4 2c-1 B2	Adult	.70796	B4
Floral Park	Str. 2A B9	Female? Young/Middle Adult	.71029	Not defined (occlusal filing)
San Lorenzo	71C	30-50	.70812	E1 (Adams 1998)
San Lorenzo	243LL	Female 35-45	.70938	A1, A4, B4 (Adams 1998)
Saturday Creek	SC18 B5	40-50	.70912	B4 (Piehl 2002)
Saturday Creek	SC85 B1	Female 24-30	.70927	B4 (Piehl 2002)
Xunantunich	Str. A4 deposit Mandible A	Adult	.70914	Not defined (hematite inlay and notched incisor): analysis underway
Xunantunich	Op. 21D	Male >35	.71111	E1 (Adams 1998)
Xunantunich	Op. 247JJ	Male? Adult	.70800	B2 (Adams 1998)

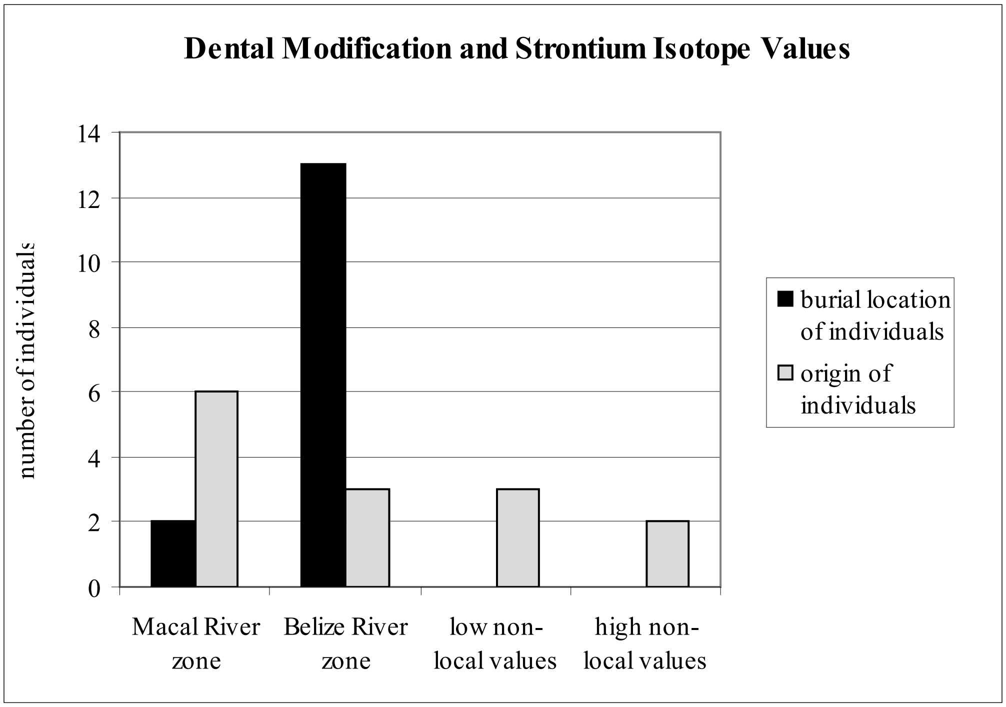

Figure 7.4. Comparison of place of birth and burial site for individuals with modified dentition: Individuals with modified dentition comparing the place of birth and place of burial.

The number of males (n = 6) and females (n = 4) with modified dentition reflects the greater proportion of males sampled in this analysis. Individuals were interred in house mounds, eastern structures in residential groups, and in public architecture. All but one adolescent were adults at the time of death. An in-depth comparison of wear on the modified teeth might provide more information on when the modification occurred. More recent analyses also focus on the overall pattern of the dentition rather than the alteration to a single tooth (Tiesler 1999).

Sample selection may play a role in the results, though not a large one. At many sites, all available burials were included, but at Barton Ramie, samples were selected to obtain a balanced demographic representation of males and females, focus on a limited number of mound groups, and use individuals for whom Gerry (1993) obtained bone collagen values. Many individuals with dental decoration were not sampled, including BR-1 B12 and B9, BR-130 B2, and BR-123

B17, 26, 31, BR-75 B3, BR-144 B5. In addition, analysis of dentition of individuals in recently-excavated burials from Xunantunich and Chaa Creek is incomplete. This includes several individuals with Central Lowland values.

Was origin a factor in dental decoration? Additional analysis will include more individuals from this study, especially those with Central Lowland zone values, as well as a consideration of other factors like burial context that are not considered here. However, these preliminary data suggest that there may be patterned variability with the Belize Valley which creates questions about 1) when individuals relocated and 2) whether origin – perhaps defined via lineage or kinship - was an important factor in this aspect of body modification and its relation to identity.

B. Neighboring regions: migration in the Vaca Plateau and Mountain Pine Ridge

Four sites in two regions adjacent to the Belize River Valley provide comparative information, including mean strontium isotope values for human populations in each region and patterns of population movement. While there are a number of individuals at Belize River Valley sites with Maya Mountain strontium isotope values, there is no measureable in-migration at the three Mountain Pine Ridge sites in this sample. In contrast, there is substantial population movement at Caracol in the Vaca Plateau, part of the Central Lowland strontium zone. However, oxygen isotope values of some Belize Valley individuals with Central Lowland strontium values differ from those identified at Caracol. There was movement between the two regions: one individual has a Macal River zone value, and another has a value similar to the low marginal values in the Belize River zone.

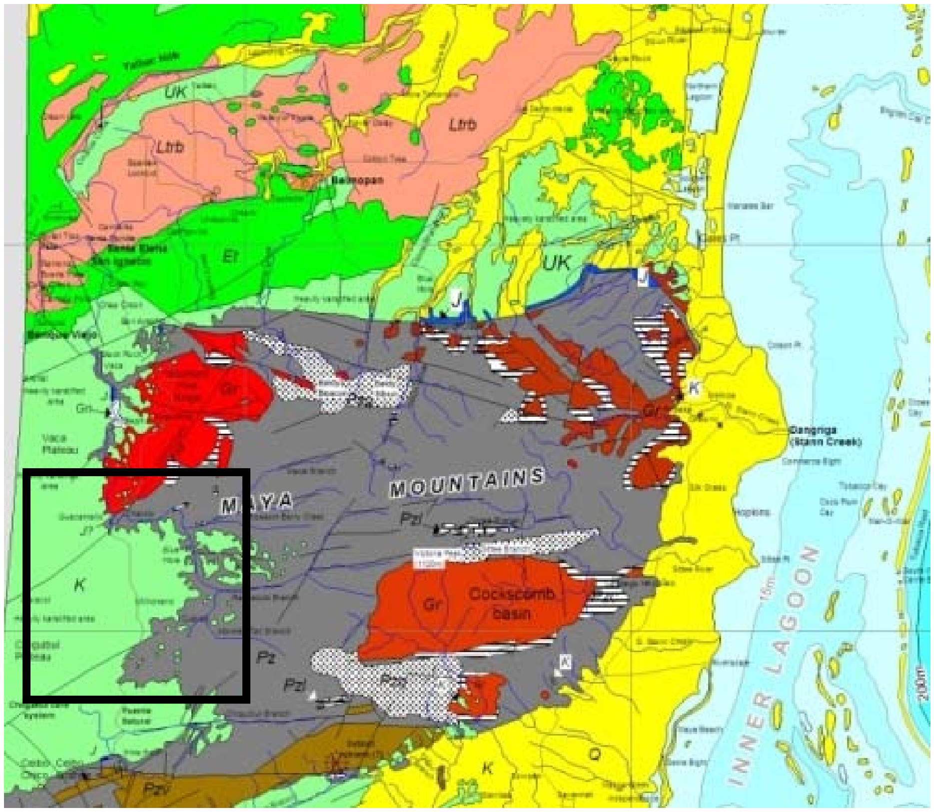

Figure 7.5. Map of the Belize River Valley, Maya Mountains and Vaca Plateau: the Mountain Pine Ridge and Vaca Plateau study area is outlined (Cornec 2008, and see key in Chapter 4).

1. Caracol

Caracol is located on the Vaca Plateau 30 km from the Belize River Valley and 20 km from the sites in the Mountain Pine Ridge in this study (Figures 7.5 and 7.6). It was one of the largest sites in the Maya Lowlands, covering a

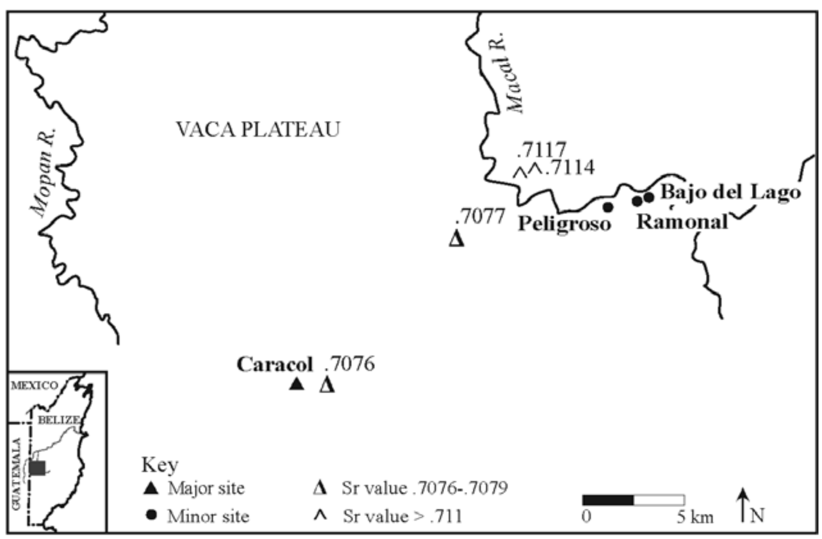

Figure 7.6. Mountain Pine Ridge and Vaca Plateau and sites in the study: Area is outlined in geologic map in Figure 90.

territory of 177 square kilometers with a population of more than 100,000 residents (Chase and Chase 2004).

The eleven individuals in this sample come from excavations conducted 2000 - 2004 by the Tourism Development Project (TDP). Eleven individuals were sampled to understand how individuals in the region would reflect the isotopic variability in the Vaca Plateau and to make an initial assessment of population movement at the site. While analysis of the burials remains incomplete, preliminary contextual information was provided by Gibbs (personal communication 2009) and is supplemented by decades of published research by Diane and Arlen Chase.

Interaction with other major centers located hundreds of kilometers from Caracol is well-documented epigraphically (Martin and Grube 2000), and includes alliances and conflicts with Calakmul, Tikal, and Naranjo. Price and colleagues (2010) documented a possible association of Caracol and Copán's K'inich Y'ax K'uk' Mo isotopically and epigraphically (also see Buikstra et al. 2004). Individuals from Caracol are named on inscriptions at other sites, but Chase (2004) notes that this is insufficient evidence to document non-local residence. Not only might the inscriptions document visits or fictional events, but the carved objects may have been stolen or moved from their original locations.

Interaction with the neighboring Belize Valley region also is probable. The Caracol polity may have incorporated sites along the Belize River for decades as a result of its military defeat of Naranjo (Helmke and Awe 2010). The site of Pacbitun may represent the farthest reach of sites with long term close connections (Schwake 2008; Chase 2004). Other similarities include some caching and burial practices (Chase 2004), so it seems plausible that interaction may also have included population exchange. Strontium isotope results from Tikal (Wright 2005b) suggest an enormous amount of in-migration from multiple regions, and it is likely that this pattern will be present at Caracol as well.

The individuals in this sample represent a snapshot of the diverse types of burials at Caracol, including adults and children buried in caches and tombs, alone or with multiple individuals (Table 7.9). Non-local individuals were identified in three distinct locations from three different regions. While most of the samples were drawn from the site center, one outlying plazuela group was included. Caracol has a large and well-studied burial population that could provide additional samples in the future as well.

Table 7.9. Caracol strontium isotope values and burial information: Information on burial position and context from Gibbs (personal communication 2008, 2009).

Burial	$^{87}Sr/^{86}Sr$	Sex	Age	Burial information	Date
CD14 B/1 and 2	.70724	I	I	Altar 23	Late-Terminal Classic
Str. A6 CD9I/4g	.70756	I	I	Multiple individuals: Str. A6 south of substructure stairs cache. Small plazuela group outside site core	Not available
Str. D7 CD20	.70799	I	I	Str. D/7 base of stairs ‘cache’	Not available
Str. D7 CD20 a/7	.70767	I	I	Str. D/7 tomb 1	Not available
Str. D7 C88	.70780	I	Juvenile	Corridor above floor or collapse	Not available
CD4C/14 3rd plaza	.70769	I	4 ± 1	Barrio plaza interment #10-27 3rd plaza	Not available
CD4C/13	.70778	I	C	Barrio plaza burial extension	Not available
CD4C/14 centro	.70956	I	I	Barrio plaza *centro* burial	Not available
CD3 A/17	.70777	I	I	B4 south wall floor deposit	Terminal Classic
CD27 B/2 B1	.70783	I	I	Caretaker foundation burial 1	Not available
CD4/B26	.70812	M?	Ao	Interment. Buried in collapse pyramidal structure south wall	Not available

1a. Identifying origin: analysis of the strontium isotope values

The three baseline values sampled from the Vaca Plateau show a relatively homogenous area. Samples from the center of Caracol and the road leading to the site have an average value of .70767 ± .00006. The values of three Vaca Plateau samples range from .70763 to .70786 (mean value .70774 ± .00012), which places the region within the Central Lowland strontium isotope zone. This value is reflected nearly perfectly in a sample of eleven teeth from five deer found during TDP excavations at Caracol. These values range from .70771 to .70787 (mean value .70775 ± .00007). The values also are reflected in the majority of the individuals included in this sample (Figure 7.7).

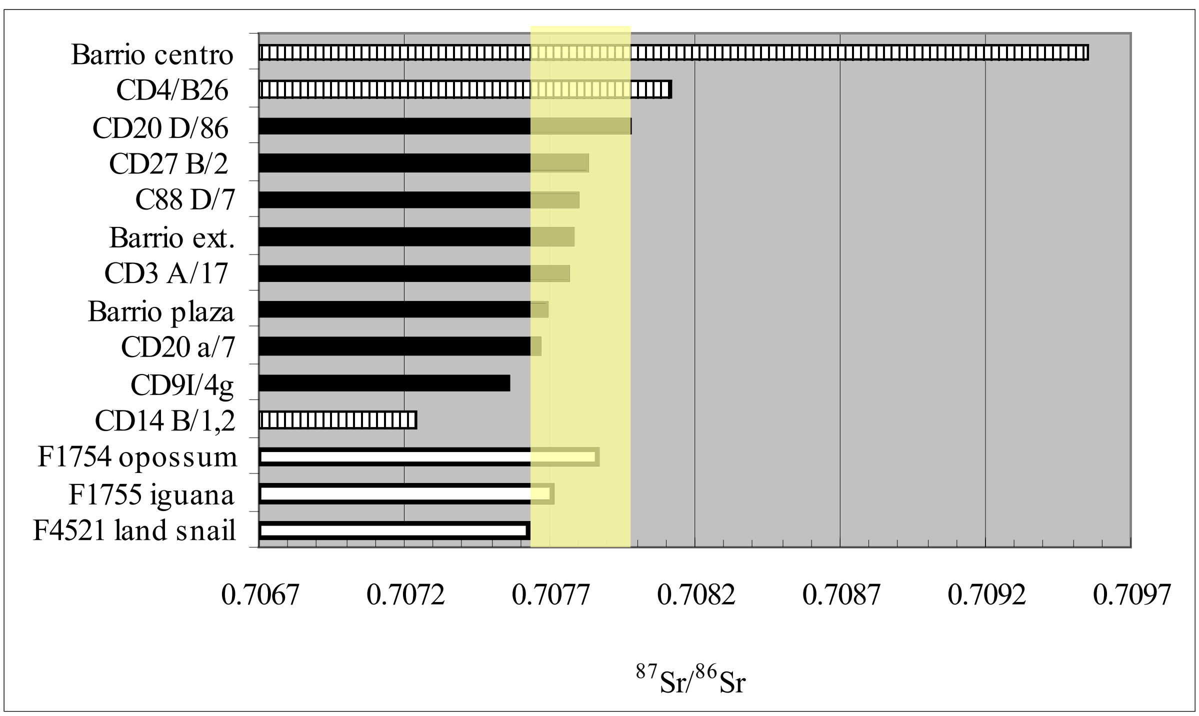

Figure 7.7. Caracol strontium isotope values bar graph: White bars represent $^{87}Sr/^{86}Sr$ baseline values and the shaded area represents the range of values identified along the Belize River. Black bars represent each individual in the study (including marginal values): striped bars are individuals with isotope values not found near the site.

Three individual have values that are distinct from those identified in the Vaca Plateau. The highest and lowest values are statistical outliers, with values beyond two standard deviations from the mean of the baseline fauna. Each non-local value represents a distinct origin, and the closest possible strontium zones are found outside the borders of the polity. This is a small sample, drawn mostly from contexts in the site center. However, if it is representative of population movement at Caracol, it reflects a highly mobile population. Strontium values are homogenous over a large region, so the short-distance movement that is visible along the Belize and Macal Rivers will remain hidden at Caracol. Given the extent of the population movement in the Belize Valley, it is probable that the amount of population movement at Caracol was even greater. When the three non-local values are removed, the average $^{87}Sr/^{86}Sr$ value of the human population is .70776 ± .00012.

1b. Burial contexts and population movement

Limited contextual information is available for these burials as the TDP analyses are not yet complete. However, non-local individuals were identified in multiple types of burials, including those interpreted as caches, in single and multiple interments, and in locations associated with residential occupation. Moreover, the three individuals with non-local strontium isotope values were born in distinct regions, and at least one relocated to Caracol before or during adolescence. Individuals with Vaca Plateau (Central Lowland) strontium values interpreted as local were identified in similar contexts. Further analysis is forthcoming as data on burial position and orientation, grave goods and types, and health and body modification become available.

At least two of the burials come from contexts described as caches. CD20 D/86 was one of two individuals sampled in Str. D7, and was interred in a burial at the base of the structure's stairs. Both this individual, and the CD20 a/7 juvenile in Tomb 1 had Central Lowland strontium values. The second cache context was associated with a small plazuela group outside the site center. This deposit also was associated with the stairs of the structure (Str. A6), and the individual also had a strontium isotope local to the Vaca Plateau.

Three burials (CD4C) came from a context with multiple individuals interred in the plaza of a residential group nicknamed the *barrio* in the site center. Two were children, and both have Central Lowland strontium isotope values. The third individual, CD4C/14 *centro* has a strontium isotope value similar to those identified in the Macal River strontium zone. Although very few non-local isotope values in the Belize Valley evidence in-migration from the Caracol region, this suggests that population exchange occurred between neighboring regions, without ruling out the possibility of a more distant origin.

Other individuals with non-local $^{87}Sr/^{86}Sr$ ratios were interred in tombs and in simple graves in building collapse or fill. The second of these individuals is identified in Burial CD4/B26, which was located the collapse of a pyramidal structure. The .7081 value is similar to those identified in the Central Petén, stretching from the western extent of the upper Belize River valley, across the Petén, to Bonampak.

The third non-local value, .70724, was associated with an individual buried near an altar with an inscription dated to the Late and Terminal Classic transition. One of the two individuals was sampled, and has a $^{87}Sr/^{86}Sr$ value that matches those expected to the south of the site in the Southern Lowlands strontium zone. Values decrease gradually to the south and west of Caracol:

a sample at Blue Creek, Toledo District, in southern Belize shows a value of .70744, so this suggests potential long distance movement.

1c. Caracol Summary

In contrast to the three sites sampled in the Mountain Pine Ridge, a sample of the same size at Caracol has a rate of in-migration of 27.2%. While the number compares favorably to that of the Belize Valley, it actually suggests substantially more population movement. Belize Valley geology varies over a short distance, allowing identification of population movement over 5-10 km. In contrast, the Vaca Plateau has homogenous values, so movement within the polity, or from any location in the Central Lowlands, is not visible isotopically.

In-migration occurred from three distinct areas with known relationships with Caracol, including the Belize Valley, the Southern Lowlands, and elsewhere in the Central Lowlands. No values were identified from the Maya Mountains, but the sample is relatively small. The large and well-studied burial population at Caracol presents an opportunity to explore these preliminary patterns further, useful in understanding interaction at the site as well as to provide a comparison with the type of mobility at Tikal.

2. Mountain Pine Ridge sites

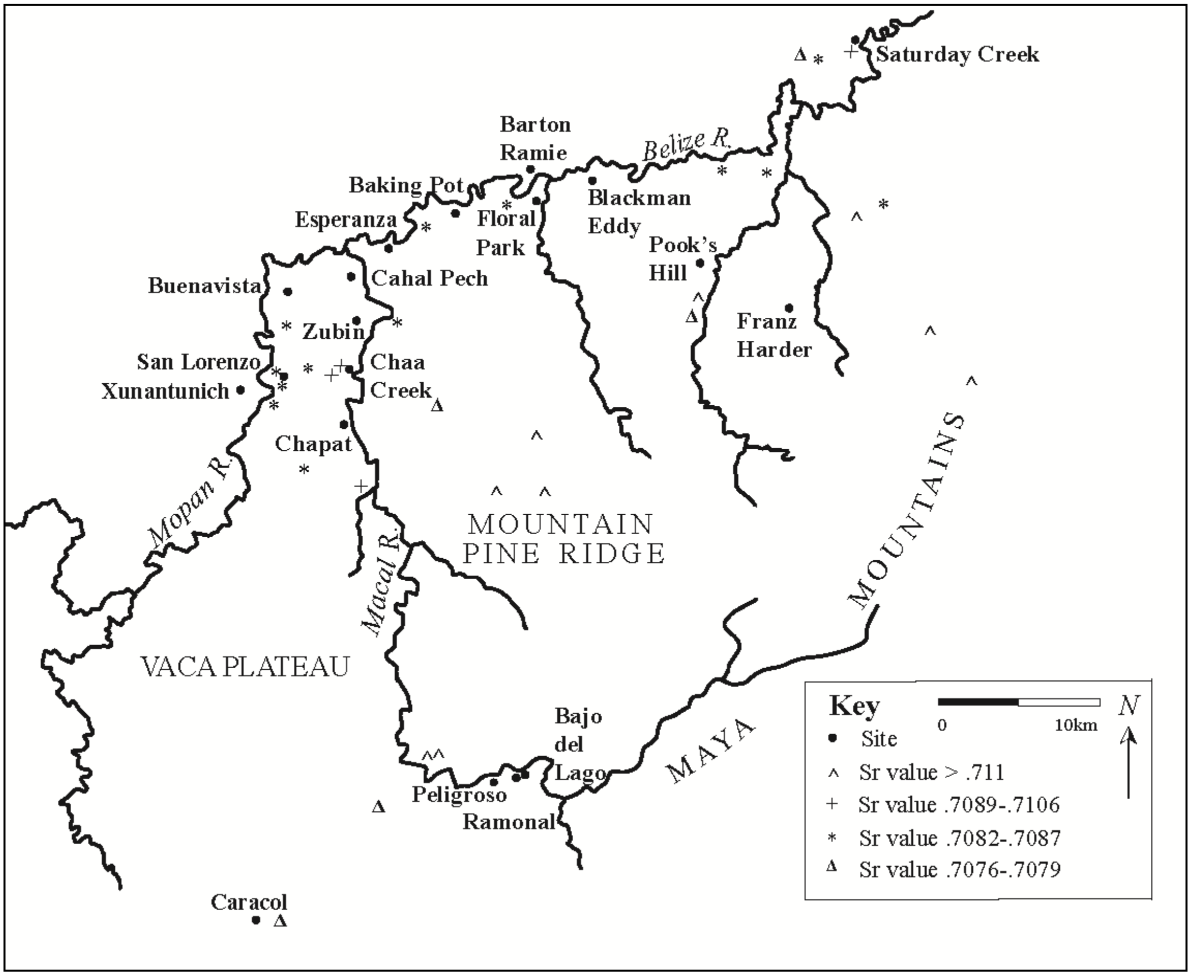

Figure 7.8. Mountain Pine Ridge sites map and strontium isotope values.

The Mountain Pine Ridge was sparsely settled during the Classic era as well as today (Awe et al. 2005; Wright et al. 1959), but archaeological mitigation by the Belize Valley Archaeological Reconaissance Project (BVAR) during 2003-2004 resulted in the description and mapping of nearly 300 structures at 112 sites along in the Upper Macal Valley (Awe et al. 2005). The information used in this analysis comes from this project's report. Settlement ranged from isolated structures to sites with multiple plazas that may compare in size to the major centers in the Belize River Valley (Figure 7.8). Awe and colleagues note similarities in settlement patterns in the two regions, where centers described as plazuela groups with surrounding settlement were distributed evenly across this part of the valley.

The three sites included in this study are located along the upper Macal River 2 - 5 km from the Chalillo Dam. Peligroso is comprised of a large plazuela group, while Ramonal and Bajo del Lago each have multiple plazas and associated architecture. Bajo del Lago likely was the largest settlement in the region, but Ramonal had the most extensively settled surroundings (Awe et al. 2005). The dense settlement is puzzling due to the proximity of poor soils (Wright et al. 1959), but may be associated with exploitation of Mountain Pine Ridge resources, like pine and granite, and trade with residents of nearby sites in the Vaca Plateau, like Caledonia and Mountain Cow.

All eleven of the individuals sampled were from structures on the eastern side of plaza groups that excavators identified as family burial shrines. Each individual was interred in a tomb or crypt with evidence for re-use one or more times, with the exception of the burial of a single individual at Bajo del Lago. Burials in tombs containing multiple individuals are common at sites in the Vaca Plateau (Chase and Chase 1994; Schwake 2008), and a similar pattern may extend to sites in the Mountain Pine Ridge. However, local burial patterns are not well known and analysis of these sites is not yet complete. While this limits interpretation of the strontium isotope results, all eleven match baseline values identified in the Mountain Pine Ridge. The strontium isotope results provide a comparison with Belize Valley data and present new isotopic information for a little-studied part of the Maya world (Table 7.10).

Table 7.10. Mountain Pine Ridge sites strontium isotope values and burial information: Information on burial position and context from Awe et al. 2005.

Burial	$^{87}Sr/^{86}Sr$	Sex	Age	Burial information	Date
Ramonal B003 #75	.71461	I	A	Crypt oriented north-south; remains not articulated	Not available
Ramonal B003 #21	.71499	I	A	Crypt oriented north-south; remains not articulated	Not available
Ramonal B005 #138	.71128	I	A	Crypt oriented north-south; remains not articulated	Not available
Ramonal B005 #12	.71217	I	A	Crypt oriented north-south; most remains not articulated	Not available
Ramonal B005 #16	.71346	I	A	Crypt oriented north-south; most remains not articulated	Not available
Ramonal B005 #55	.71513	I	A	Crypt oriented north-south; most remains not articulated	Not available
Ramonal B005 #3	.71637	I	A	Crypt oriented north-south; most remains not articulated	Not available
Bajo del Lago B001 #20	.71347	I	I	Crypt oriented north-south, head oriented to the south	Not available
Peligroso B008 cluster A vessel 17	.71464	I	A	Tomb oriented east-west; remains not articulated	Early-Late Classic transition
Peligroso B008 cluster A #22	.71482	I	A	Tomb oriented east-west; remains not articulated	Early-Late Classic transition
Peligroso B008 cluster D #32	.71508	I	A	Tomb oriented east-west; remains not articulated	Early-Late Classic transition

2a. Identifying origin: analysis of the strontium isotope values

The complex geology of the Maya Mountains and Mountain Pine Ridge results in a wider range of strontium isotope values than in other parts of the Maya Lowlands. Values of modern baseline samples range from .71114 to .72552 (mean value .71633 ± .0055). These values are reflected in the $^{87}Sr/^{86}Sr$ ratios of the human population, which range from .71128 to .71637 (mean value .71418 ± .0015).

The baseline values appear to be more variable than the human population because the sample was drawn from across the Mountain Pine Ridge: the two values collected in the upper Macal River valley are more limited. Two freshwater snails, *jute* or *(P. indiorum),* have strontium isotope values of .71141 and .71176. Another sample collected < 10 km away in the Vaca Plateau has a value of .70771 $^{87}Sr/^{86}Sr$.

All human values exceed $^{87}Sr/^{86}Sr$ .711 (Figure 7.9). The only place these values have been identified in biological populations in the Maya region is in the Maya Mountains and Mountain Pine Ridge. Hodell and colleagues (2004) measured three similar values in rocks and plants in the Metamorphic strontium zone, but these do not appear to represent the average values for that area or those reflected in biologically-available strontium.

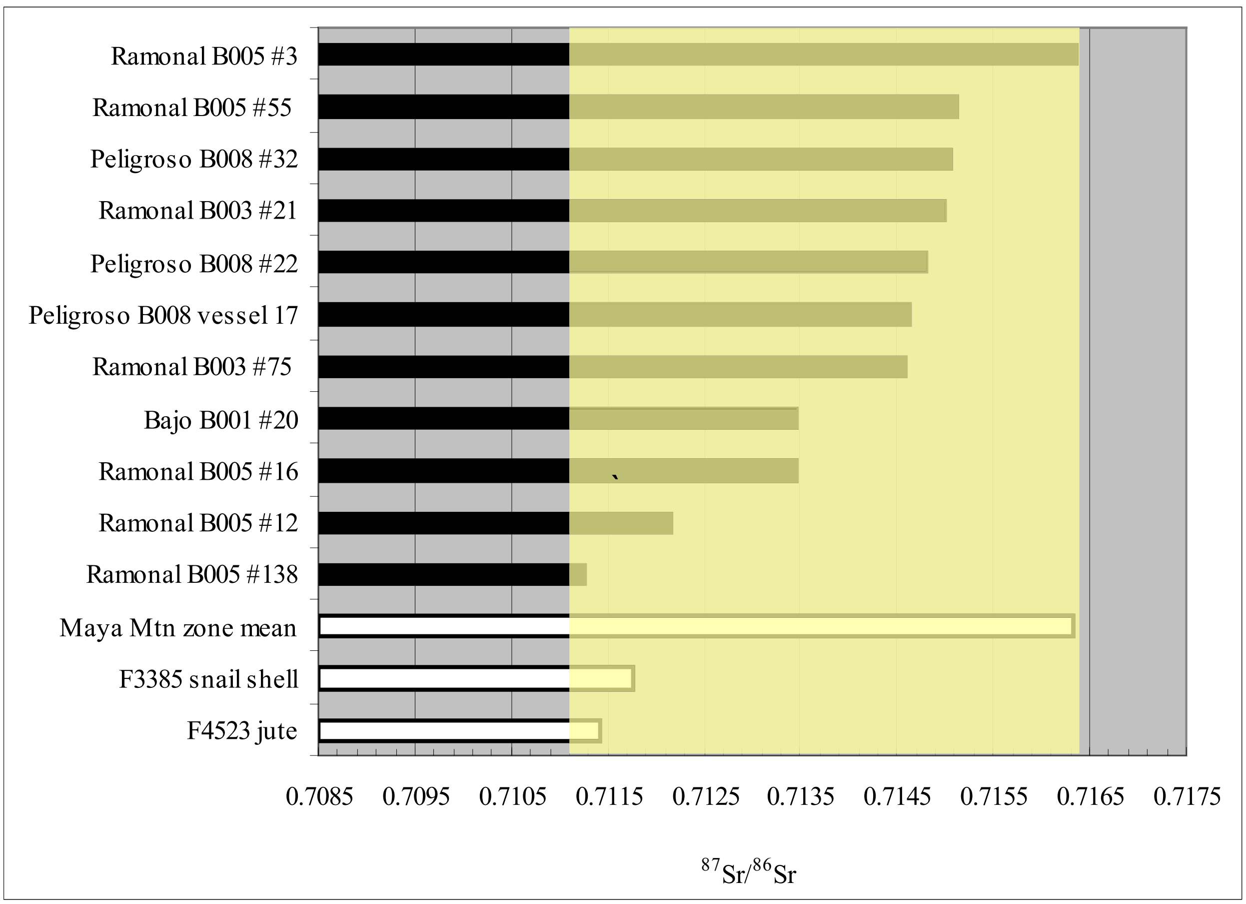

Figure 7.9. Ramonal, Bajo del Lago, Peligroso strontium isotope values bar graph: White bars represent $^{87}Sr/^{86}Sr$ baseline values and the shaded area represents the range of values identified along the Belize River. Black bars represent each individual in the study (including marginal values).

2b. Ramonal

Ten burials at Ramonal were discovered in the eastern structures of Groups A and C. The majority of the burial chambers were oriented north-south, and in the small number of individuals where body position could be discerned, the bodies lay in a flexed position with the heads oriented to the south. Each of the five burials in the Plaza C eastern structure contained one individual, and all but one were interred in simple graves. Grave goods were sparse, and where the burial position could be described, the individuals lay in semiflexed positions with the head oriented to the south.

Five burials also were identified in the Plaza A eastern structure. Grave types were more varied, ranging from tombs with multiple individuals, to simple burials with one individual. The seven individuals in this sample come from two of these burials. Each contained two or more individuals and a large number of grave goods (Awe et al. 2005).

The burials were discovered in front of the basal platform of the structure, and capstones for both burials in this sample were aligned north-south. Crypt 1 Burial 3 (B003) contained a series of burials that extended below a crypt into the subsoil. The remains were disarticulated and arranged vertically, along with six whole vessels. Two of the individuals sampled in this burial have low Mountain Pine Ridge $^{87}Sr/^{86}Sr$ values, while the third has a high one that approximates the average value for the strontium zone.

Tomb 2 Burial 5 (B005) contained the remains of at least four crania, each of which were sampled. The remains of one individual were still articulated, with a flexed body position and head oriented to the south. The other remains are reported to be of individuals who were interred earlier. The burial contained a substantial number of grave goods, including jaguar tooth pendants and obsidian and at least 16 vessels.

2c. Peligroso

Burial 8 (B008) contained multiple individuals in a tomb in the eastern structure of a plazuela group. It was oriented in an east-west direction, but body for the individuals could not be discerned, as bones were re-arranged in the tomb post-mortem (Awe et al. 2005). Long bones reportedly were stacked, and the tomb was crowded with an assemblage of Early – Late Classic vessels and other artifacts. The three individuals in the sample had similar Mountain Pine Ridge strontium isotope values.

2d. Bajo del Lago

The site consists of three formal patio groups surrounded by house mounds. The minor center has a ballcourt and other monumental architecture surrounding a central plaza. One of these is a tripartite complex that normally serves as family burial shrine. The single individual in this sample (B001) was interred in a crypt in the tallest of the three structures, in what may have been one of the earliest sequences of the building. The remains were fragmentary, but the cranium appeared to be oriented to the south and the crypt was aligned on a north-south axis.

2e. Mountain Pine Ridge sites summary

It is unusual to have no measureable population movement in a site, especially when different strontium isotope values are located less than 20 km away in a well-populated region that includes the enormous center Caracol. Population movement might also be assumed where low-quality soils might drive additional relocation between regions, and could result in an area being settled late in the regional population expansion that filled in more fertile areas first.

Population movement may have occurred within the Maya Mountain region, but there are fewer reported sites, so the assumption of local origin for the individuals in the sample seems valid.

There are no strong patterns that differentiate one site from another. Individuals in two burials have similar values, but contained only 2-3 individuals. Individuals in the largest burial sample from Ramonal have a broad range of values. While it is tempting to draw a comparison with residential groups at Baking Pot, where individuals have diverse, but mostly local values, this may be the result of heterogeneous geology that produces more variable signatures in the baseline samples as well.

Burial patterns for these sites are not yet published, but may differ within the region. Graves at Ramonal and Bajo del Lago are reported to have north-south orientations, while east-west alignments are described at Peligroso. Temporal differences may also be important: one shrine structure at Ramonal contained the burials of single individuals, while the other contained burials with multiple individuals. Burials of multiple individuals became more common during the Late Classic in the Belize Valley (Schwake 2008). However, burials with multiple individuals are common at Caracol, and Mountain Pine Ridge sites may have participated in the same sociopolitical networks.

Perhaps isotopic values can contribute to the establishment of burial patterns in the region. Normally, patterns at sites are established with the assumption that practices represent local norms. This study shows that comparison of LEH patterns in tooth enamel changes once the individuals' origins are identified. Isotopic values can explain some variability in burial practices as norms for the region are identified, and in this area, there may be substantial variability in local burial practices.

C. Broader patterns: patterns of population movement in the Maya region

There are now nearly a dozen studies and more than 300 strontium isotope values published for sites across the Maya region, in addition to the values presented here. However, even though population movement from diverse locations is identified at each of these sites, the small number of non-local individuals makes it difficult to reconstruct broader migration networks. Even if 10-20% of each sample population has a non-local strontium isotope value, this may result in only one individual from a particular strontium zone at each site.

It is still possible to identify several trends that suggest how the process of migration was structured, even if there is insufficient data to show exactly where it occurred. Published information from Copán, Tikal, and other smaller studies suggests that, like the Belize Valley and neighboring regions, population movement commonly occurred locally and between neighboring regions. Long distance population movement is infrequently identified, and in-migration from outside the Maya region has not yet been identified, though this cannot be identified using strontium isotope analysis alone. These data are supported by dental morphometric studies that suggest widespread movement via interconnecting, but bounded, regional networks.

1. Copán

Copán is one of the most well-studied Maya centers, especially where research on population movement is concerned. Detailed information on the life histories of a number of individuals at the site is complemented by a sample of the burial population that includes both low and high status individuals (Buikstra et al. 2004; Miller et al. 2008; Price et al. 2008, 2010). The history of the site poses intriguing questions about population movement, including evidence for the presence of foreign kings and non-Maya inhabitants. Substantial population movement is documented at the site, and the origins of the individuals appear to be diverse.

Average strontium isotope values expected for the human population are derived from modern and geological baseline samples. These have average values of .70644 (Hodell et al. 2004 for five samples) and .70659 ± .00085 (Price et al. 2010 for eleven samples). Multiple strontium isotope values for 38 individuals show that, like the Belize Valley sample population, most individuals have values that fall within the range of the local baseline samples (Miller et al. 2008; Price et al. 2010).

However, individuals buried in both commoner and elite households and the acropolis have values suggesting a non-local origin in one of at least three distinct strontium zones, and that some individuals relocated more than once. Two individuals interpreted as commoners have Central Lowland zone values, as do at least three individuals in Acropolis interments (Price et al. 2010) and two individuals buried in an elite residential complex sampled by Miller and colleagues (2008). Longer distance movement is suggested by a Pacific Coast/Volcanic Highlands zone value in the same complex, and a Northern Yucatan or Belize Valley value identified in an Acropolis burial.

In addition, inter-tooth sampling suggests that some individuals moved more than one time during childhood, adolescence, or as an adult (Price et al. 2010). Miller and colleagues (2008) also report an individual with a Pacific Coast/Volcanic Highlands strontium zone value. In all, nine individuals (24% of the sample population) have at least one strontium isotope value that is not local to the vicinity of Copán. This shows a rate of in-migration comparable to that of the Belize Valley, though it is not clear whether geologic heterogeneity in the two regions is comparable.

Identification of potential homelands for all of these individuals comes with one caveat: strontium isotope values in Honduras are not yet known. Values identified in the Maya region might also be found in Lenca or other non-Maya areas: population movement from outside the Maya region has potentially greater cultural implications than population movement within it. Copán may present the best place to study not only interregional, but intercultural mobility in the Maya region.

2. Tikal

Strontium isotope values for 83 individuals buried at Tikal represent the largest study of paleomigration published in the Maya region prior to this study (Price et al. 2008; Wright et al. 2005a, 2005b). As one of the largest centers in the Maya region, its population may have exceeded 60,000 individuals (Culbert et al. 1990), so the demographic composition of the population is a critical question. Like Copán, reconstructing life histories of individuals has been a key focus of isotopic analyses, but Wright (2005b) also presents data for the center as a whole that suggests a substantial number of migrants with diverse origins.

The average human value is somewhat higher: .7080 before outlier values are removed, with a trimmed mean of .7081 $^{87}Sr/^{86}Sr$. Wright (2005b) attributes the elevated values to consumption of imported salt, interpreting approximately 8% of the values as non-local. Values identified in local fauna suggest that the local human values should have an average of approximately .70785 ± .00006 $^{87}Sr/^{86}Sr$ (Wright et al. 2005b). Hodell and colleagues (2004) find similar values.

The origin of one individual with a value > .716 is clearly linked to the Maya Mountain strontium zone. Three individuals have values associated with the Pacific Coast/Volcanic Highlands, two likely had origins in the Motagua/Copán strontium zone, and two have values similar to those identified in the Northern Lowlands or the Belize Valley. In addition, the wide range of values within the statistically-determined local range suggests that more migrants are present within that population.

A rate of ~10% in-migration is similar to other smaller, published studies (e.g., Krueger 1985; Wright and Bachand 2009). However, when Wright (2005b) interprets marginally low and high values in conjunction with archaeological evidence, she suggests that 4-13% more also had non-local origins, resulting in a value similar to that identified in the Belize Valley. In fact, substantially more population movement probably occurred at Tikal because like Caracol, the Central Lowland zone covers a very large area and movement within the region cannot be measured using strontium isotope analysis alone.

3. Other studies

In-migration from distant and diverse regions is expected at large centers like Tikal, Caracol, and Copán, especially considering iconographic, architectural, and artifactual evidence suggesting in-migration from regions as distant as Teotihuacan. However, strontium isotope values suggest that most population movement actually occurred between neighboring regions. At Copán, most non-local individuals have $^{87}Sr/^{86}Sr$ values from an adjacent region, with one exception (and limited by currently known strontium isotope values). At Tikal, since Southern Lowland values are not distinguishable from local ones, all but one value also can be sourced to a neighboring region.

This is based on the assumption used to interpret Belize Valley values, a conservative one used in most isotope studies (e.g., Killgrove 2010), that the closest source is the most likely one. Most of these values also could represent a more distant origin, and thus more long distance movement in proportion to regional relocation. However, the same trend is visible in studies using a smaller number of samples in other parts of the Maya area.

Individuals with non-local strontium isotope values are identified in each of two studies in the Pasión region ay Punto de Chimino and Seibal, and each likely came from neighboring regions including the Central Lowland and the Metamorphic zones (Krueger 1985: Wright and Bachand 2009). At Pusilhá, south of the Maya Mountains, a wide range of local values is suggested by the local human population (Somerville 2010). The non-local values come from the neighboring Metamorphic zone, and more non-local individuals might be identified once additional faunal baseline values are available.

Wright and colleagues (2010) recent publication of strontium isotope values at Kaminaljuyú include a limited number of Late Classic individuals (n = 2), but samples from earlier time periods include likely in-migration from the neighboring Metamorphic zone, as well as a high value that suggest long distance relocation from the vicinity of the Macal River zone, though it is important to mention again that additional baseline information could point to origins elsewhere in Mesoamerica.

This does not represent all published studies to date: additional information on Wright's (2007) report on Mayapán is forthcoming, as is analysis of the Preclassic Chiapas sites on the Pacific Coast and at Chiapa de Corzo. However, at the sites where population movement is identified in the Belize River Valley and at Caracol, values indicate in-migration from adjacent regions. Most of these regions are large and include several hundred square kilometers or more. However, oxygen and strontium isotopes at Xunantunich document movement at the smallest scale possible using isotopic assays.

Scherer's (2004) research on population exchange in the Maya lowlands supports a model of enduring networks of migration and population movement between different Maya regions. While he documented many trends that are beyond the analytical limits of isotopic analysis, like the scope of population exchange between the geological similar locales of Tikal and Calakmul, he noted ongoing genetic exchange across the entire region. This could result from in-migration in each region that came from adjacent regions, forming interconnecting regional migration networks.

For example, analysis of dental traits at Belize sites generally showed below average extra-local gene flow, which is supported by the very limited observations of interregional migration in the isotopic assays. While Scherer (2007) characterizes gene flow at the site of Barton Ramie as high, Wrobel (2004) also identified differences between Belize sites (including a larger Barton Ramie sample) and those in more distant regions like the Pasión. A finding of overall gene flow with regional groups fits the preliminary patterns suggested by the isotopic analyses.

D. Conclusion

Isotopic and archaeological evidence suggests that 23% of the individuals sampled from 15 Belize Valley centers relocated at least once during life. Most movement occurred within the region, and is visible because strontium isotope values differ along the floodplains of the Macal and Belize Rivers, creating two strontium zones within the Belize Valley. It is likely that more substantially population movement occurred since movement within each zone is not detectable isotopically.

Movement was not limited to individuals residing at large centers or those with greater access to material wealth. Individuals with non-local origins, including long distance migrants, are identified at centers of all sizes and include males, females, and children. There is no statistically significant difference based on sex, age, burial location, or burial context. Nor is there a correlation between the presence of burial goods associated with an individual and origin. Individuals with non-local origins even are found in eastern shrine structures and are commonly identified in burials with locally-born individuals.

There is a relationship between burial treatment and origin: the orientation of the body in a grave, from tombs to simple pits, is overwhelmingly to the south for those with Belize Valley isotope signatures, regardless of whether the individual was born and buried at sites along the Macal or Belize Rivers. There is no indication that perimortem trauma or other health indicators might be more visible in non-local individuals, but this likely is due to the types of burials sampled in the study. No human bones in caches or contexts with unambiguous evidence for human sacrifice were selected as part of this study.

Crania and skull-only interments contained individuals with non-local strontium isotope values at more than double the rate identified in the rest of the burial population. The large number of Central Lowland values identified in the crania in the Xunantunich deposit, combined with the architectural evidence for drastic change at the site center, suggests a strong relationship between origin and burial treatment, even if it does not provide evidence for the cause of death (i.e., sacrifice). Ancestor veneration at Chaa Creek shows that non-local individuals also were likely to have non-local origins, though these interments generally contained complete or nearly complete remains. Still, it is possible that these crania-only burials demonstrate post-mortem movement of remains as well.

This pattern is not unique to the Belize Valley. Population movement in excess of 10% of the burial population sampled is reported at nearly every site published to date. In fact, some individuals may even have moved multiple times (Price et al. 2010). Like findings for the Belize Valley, most in-migration likely came from adjacent regions, though this is based on the conservative assumption that the closest possible origin is the most likely one. Even high estimates of population movement are likely low: the homogenous geology of the Central Lowlands masks local and region movement into the large centers of Caracol and Tikal. Extremely heterogeneous geology may also mask population movement: no non-local individuals were identified in the three Mountain Pine Ridge sites, but strontium isotope values in that region are extremely variable.

All of these findings have broader implications, not only for understanding the impact of migration on social, political, and economic organization, but on osteological analysis and studies of burial patterns. Analyzing patterns in tooth formation and morphology must take into account an individual's origin, since any burial population will contain individuals who spent their childhood in a different location. Likewise, any study of burial patterns must include the understanding that origin played a role in treatment, if myriad other aspects of identity did as well. This can be visible archaeologically – not in the types of burial goods included in the grave – but in other aspects of burial treatment.

Chapter 8 Broader Implications of Population Movement in the Maya Lowlands

A. Modeling paleomigration

The goal of this study was to reconstruct key aspects of population movement in one region of the Maya lowlands during the Late and Terminal Classic, a period during which critical social, economic, and political changes occurred. Population movement was fundamentally the most visible result of these changes. Multiple lines of evidence show that the Belize River Valley population was a mobile one. Variation in migration patterns within the region may relate to distinct social networks of family or corporate groups, political affiliation, or availability and/or control of land and resources that limited peoples' ability to move in certain parts of the region.

The findings of this study also relate to how isotope methods can be used to identify and population movement, and how to interpret it using a framework explicitly based on findings of research on modern migration. The results of the study were presented in detail in Chapters 4-7, but there are other implications worth exploring in a more creative manner than the conservative conclusions presented in each of these chapters. As noted in the introduction, migration patterns both reflect and affect a society's social structure, which in turn is deeply intertwined with the political and economic organization. The nature of population movement in the Belize Valley provides some intriguing ideas on how these were structured.

1. Framing the question

Studies of modern migration provide a model for identifying ancient patterns of population movement. Research on contemporary populations provides testable expectations about the demographic profile of the individuals who migrate, as well as the rate and direction of the movement, and how that movement is structured. The reasons that people move also can be ascertained to some extent in living populations, but the effects of population movement are easier to identify than its causes. These observations frame a series of questions that serve as a baseline for understanding both similarities and difference in ancient societies.

As outlined in Chapter 2, the questions drawn from modern studies provide the framework for the model. The first question addresses the rate and direction of migration in order to understand where population movement occurred and how common it was. Despite the frequent misunderstanding in the archaeological literature that migration only involves long distance mass movements, most relocations in modern and historic populations consisted of movement over short and medium distances (e.g., Coombs 1979; Hoerder 2004). This forms the basis for reconstructing each community's migration networks, and because migration is a socially-structured phenomenon (e.g., Denich 1970; Mantra 1981), to understand aspects of their social networks. It also provides an estimate of the rate of population movement. It is clear that people move today, and did in the past as well. Assuming that migration did not impact any ancient community is not supported.

The second question explores variability within a region, which in this case is the Belize Valley. To what extent will each center's history predict its place within larger networks of population movement? The time depth of the connections between particular communities, and the nature of the relationship, are important factors that should influence networks of population movement. The resulting social ties form the basis of political and economic connections, as well.

The final question explores the demographic profile of the migrant population: who moved? Modern studies suggest that movement does not occur equally across the population.

Analysis of the movement of individuals allows identification of the sex, and to some extent the age, of the migrant population. Some aspects of an individual's status can be inferred from an examination of the burial context, such as where the individual was interred, whether goods were included or not, and how the body was treated by survivors and/or those in charge of the burial process.

Using these questions to examine migration in ancient societies requires careful choice of methods. It requires a focus on the individual, and a discussion of how the burial sample relates to the ancient living population. Bone chemistry methods offer the appropriate scale of analysis, but they must be supplemented with other types of data in order to interpret the results. There is flexibility in the method(s) employed, as studies of societies outside of the Maya region and Mesoamerica offer their own unique challenges.

2. Methods: approaches to identifying migrants

Isotopic results cannot be assessed using only geologic or statistical approaches (Evans et al. 2006, 2009; Wright 2005b). Geologic maps cannot substitute for a large sample of fauna from the catchment areas of each site, as well as samples of neighboring regions. Humans should have values similar to those of local fauna, although may slightly elevated and show additional variability, particularly in large samples. Likewise, statistically significant patterns may conflict with both archaeological patterning and known geologic differences in strontium isotope studies. Statistical analysis does, however, provide a guideline for understanding differences between regional populations and divisions within each region, and even each site.

Use of a range of one (or two) standard deviations around the mean as the cut-off for identifying the local population presents problems, particularly with strontium isotope values. If the values derive from the human population, a circular argument is created because the range of local isotope values may include migrants. If local fauna are used as the cut-off instead, the range of values identified as ‘local’ in this study would encompass all known geologic variability in Mesoamerica.

There likely will always be some ambiguity that requires additional analysis. In this study, burial treatment and other isotopic assays proved useful in determining the origin of individuals with marginal values. For example, oxygen isotope values vary within some strontium isotope zones and were used to differentiate individuals from different parts of the Central Lowlands. However, it is not possible to eliminate all ambiguity. Geologic and behavioral variability will almost always exceed the analytical precision of the method, and it is better to explore multiple possibilities than to offer an overly specific explanation of an individual’s life history or origin.

There are other limits to the information isotopic analysis can provide, and these are important to remember. Only first-generation movement can be tracked, and only for limited time periods (i.e., when tooth enamel or bone is formed). Furthermore, it is only possible to identify movement into a center or region: Out-migration is a particularly critical question during the Terminal Classic period, when many Maya Lowland centers witnessed depopulation and abandonment.

Moreover, individuals can only be identified as non-local to particular strontium zone, not to a site or polity. Nearly all strontium zones encompass multiple polities; in the case of Xunantunich, a single polity cross-cut two strontium zones. As a result, it is not possible to identify “residential mobility” because the term is defined as movement within a polity. The strength of isotopic assays is the ability to identify population movement, even if the specific category of migration remains unknown.

3. Modeling Migration

This study shows that during the Late and Terminal Classic, population movement occurred mainly over short and medium distances, in some cases between zones less than 10 km apart, and that it included individuals from both large centers and rural farming communities. Both men and women relocated to new communities, and the identification of children with non-local origins suggests that people moved in groups moved as well. While migration is a socially-driven phenomenon, relocation for marriage does not appear to be the only reason for population movement. People likely moved for as many reasons in the past as they do today.

Migration patterns were not the same in each polity, which suggests that there is additional variability in other areas in the Maya lowlands, specifically in areas adjacent to non-Maya cultures, like Copán, and in the largest Classic era centers, like Tikal. This framework will serve as a tool to compare different parts of the Maya area, as well as different time periods and different societies. It also poses interesting questions about how population movement was structured during the Terminal Classic period as massive changes were occurring in the Maya sociopolitical system. Even if population movement occurred incrementally, it should differ dramatically in scale, including both the direction and rate of migration, as regions were abandoned. Perhaps different patterns will emerge if this model is applied elsewhere in the Maya lowlands, especially where substantial in-migration may have occurred. An estimate of out-migration might be possible, and would present an interesting challenge. Understanding similarities and differences with other regions for this time periods will prove very useful in addressing these questions. It will be useful to assess the extent to which centers that retained populations during the Postclassic had distinct population movement patterns from those that did not.

This framework also is useful to study migration patterns in other societies. Killgrove's (2010) study of ancient Rome shows significantly different patterns of movement than those identified for the Maya. Posing the same questions can result in very different answers about who moved, how far they moved, how the movement was structured, what migration meant, and the impact it had on different aspects of society.

B. Implications for social organization

The demographic profile of the migrant population in this study does not support a simple model of a patrilocal postmarital residence system where a woman joins her husband's household. It is possible that patterns in which both males and females move instead reflects the more complex situation documented in Colonial records (Farriss 1984; Restall 1997). Newly married couples might move in with either family, but the arrangements were not always permanent. Similar flexibility in marriage customs may have existed during the Classic period, as well. However, the data in this study do not strongly refute or support any type of post-marital relocation patterns. Identification of males, females, and children in the migrant population may simply mean that there were multiple reasons for moving, as there are in modern societies.

It does appear that households were complex entities that were able to accommodate new individuals, sometimes from multiple locations. Social groups also accommodated the loss of household and community members, and some individuals with non-local origins were treated as venerated ancestors. There is little information on what this meant during an individual's life.

Whether a migrant retained his or her accent or a particular style of dress is beyond the scope of this study. That said, it is possible to observe that many migrants received the same burial treatment as those born locally, or at least when they relocated within the same strontium zone. The broader implication is that kinship connections formed the basis for widespread networks in the Belize Valley.

Another important dimension of Maya society that was potentially shaped by migration was its vertical organization. Ruling and elite individuals may have moved in the same general directions as farmers or itinerant workers, but this does not mean they moved in the same circles. There is very little evidence for population movement over either long or short distances in the few individuals from the top echelons of Maya society included in this study (Freiwald et al. 2011). Nine individuals are identified as rulers at four Belize Valley major centers; only one has a non-local strontium isotope value. This individual, Buenavista BV-88-B13-1, has a Macal River zone value (Mitchell 2006), which indicates movement within the region. In sum, all rulers had Belize Valley origins. This carries meaning for the political and economic organization as well, since communication within social networks would facilitate movement of goods and ideas as well.

C. Implications for political and economic organization

Although the Belize River floodplain was densely settled, individuals still were able to move. Even case at sites settled during the Late Classic, such as Esperanza where all individuals sampled have non-local strontium isotope values, individuals and families were able to negotiate access to land. More important, the ability of so many people to move – and in some cases groups of people – reflects the limits of political control exercised by Maya rulers. Although labor and tribute certainly were important, it seems that like their Spanish analogs, they were unable to limit movement within the region, and potentially out of it as well. People were able to move between parts of the valley controlled by rulers of different polities.

Conversely, rulers may have actively recruited people from other polities to immigrate and provide sources of labor and tribute. What they offered in return may have included economic or military security, or access to land, social capital, and/or other resources. This seems likely at least during the Terminal Classic, when rulers in many Belize Valley polities asserted independence from larger centers in the Central Lowlands, and when population levels were declining rapidly, leaving some rulers with fewer and fewer tributary subjects.

The strontium isotope values, and the larger patterns they show, also have implications for economic organization. First, at many sites, individuals buried in the same residential group have strontium isotope values that cluster closely together, suggesting that they shared very similar diets and that basic foodstuffs were not transported over long distances. This downplays the role of imported foods, like marine resources, in shaping isotopic differences within the local population during the Late and Terminal Classic periods. Wild game from different strontium zones has been identified at Xunantunich, Chaa Creek, and San Lorenzo (Yaeger and Freiwald 2008), but there does not appear to be a strong relationship between these foods and variability in strontium isotope values.

Salt is the main dietary input suggested to have resulted in strontium isotope values that differ from expected values, as in the case of Tikal (Wright 2005b). This is a perplexing problem. First, samples of tooth enamel represent diet during infancy and early childhood. High salt intake during infancy could have serious consequences, and health problems like hypertension and high blood pressure could be endemic in society.

Moreover, strontium isotope values in human populations in most studies, including this one, are similar to those identified in modern fauna sampled in the same strontium zone. The Tikal pattern could be the result of substantial trade in foodstuffs to which salt was added as a preservative. Intensive sampling of strontium isotope values in the broader Tikal region could help to determine whether or not elevated strontium isotope values result from imported food or from local and regional population movement.

In either case, trade networks are closely linked to social ones, and migration creates social connections with great time depth. In the Belize Valley, migration networks are mainly regional in scale. If economic networks parallel migration those migration networks, it would suggest an important role for down the line trade networks in the distribution of goods acquired over long distances. Trade patterns may have varied for each region and resource, but it is an interesting possibility.

D. Other implications

Each of these interpretations hinges on how well the Maya burial population reflects the living one. If selective burial practices bias the study, the individuals in this sample may have had higher rates of migration than the norm for the society. Would the results change with a more representative burial population from a cemetery? This can be explored further by incorporating additional interments from cave and rockshelter contexts interpreted as burial grounds for nearby communities (Gabe Wrobel personal communication 2010).

The reverse side of the question can be addressed with other cave populations. Some had very specific non-normal burial profiles (e.g., Tiesler 2007. How different will these patterns of population movement look, and will it be possible to identify different types of population movement? It is necessary to further explore these patterns in the Belize River Valley to recreate the total picture of population movement in the region.

E. Conclusion

Investigation of almost every social process requires some understanding of migration. Maya households and communities accommodated population movement, as people from many non-local places came to be venerated as ancestors and were buried in and around people's homes. In the Belize Valley, movement within the region had great time depth at both small centers and large ones, while in-migration from neighboring regions may be associated with political change at Xunantunich, and the formation of new sites in the minor centers of Esperanza and Floral Park. The political structure in the region had to accommodate movement of people as well, as immigrants included individuals from rich and poor households and commoners and elites.

Use of the term migrant implies voluntary movement into the Belize Valley region, so it is important to reiterate that migration includes voluntary and involuntary movement. The assumption of a relationship between the place of burial and the residence during life may be violated, or redefined, by the crania and skull-only burials. Despite a lack of unambiguous evidence for sacrifice or post-mortem movement of the remains, the relationship between some of these individuals and the site may be one that relates to politics or warfare (though at least one is interpreted as a venerated ancestor). Individuals interpreted as important ancestors also have non-local strontium isotope values, but not on the scale of the individuals represented only by crania and skulls. However, removing these individuals from the overall rate of migration does not impact the overall findings.

This study shows that multiple lines of evidence can be used to piece together the complex picture of migration during a short, but important, time in Mesoamerican history. A review of scholarship on modern and ancient societies shows that an expanded definition of migration, and use of modern analogy, can provide a useful framework for studies of ancient migration. Isotopic analysis is complemented by other lines of evidence, including osteological and archaeological data that allow 1) the identification of patterns or migration, and 2) provide a better understanding of what it meant to be a migrant. These reflect important aspects of life from birth to burial that show how origin was, or was not, an important factor in the individual's identity. Bones actually reveal more information about the life of an individual than about the death and burial (Parker Pearson 1999:3).

It is critical to address the question of migration directly, rather than to assume a stable population or ignore the question altogether. The rate and direction of migration affects political and economic organization, and is intimately connected to the social structure of a society. It is a critical issue in societies around the world today, and surely was equally important in the past. Understanding patterns of migration, with their subsequent effects, not only can help to understand aspects of ancient societies, but can provide new insights into how migration affects modern societies as well.

Appendix A: Osteology and the Belize River Valley Skeletal Population

Methodological consistency is an important consideration in any regional study, and it is particularly important in one that relies on osteological identifications for its interpretations. Part of the burial population used in this project was studied multiple times, like interments excavated at Barton Ramie by Willey and colleagues (1965) and Xunantunich burials at Group D (Adams 1998; Braswell 1998). In contrast, analysis of human remains from other sites is incomplete and/or not published, and only limited information is available about burial context. The collection history also differs significantly for human remains at the sites in the study. Given these differences, an overview of efforts to standardize interpretations is provided, and it is followed by a description of the osteological methods employed in the analysis of three sites reported as part of this study. This includes a summary version of the skeletal inventory for the sites of Esperanza, Floral Park, and Blackman Eddy.

A final but critical piece of this discussion is curation. Care and storage of skeletal materials affected every aspect of this study, from availability of samples, to evaluating the interpretations and the comparability of previously studied skeletal materials. A guide for tropical care of skeletal materials is included, along with a description of curation of human remains in Belize completed as part of this study. While the upper Belize River valley is one of the most extensively studied areas in the Maya Lowlands, there are few publications on skeletal remains. There are even fewer histories of research on the collections, and this summary may serve as a starting point for compiling information on these important assemblages.

A. Comparability of skeletal analyses

The first step was to identify the state of research on each assemblage. The human remains from most of the major centers are the result of work by multiple projects, many of which did not have an on-site project osteologist. In some cases, research consisting only of analysis in a field laboratory, with no comparative skeletal materials, is summarized in a field report. Analysis is ongoing for many of the assemblages, and planned for others, and some scholars have begun to tackle the complex task of summarizing regional data (Schwake 2008).

Analysis has not been completed for several sites used in this study, including Tourism Development Project (TDP) human remains from Caracol, Bajo del Lago, Ramonal, and Peligroso in the Vaca Plateau and the Mountain Pine Ridge. Analysis is underway for remains excavated as part of other projects, like the individuals sampled from the Chapat and Franz Harder caves as part of the Belize Valley Archaeological Reconnaissance Project (BVAR), including the Western Belize Regional Caves Project. This also applies to remains from BVAR Baking Pot and Cahal Pech excavations.

Completed analyses are available in a combination of reports and publications for Saturday Creek human remains excavated as part of the Valley of Peace Archaeological Project (VOPA). Preliminary analyses of Xunantunich Archaeological Project (XAP), Western Belize Regional Caves Project (WBRCP), and Belize Valley Preclassic Maya Project burials also are available in a series of reports and publications (Adams 1998; Bassendale 2000; Braswell 1998; Helmke 2000a, 2000b, Helmke et al. 2001; Piehl 2008, 2006, 2002; Song 1995; Yaeger 2000). Analyses of Willey and colleagues' (1965) and Ricketson's (1931) excavations are published, but more recent unpublished analyses have been conducted (Vera Tiesler personal communication 2009). Esperanza, Floral Park, and some Blackman Eddy remains were analyzed as part of this study. Each of these analyses was conducted by a different osteologist.

The second step was to assess the comparability of each analysis, which was a complex process. For example, seven individuals contributed to the skeletal analyses of XAP material from Xunantunich. Adams' (1998) report provides the most comprehensive information, including descriptions of pathologies and health indicators, as well as a general skeletal inventory. Yaeger's (2000) dissertation on San Lorenzo contains additional detail by Adams on the three burials and other human remains found in this settlement zone. Scopa Kelso (2005) focuses on information derived from the dentition of the burial population. Her study of linear enamel hypoplasias complements that of Adams (1998) and describes weaning practices and health indicators of the population. Many of these reports and dissertations are not widely available.

Burial contexts from Group D at Xunantunich also are described in detail by Jennifer Braswell (1998), with a contribution by Ana Maria Boada. Boada's analysis is notable for its description of conservation, including treatment and reconstruction of the bone. There are minor discrepancies between the Adams' and Boada's analyses. For example, Op. 21 C/1 Individual #2 is described as a young adult male aged 25-29 years by Adams, while Boada notes a male approximately 20 years old. Adams documents observations of the auricular surface of the pelvis and possible fusion of the first and second sacral vertebrae, while Boada describes tooth wear. Both age estimations fall into the category of young adult (Ubelaker and Buikstra 1994), so are considered the same for the sake of this analysis. Other conflicts were resolved by re-assigning age or sex to a higher-level category or using observations made by the author during collection of samples and/or curation of burial materials. None of these observations conflict with those of Adams (1998).

In contrast, observations made during an inventory of some TDP Xunantunich and Baking Pot burials results in significantly different interpretations than those cited by Audet (2006). These are similar to observations made by Piehl (personal communication 2010) during her re-analysis of the materials, and she generously shared additional unpublished information about skeletal materials used in this study from Xunantunich, Baking Pot, and Pook's Hill. Tooth identifications were made by the author for all sites except Ramonal, Bajo del Lago and Peligroso, which were made by Lenna Nash, and Pook's Hill and three Baking Pot individuals, which were made by Jennifer Piehl.

Vera Tiesler (personal communication 2009) also shared results of a re-analysis of Baking Pot and Barton Ramie remains housed at the Peabody Museum at Harvard University. These are supplemented by observations made by the author for a small number of burials. Tiesler's analysis provides more specific age estimates for one individual, and reassigns the age and sex of two other individuals to a more general age category. A more specific list of references is provided for each burial in Appendix B.

Analyses by different researchers at times results in conflicting findings. This is evident in a comparison of identifications of Barton Ramie remains by different osteologists. Interpretation of burial treatment at Xunantunich also changes when the contexts are re-analyzed with a more in-depth consideration of taphonomic processes. For example, the burial position of Xunantunich Group B Op. 211 Burial 1 was initially interpreted as possible evidence for sacrifice, but can be explained by centuries-long erosion processes that resulted in slumping terrain (Etheridge 1996). Trowel marks also were mistaken for cut marks (described in field laboratory notations) for one individual in the Xunantunich Str. A4 burial assemblage, perhaps because poor preservation limited observations of bone surfaces. In contrast, excellent preservation in an assemblage from Xunantunich Group B allowed identification of clearly-defined cut marks on well-preserved human bone.

Obtaining a representative sample of the population relies on sex and age identification. Many of the Barton Ramie observations were made in the field, and although in-depth analysis was later conducted at Harvard, a description of the age and sex indicators used by osteologists is not described (Willey et al. 1965). At least two additional analyses have been conducted on the remains (e.g., Danforth 1997), and this study uses a 2009 analysis by Vera Tiesler (personal communication 2009). Data from Gerry's (1993) dissertation also are available, and are relevant because many of the same individuals were analyzed.

Some differences result from methodological advancements. For example, Tiesler adds more fine-grained age categories than those used in the original analysis more than 30 years ago. In addition, categories of probable sex assignment are common now, but were not used in the original analysis. This made a large difference in results on file at the Peabody (no reference is available), where the sex assignment was removed in ten cases, added in two, and changed in two more. Age designations also are placed in more general categories: they are changed for eleven individuals and added for four others. This results in substantial changes in a sample of twenty individuals.

Age and sex estimates from the Peabody Barton Ramie and Baking Pot samples used in this analysis come from a combination of observations made by the author while collecting the samples, and Tiesler's observations (personal communication 2009, received after the samples were collected). These result in a dramatic shift in the demography of the sample population.

Teeth collected from individuals originally identified as 4 males, 10 females, 4 adults, and 2 children now form a sample population of 8 males, 6 females, 2 adolescents, and 2 children. No assignments were made for the other individuals in the sample, and 7 of these assignments are probable. Re-analysis of collections often results in increased identification of females, but the opposite occurred in this burial population. The re-identification does affect the results: where Willey et al.'s (1965) identifications resulted in mainly female migrants, the new analysis indicates that migrants included both females and males.

Isotopic analysis also can alter results of paleodemographic studies. A reanalysis of Adams (1998) study of dental hypoplasias shows that differences in weaning age identified between people buried in urban and rural centers (Scopa Kelso 2005) are no longer visible when populations are compared by place of birth instead of burial. It may be necessary to establish a baseline estimate of population movement in a region before interpreting demographic data.

It is not possible to eliminate inter-observer variability, but in this case it is mitigated by open communication and sharing of published and unpublished data by researchers. This is an important component of a regional study.

B. Osteological Analysis

Human remains from three sites, Esperanza, Floral Park, and Blackman Eddy, are analyzed for the first time as part of this study. The analysis relies on standard age and sex categories (Ubelaker and Buikstra 1994), including old-age adult (>50 years), mid-age adult (35-50 years), young adult (20-35 years), adolescent (12-20 years), child (3-12 years), infant (1-3 years), and newborn or perinate (fetal). The analysis is supplemented by additional reference material (e.g., Bass 2000; Hillson 2005, 1996; White and Folkens 2000). Bone elements were identified using the reference collection at the University of Wisconsin – Madison Department of Anthropology. Age estimates were made according to Ubelaker and Buikstra's (1994) categories, though Barton Ramie identifications by Tiesler (personal communication 2009) use more precise divisions for childhood years. In some cases an age estimate spans two categories and is described accordingly, e.g., mid-old age adult. It is important to note that these categories describe biological development and are not meant to directly reflect stages of life as they are viewed in western societies today.

Age determinations are based primarily on development and wear of tooth and bone. Age assignments for dentition are based on development as described by Hillson (1996), and wear categories are based on Ubelaker (1989) in White (2000). Sex designations include three categories: 1) male or female when multiple and consistent osteological indicators are present, 2) probable male or female when multiple osteological indicators are present, but some uncertainty exists, and 3) possible male or female when the estimate is made using only a single marker. Descriptions of tooth modification rely on Romero (1970) and cranial modification on Tiesler (in press). Information on dental metrics and enamel hypoplasias was not collected.

The poor preservation and complex taphonomic history of this collection limit observations on health and pathology, which affects even basic identification of bone elements. First, procedures for identifying and sorting bones in the field laboratory and during initial osteological analyses are not reported. It is unclear whether associations of bone elements packaged together or marked with similar field labels were made in the field, when the bones were in situ and possibly in anatomical position, or during laboratory analysis. These identifications were retained only when supported by observation of bone morphology. Second, nearly every bone fragment was labeled, obscuring much of the surface. The labels were then coated with a preservative. Finally, many bones were reconstructed using glue that already has begun to deteriorate, which makes identification of some elements easier, but also precludes additional refits and has distorted the shapes of some bones.

C. Summary of Osteological Results for Esperanza, Floral Park, and Blackman Eddy

1. Esperanza

Two burials were identified in Str. A4, interpreted as the residential burial shrine for the plazuela group (Schubert et al. 2001). They contained the partial or fragmentary remains of five individuals. The remains were comingled, and body position and orientation was not identified.

Multiple units in Ops. 2b and 2c contained the remains of three individuals. Although two burials are described, the number of individuals (MNI) is based on duplication of elements due to the proximity to looter's trenches and the fragmentary nature of the remains. Op. 2d contained a second burial with two individuals. No burial goods were reported. Three individuals were sampled for isotopic analysis, and the detailed burial context is described in Chapter 5.

1a. Esperanza Burial 1: Op. 2b-1, 2b-2

Operation 2b was placed on the eastern side of Str. 4A to clear trenches left by looting activity. The burial was discovered under a marl cap that was oriented north to south across the 3 x 5 m unit, approximately 40 cm above an eroded floor with a partially burned surface. Preservation is described as poor (Schubert et al. 2001).

Burial 1 consists of 114 bone fragments, none of which are identified to element. These are only identified as human remains based on the burial context. Many of the bones are fragments of limb shafts, with differing levels of preservation, and most are 1 x 5 cm or smaller (Table A1).

Table A1. Osteological inventory for Esperanza Str. A4: Burial 1 Op. 2b-1, 2b-2.

Element	Side	Age and sex	Detail	% complete	# bones	Notes
not identified	I	-	-	-	114	includes limb shaft fragments

1b. Esperanza Burial 2: Op. 2c-1

Op. 2c was placed along the western edges of Ops. 2b and 2a, and additional human remains were identified in Ops. 2b-4 and 2b-6. Burial 2 consists of the partial remains of at least two individuals based on the presence of duplicate limb shafts (femur) and teeth. An additional lower left first molar and right femur indicate the presence of at least one additional individual. The remains come from three different units and no bones were matched between units to demonstrate their association to one another. The number of individuals was not incremented by the unidentified bone fragments described as Burial 1 in other Op. 2b units.

A dense lens of chart flakes served as a cap for the burial. While no grave goods were reported, four awl fragments (that did not fit together) were identified with the remains. Both individuals are determined to be adults based on tooth development. Tooth wear on one individual (sample F5908) suggests an age estimate of young adult, but is not sufficiently reliable for an accurate age (or sex) estimate. There are 1657 bone fragments in the two excavation units that are described as Burial 2.

Op. 2b-4 consists of the partial dentition of an adult with overall minimal tooth wear. These include both upper and lower teeth marked ‘Burial 2? Teeth C’ (Table A2). This unit also contained the fragments of a radius and other limbs, along with hand and foot elements. Op. 2c-1 contained most of the remains identified as Burial 2, including the nearly complete dentition of an adult (one third molar is present, but with minimal wear.) Both assemblages appear to have extra teeth. It is possible that teeth from one individual are mixed with the other, but the presence of a third lower left molar shows that the remains of at least one additional individual are present.

Op. 2c-1 also contains parts of the skull, including temporal, parietal, and mandible fragments, a small number of lower arm and hand bones, and the lower leg (includes tibia, fibula, and foot bone fragments.) It also includes the femora of three individuals, along with hundreds of unidentifiable limb shaft bones. Additional limb bones are identified in Op. 2b-6, which also includes bones of the crania, and the lower leg (fibula) and foot, and Op. 2b-4, along with lower arm, hand, and foot elements (Table A3).

Table A2. Osteological inventory for Esperanza Str. A4: B2? Teeth C.

Element	Side	Age and sex	Detail	% complete	# bones	Notes
Op. 2b-4						
first molar	L	possible young adult	lower	-	1	wear stage E LARCH sample F5908
third premolar	L	-	upper	-	1	no wear
third premolar	R	-	upper	-	1	no wear
third premolar	L	-	upper	-	1	no wear
fourth premolar	R	-	upper	-	1	no wear
canine	L	-	upper	-	1	wear stage B. 3-4 dental hypoplasias visible (not measured) on 2 of 3 teeth, obscured by poor preservation
canine	R	-	upper	-	1	wear stage B-C
canine	R	-	lower	-	1	wear stage B-C
second incisor	L	-	lower	-	1	wear stage B-C
second incisor	R	-	lower	-	1	wear stage B-C
first incisor	R	-	lower	-	1	
root		-		-	1	
first incisor	R	-	upper	-	1	
first incisor	L	-	upper	-	1	
second incisor	R	-	upper	-	1	
second incisor	L	-	upper	-	1	
premolar	I	-	upper	-	1	
third premolar	L	-	lower	-	1	

Table A3. Osteological inventory for Esperanza Str. A4: Burial 2 Op. 2c-1.

Element	Side	Age and sex	Detail	% complete	# bones	Notes
Op. 2c-1						
canine	I	-	upper	-	1	Romero's (1970) B4 dental modification
second molar	L	-	upper	-	1	wear stage B
first molar	L	-	upper	-	1	wear stage B
first incisor	L	-	upper	-	1	no wear visible
first molar	R	-	upper	-	1	wear stage B
third molar	R	-	lower	-	1	no notable wear
first molar	R	-	lower	-	1	no notable wear
second molar	L	-	lower	-	1	wear stage B
first molar	L	-	lower	-	1	LARCH sample F5910
canine	I	-	lower	-	1	wear stage B
first molar	L	-	-	-	1	minimal wear: still developing
third molar	I	-	-	-	1	
molar	I	-	upper	-	1	
third premolar	L	-	upper	-	1	
fourth premolar	R?	-	not same individual?	-	1	
premolar	L	-	not same individual?	-	1	
premolar	I	-	upper	-	1	
canine	R	-	-	-	1	wear stage B-C
not identified	I	-	-	<25	652	many limb shaft fragments
cranial	I	-	not identified	25-50	60	
temporal	I	-	2 petrous pyramid	<25	2	
mandible	L	-	condyle	<25	3	
mandible	R	-	coronoid process	<25	1	
mandible	-	-	mental spines	-	1	
temporal	I	-	-	-	1	
first phalanx	I	-	-	>75	1	bags were mixed: Is Op. 2? B1 or B2
limb	I	-	shaft	<25	8	4 refit (glued)
fibula	I	-	shaft	25-50	7	2 sets of 2 refit
fibula	I	-	shaft	25-50	7	
radius	I	-	shaft	<25	1	
shafts	I	-	-	-	48	2 manual phalanges and probably parts of hand and lower arm
first phalanx	I	-	manual	25-50	6	separate elements
third phalanx	I	-	pedal	<75	2	separate elements
second phalanx	I	-	manual	25-50	1	
phalanges	I	-	shafts	50 to 75	7	
metatarsal or	I	-	shafts	50 to 75	7	separate elements

metacarpal						
femur	R	-	shaft at gluteal attachment	25-50	7	refit nearly whole lateroposterior section of the shaft
femur	R	-	shaft at gluteal attachment	<25	1	marked "2 more right femur sections". Probably represent different individuals
femur	R	-	shaft at gluteal attachment	25-50	5	see above. Refit lateroposterior section of the shaft. Significant deterioration of bone, with fossa several mm deep and very little bone surface preserved.
femur	L	-	shaft at gluteal attachment	25-50	11	fragments refit
femur	L	-	medial shaft	<25	1	
femur	L	-	lateral shaft	<25	6	fragments refit. Significant deterioration of bone, with fossa several mm deep and very little bone surface preserved.
tibia	I	-	shaft	<25	3	2fragments refit
limb	I	-	limb shaft	<25	9	1 set of 2 fragments refits, 1 set of 3 refit. Looks like same bone, probably femur
limb	I	-	limb shaft	<25	50	3 sets of 2 refit, 1 set of 3 refit
limb	I	-	shaft	<25	390	
femur	R	-	proximal shaft	<25	9	6 refit, 2 refit
tibia	*cf* L	-	anterior crest	<25	11	3 refit, 2 sets of 2 refit
limb		-	shaft	<25	1	rehealed break possible pathology, but bone too small to say for certain
not identified	I	-	not identified	<25	25	includes limb shaft
Op. 2b-6						
cranial	I	-		<25	1	
fibula	I	-	shaft	<25	1	
limb	I	-	shaft	<25	3	
metatarsal	I	-	shaft	50 to 75	2	separate elements
limb shaft	I	-	possibly femur	<25	5	
limb shaft	I	-	not identified	<25	24	2 sets of 2 refit
limb	I	-	shaft	<25	18	
not identified	I	-	not identified	<25	54	
not identified	I	-	not identified	<25	8	
Op. 2b-4						

radius	I	-	shaft	25-50	2	1 is radius. Other likely lower arm
metacarpal	I	-	shaft	25-50	1	
third phalanx	I	-	pedal	comp	1	
first phalanx	I	-	manual	25-50	2	2 separate elements
limb	I	-	shaft	<25	3	
limb	I	-	shaft	<25	1	

1c. Esperanza Burial 3: Op. 2d-1

The excavation unit was located on the centerline in front of Str. A4 on a north-south axis. A circular altar was the focal point of the 2x2 unit, but it is not clear whether the burial was related to either the building or Altar 1. The field report states that no cache or deposit was found beneath the (broken) altar.

This burial includes the fragmentary remains of two individuals, including two partial skulls, one cervical vertebra, one clavicle, a small number of limb shaft fragments, and the partial dentition of one adult (Table A4). The total number of bone fragments is 359, which represents only 19 distinct bones. It is possible to assign a possible male sex to both individuals based on the size and morphology of the mastoid process (Ubelaker and Buikstra 1994). Age estimation is more problematic, but both individuals likely were mid- to old-age adults at the time of death based on their tooth wear and attrition (Ubelaker 1989 adapted in White 2000). Both of these assignments are tentative based on the highly fragmentary nature of the burial.

Wear estimates on teeth are variable, ranging from minimal to heavy wear on different teeth. The teeth likely came from the same individual, an observation based on tooth size and patterns of tooth loss observed in both mandible fragments. One individual probably lost all lower teeth antemortem. Only the alveoli for the right lower second incisor had not completely remodeled after the loss of the tooth. The second mandible also shows signs of significant tooth loss, though not to the extent of the other individual. A final observation is that the right first upper incisor also has type B4 dental filing (Romero 1970).

Multiple duplicate skull elements show the presence of two individuals, but further interpretation of the burials based on the inventory of the remains is difficult. It is possible that one individual was originally interred complete, based on the presence of one vertebra, two or more limbs, one metatarsal, and the skull. The second individual may have been represented by only a skull (or a skull and cervical vertebra). However, despite the fragmentation, the surfaces of some bones are very well preserved.

Table A4. Osteological inventory for Esperanza Burial 3: Op. 2d-1.

Element	Side	Age and sex	Detail	% complete	# bones	Notes
temporal	R	probable male adult	mastoid process	50-75	1	pronounced mastoid process
temporal	R	probable male adult	mastoid process	50-75	1	pronounced mastoid process
temporal	L	male adult	mastoid process	50-75	1	pronounced mastoid process
petrous pyramid	R	-		50-75	1	
petrous pyramid	L	-		50-75	1	
atlas	A	-		<25	1	
parietal	L	-		-	1	
orbit	L	-		-	2	
not identified	I	-	cranial, small shaft fragments	-	190	two fragments refit
mandible		-		-	1	edentulous: only second incisor could have remained in place
clavicle	L	-	shaft	50-75	1	
mandible	R	-		-	6	two fragments refit, antemortem tooth loss visible
cranial	I	-		-	89	multiple fragments refit
temporal	I	-	other fragments	-	3	

third molar	I	-	lower?	-	1	heavy wear (wear stage H-I)
third premolar	R	-	upper	-	1	bifurcated root. Light wear (wear stage C)
fourth premolar	R	-	upper	-	1	light wear (wear stage D)
canine	I	-	upper	-	1	light wear (wear stage C): distinct band present
premolar	I	-	lower	-	1	moderate to heavy wear (wear stage H?)
first incisor	R	-	upper	-	1	light wear (wear stage D) and modification type B4
canine	L	-	lower	-	1	light wear (wear stage C)
incisor	I	-	lower?	-	1	moderate wear (wear stage F)
limb	I	-	shaft of lower arm	<25	1	
shaft	I	-	metatarsal	-	1	
shaft	I	-	not identified	-	49	
first molar	R	-	lower	-	1	LARCH sample F5909: heavy wear (wear stage H)

2. Floral Park

Nine burials were identified in the Str. 2A, the eastern structure of the plazuela group northwest of the site's main ceremonial architecture. A total of ten individuals are identified, and all but Burials 1 and 2 were discovered in a platform added to a circular structure. These burials were found during excavation of the staircase leading to the main summit of the round structure. Burials at Floral Park are defined as deposits containing human remains (Brown et al. 1996), though several are single bones found in structural fill with no evidence for grave preparation or intentional placement. None of these deposits were sampled. The detailed burial context is described in Chapter 5, and three individuals were sampled for isotopic analysis (all the remains that included teeth).

2a. Floral Park Str. 2A: Burial 1 Op. 4a

Burial 1 is represented by 228 bone fragments that include cranial elements (parietal and occipital), fragments of both ulnae, and the right humerus, left tibia, right femur, left radius, and mandible (Table A5). Antemortem tooth loss and fusion of cranial sutures show that these are the remains of an adult, possibly one advanced in age. The linea aspera and gluteal lines of the femur are very rugose (see below). Multiple taphonomic processes affected bones, including rodents (gnaw marks), modern humans (trowel marks), and other unknown agents.

Table A5. Osteological inventory for Floral Park Str. 2A: Burial 1 Op. 4a.

Element	Side	Age and sex	Detail	% complete	# bones	Notes
parietal	L	Adult	-	25-50	3	refit and glued
parietal	I	-	-	<25	1	
ulna?	L	-	-	<25	1	
not identified	I	-	-	<25	80	
ulna	R	-	proximal at semilunar notch		3	2 refit
cranial	I	-	-	25-50	47	many refits, some sutures no longer visible
ulna?	R	-	-	<25	1	
humerus	R	-	distal	<25	2	
limb	I	-	shaft	misc	53	possibly femur and lower arm. multiple bone fragments refit and may represent tibia, ulna, and femur. Rodent gnawing visible on lower limbs.
tibia	L	-	shaft	25-50	5	trowel marks and rodent gnawing, along with deep gashes of unknown origin.
femur	R	-	-		18	refit and glued. Very rugose muscle attachments. Significant rodent gnawing damage.
occipital	I	-	-	25-50	10	refit and glued. Some sutures no longer visible
mandible	L	-	antero-distal portion with alveoli for I1,	25-50	2	2fragments refit (not glued). M1 missing and bone remodeled, P4 significant marginal loss, tooth no

			I2, C P3, P4, M2. No M3 alveoli noted.			longer well anchored, M2 shows remodeling of jaw associated with loss or pending loss of tooth.
radius	L	-	-	<25	2	glued

2b. Floral Park Str. 2A: Burial 2 Op. 4a

Burial 2 consists of only 20 fragments of the left femur, right tibia, one manual phalanx, and bone fragments embedded in a cement-like matrix (Table A6). A single molar is present and the tooth enamel was sampled for strontium, carbon, and oxygen isotopic values. The molar has moderate calculus buildup on the buccal surface and caries on mesial cementoenamel juncture. Moderate tooth wear on this single molar, along with the size of the well-preserved bones, suggests the remains belonged to an adult, possibly of mid-old age.

Table A6. Osteological inventory for Floral Park Str. 2A: Burial 2 Op. 4a2.

Element	Side	Age and sex	Detail	% complete	# bones	Notes
not identified	I	adult	not identified	-	1	bone fragments embedded in matrix
femur	L	-	shaft at foramen	<5%	1	
tibia	R	-	shaft	25-50%	4	Refit
first molar	R	-	upper	-	1	LARCH sample F5902. Wear stage H
Limb	I	-	shaft	<25%	9	several refits, may be femur
not identified	I	-	not identified	-	4	
manual phalanx	I	-	shaft	25-50%	1	

2c. Floral Park Str. 2A: Burial 3 Op. 2b

Burial 3 consists of fragmentary human remains that are interpreted as an offering associated with the second construction phase of the platform, and possibly a secondary burial (Brown et al. 1996:42). It consists of the shaft of one left humerus reconstructed from 13 fragments, some of which exhibit marks left by rodent gnawing, which was associated with a cache of three obsidian blades, a metate fragment, and ceramics (Table A7).

Table A7. Osteological inventory for Floral Park Str. 2A: Burial 3 Op. 2b-3.

Element	Side	Age and sex	Detail	% complete	# bones	Notes
humerus	L	-	shaft	>75%	13	

2d. Floral Park Str. 2A: Burial 4 Op. 4d

Burial 4 was disturbed by looter activities, and more remains are described in the excavation report than are identified in this analysis. The upper body was located in the disturbed area, and the identified remains include only the distal shaft of a femur and fragments of the lower limbs. There are 95 bone fragments (Table A8). One of the limbs exhibits an osteomyelitic reaction that is visible along the entire 18 cm long shaft, and two other fragments show evidence of a systemic infection. Each of the three limb shafts were reconstructed from small bone fragments, and it is unclear how many elements they represent. However, the field report describes the presence of both femora, both tibiae, a possible fibula fragment, a fragmentary skull, and other unidentified pieces. The orientation of this burial was north-south, and the body position is described as flexed. Carved slate and a miniature vessel accompanied the burial (Brown et al. 1996:42).

Table A8. Osteological inventory for Floral Park Str. 2A: Burial 4 Op. 4d-5.

Element	Side	Age and sex	Detail	% complete	# bones	Notes
femur	I	-	-	-	8	marked as femur fragment. Periostitis possible, surface poorly preserved
not identified	I	-	-	<1/4 in.	19	marked femur and tibia fragments
not identified	I	-	-	<1/4 in.	20	
limb	I	-	-	-	13	some refits: osteomyelitic reaction
limb	I	-	-	-	8	some refits, pathology noted
not identified	I	-	-	<1/4 in.	27	

2e. Floral Park Str. 2A: Burial 5 Op. 4d-5

Burial 5 is described as a secondary burial that was identified in structural fill. However, it did not form part of an intentionally-placed deposit (Brown et al. 1996). It consists of 93 bone fragments and includes a right tibial shaft, a possible femur, and fragments of the cranium that may have been part of a disturbed primary or secondary burial (Table A9).

Table A9. Osteological inventory for Floral Park Str. 2A: Burial 5 Op. 4d-5.

Element	Side	Age and sex	Detail	% complete	# bones	Notes
tibia	R	-	-	-	9	some bones refit and glued. Was marked as femur
cranial	I	-	-	-	6	
cranial	I	-	-	-	1	
not identified	I	-	-	-	1	
not identified	I	-	-	-	38	small shaft and other bone fragments

2f. Floral Park Str. 2A: Burial 6 Op. 4d-7

Burial 6 was associated with the second construction phase of the structure and was located beneath its summit. It was initially interpreted as the secondary burial of multiple individuals, consisting of long bones placed on a north-south axis with a cylinder jar, a ceramic figurine, and other ceramic fragments. Identification of two individuals is based on the presence of duplicate limb elements. Tooth enamel from one individual was sampled for strontium isotope values.

This burial includes the partial remains of one individual who likely was a complete, primary burial, and several limb bone fragments of a second individual. The remains are highly fragmented and include more than 1323 bone fragments (Table A10). Although many of the 900 bone fragments that are not identified are limb bone shafts, identified bones include the right radius, an ulna, two humeri, both femora and tibiae, the left fibula, elements of the hands and feet, and the nearly complete dentition of one individual. Duplicate elements include an additional right humerus and left tibia that belonged to a more robust, but not necessarily larger person. Only the shafts of the limbs are present, and bones that consist mainly of trabecular tissue, like vertebrae and cranial fragments, are completely absent.

The age of one individual can be estimated using tooth wear and development. Two of the third molars are present, and other teeth exhibit slight to moderate wear, suggesting an individual in the young adult age category (Ubelaker and Buikstra 1994). Observations on the nearly complete dentition include moderate wear, slight calculus buildup, and two caries. Enamel on the labial surfaces of the upper first incisor and all canines show some defects, but these were not recorded. The paired humeri are gracile and small in size, but with epiphyses missing from all bones, it is difficult to assign an age or sex to the individual. A previous analysis identified this individual as female: in this analysis, an estimate of possible female is used.

The second individual consists only of fragments of two long bones, including the right humerus and left tibia. It is only prudent to comment that this individual was more robust than the primary burial. No age or sex estimate is possible.

Table A10. Osteological inventory for Floral Park Str. 2A: Burial 6 Op. 4d-7.

Element	Side	Age and sex	Detail	% complete	# bones	Notes
not identified	I	-	-	<25% (1-3 cm)	130	includes limb shafts and a probable carpal
not identified	I	-	-	<25%	659	< 1x2 cm in size
limb	I	-	shaft	<25%	259	larger fragments, some refit
ulna?	I	-	-	<25%	3	ulna, probable refit
radius	I	-	-	<25%	5	radius, probable 5 refit
fibula	L	-	-	25-50	19	multiple refits
fibula	I	-	-	25-50	7	6 fragments refit
tibia	R	-	-	<25%	10	all refit
radius	R	-	-	25-50	8	7 refit and glued
femur?	I	-	shaft	<25%	28	
tibia	I	-	-	<25%	7	anterior crest

tibia	I	-	-	<25%	37	possible tibia
limb	I	-	-	<25%	15	
limb	I	-	-	<25%	7	multiple refits
ulna	R	-	-	25-50	15	14 fragments refit
tibia	L	-	-	25-50	1	1/2 shaft at anterior crest
tibia	L	-	-	25-50	8	Part of pair with below
tibia	R	-	anterior crest	25-50	10	Part of pair with above
femur	R	-	at nutrient foramen	25-50	15	
femur	R	-	-	<25	16	multiple pieces refit
femur	L	-	-	25-50	7	
humerus	L	-	-	50-75	4	gracile, part of pair with below
humerus	R	-	-	50-75	5	Part of pair with above. Also gracile, small size.
humerus	R	-	-	50-75	6	more robust
humerus	R	-	-	<25	1	fragment
metacarpal	I	-	-	25-50	4	epiphyses missing, probable identification. Four distinct bones
metatarsal	I	-	-	50-75	6	epiphyses missing, probable identification. Six distinct bones
manual first phalanx	I	-	shaft	50-75	2	epiphyses missing
hand/foot elements	I	-	-	25-50	8	epiphyses missing, probable ID. Six distinct bones
third molar	R	-	lower	50	1	roots missing: siding less certain wear stage D
second molar	L	-	lower	50	1	roots missing: identification less certain wear stage G
first molar	L	-	lower	>75	1	Wear stage F-G LARCH sample F5903.
second incisor	L	-	lower	complete	1	slight calculus buildup on labial and lingual surfaces. Wear stage C
third premolar	L	-	lower	complete	1	Wear stage B1 to B2
fourth premolar	L	-	lower	complete	1	Wear stage B1 to B2
canine	L	-	lower	Complete	1	slight calculus buildup on labial and lingual surfaces. Wear stage C.
canine	R	-	lower	complete	1	slight calculus buildup on labial and lingual surfaces. Wear stage C.
root	I	-	not identified	fragments	2	
third molar	L	-	upper	-	1	wear stage D-E
third premolar	R	-	upper	-	1	wear stage D
third premolar	L	-	upper	-	1	wear stage B2
fourth premolar	R	-	upper	-	1	wear stage C
fourth premolar	R	-	upper	-	1	wear stage B2

canine	R	-	upper	-	1	wear stage B2
first incisor	R	-	upper	-	1	wear stage A-B1
second incisor	R	-	upper	-	1	wear stage A-B1
second molar?	R	-	upper	-	1	wear stage H
first molar	L	-	upper	-	1	wear stage C
first molar	R	-	upper	-	1	wear stage E

2g. Floral Park Str. 2A: Burial 7 and 8 Op. 4d-11

Burials 7 and 8 are single bones deposited in structural fill without prepared graves or associated burial goods (Brown et al. 2006:43). Burial 7 includes one unidentified limb shaft fragment and Burial 8 includes 16 upper left femur fragments (Tables A11 and A12). Burials 6, 7, 8, and 9 were located in close proximity, but their relationship is not described.

Table A11. Osteological inventory for Floral Park Str. 2A: Burial 7 Op. 4d-11.

Element	Side	Age and sex	Detail	% complete	# bones	Notes
limb	I	-	shaft	<25	1	includes limb shaft fragments

Table A12. Osteological inventory for Floral Park Str. 2A: Burial 8 Op. 4d-11.

Element	Side	Age and sex	Detail	% complete	# bones	Notes
femur	I	-	proximal shaft	25-50	16	includes limb shaft fragments

2h. Floral Park Str. 2A: Burial 9 Op. 4d-12

Burial 9 contains the partial remains of a single individual who was interred in a cyst placed in the summit of the Str. 2A-2nd sometime after it was built. The body lay in a prone position, with the head oriented to the south and facing down or west. No grave goods were noted. The 684 bone fragments represent parts of nearly the entire skeleton, including both humeri, ulnae, radii, and femora, the right tibia, and fragments of the spine and rib cage, hand, and skull, including the nearly complete dentition of an adult (Table A13).

Moderate wear on the canines and incisors corresponds to that of a young adult, but each of the incisors is filed at a slight angle. Wear is greater on the premolars and molars, and antemortem tooth loss suggests an older age estimate. A single attribute on the mandible suggests a possible female assignment for this burial, but one that is not supported by additional traits.

Table A13. Osteological inventory for Floral Park Str. 2A: Burial 9 Op. 4d-12.

Element	Side	Age and sex	Detail	% complete	# bones	Notes
humerus	L	-	shaft, distal	50	14	
humerus	R	-	shaft	50 -75	13	
radius	L	-	shaft, distal	50	1	
rib	I	-	shaft	< 25	1	
phalanges, manual	I	-	shaft	50 -75	4	no epiphyses
clavicle	L	-	shaft	>75	1	no epiphyses
atlas	A	-	facets	25-50	2	probable identification
ulna	R	-	shaft, proximal	25-50	1	
metacarpals	I	-	shaft	50 -75	3	3 elements
ulna	L	-	shaft	50	3	
radius	R	-	shaft	50	3	2 refit
cranial		-	-	-	83	includes parietal, frontal at orbit, mastoid process fragment: multiple refits
femur	R	-	shaft	50-75	5	
femur	L	-	shaft	50	62	
mandible	L	probable female	mental eminence	50-75	2	antemortem loss of at least 1 molar on left side
not identified	I	-	-	-	54	may include tibia
not identified	I	-	-	-	29	hand or foot elements present (shaft fragments)
not identified	I	-	limb shafts	-	136	multiple refits: lower arm elements present
first incisor	R	-	upper	-	1	wear stage C
first incisor	L	-	upper	-	1	wear stage C
second incisor	R	-	upper	-	1	wear stage B1
second incisor	L	-	upper	-	1	wear stage B1
canine	L	-	upper	-	1	wear stage B2-C
molar	I	-	lower	-	1	LARCH sample F5904
molar	I	-	-	-	1	may be M3
canine	R	-	lower	-	1	wear stage C-D
canine	L	-	lower	-	1	wear stage C-D
roots	I	-	-	-	2	

first incisor	L	-	lower	-	1	wear stage C
first incisor	R	-	lower	-	1	wear stage C
second incisor	L	-	lower	-	1	wear stage C
second incisor	R	-	lower	-	1	wear stage C
third premolar	L	-	lower	-	1	wear stage D also note band – hypoplasia
third premolar	R	-	lower	-	1	wear stage D also note band - hypoplasia
third premolar	L	-	upper	-	1	wear stage F distinct band/growth defect
third premolar	R	-	upper	-	1	wear stage F distinct band/growth defect
fourth premolar	I	-	not identified	-	1	
tibia	R	-	shaft, other	-	11	multiple refits, includes cranial and vertebrae fragments
vertebrae	A	-	-	-	1	
not identified	I	-	-	-	235	was included with tibia but consists of other limbs and cranial elements

Twenty two additional bone fragments were identified in four different excavation units, including a human cranial fragment and burned limb bones that likely are whitetail deer.

3. Blackman Eddy

One burial was recovered from Str. A4, a tripartite structure on the east side of Plaza A, during 1990 excavations by the Belize Valley Archaeological Project (BVAP). The burial was discovered as a looter's trench was cleaned and consists of one adult interred with another adult and a child (Garber et al. 2004). The burial context is described in Chapter 5, and each of the three individuals is included in the strontium isotope analysis.

3a. Blackman Eddy Str. A4: Burial 1 Op. 2c

Burial 1 includes 486 bone fragments that represent the partial remains of one individual (Table A14). The brow ridge is pronounced and suggests a male individual, while antemortem tooth loss and remodeling of the mandible suggests an individual older than a young adult.

However, the more conservative adult age and indeterminate sex are used. Portions of both the appendicular and axial skeleton are present, including ribs, vertebrae, and both scapulae. However, less than 25% of each of these identified elements remains. Very fragmentary remains of the hands or feet also are present, along with only the shafts of long bones, suggesting that the individual is a poorly preserved - but complete - burial.

Table A14. Osteological inventory for Blackman Eddy BME 2c Burial 1.

Element	Side	Age and sex	Detail	% complete	# bones	Notes
parietal	L	I	-	50-75	1	
temporal	L	I	petrous pyramid	50-75	2	
temporal	L	I	zygomatic process	25-50	1	
cervical vertebrae	A	I	body and fragment of transverse process	<25	1	
thoracic vertebrae	A	I	4 vertebrae	25-50	5	
molar	R	A	possibly LM1	comp	1	LARCH sample F5907
vertebrae	A	I	fragments	<25	8	at least 2 vertebrae (did not refit).
vertebrae	A	I	fragments	<25	12	
temporal	R	I	at articulation with mandible	25-50	1	poor preservation.
mandible	R/L	I	-	50-75	5	remodeling visible in right alveoli and at least one left molar lost antemortem with complete resorption. Prominence and angularity of the mental eminence, along with the narrow body, suggests that jaw remodeled as reaction to tooth loss.
zygomatic	R	I	-	50	1	
frontal	A	I	at brow ridge	50	1	very prominent brow ridge and it appears that metopic suture still visible.
cranial	I	I	not identified	25-50	17	
scapula	I	I	glenoid process	<25	2	

manual phalanx	I	I	distal shaft	50-75	1	
humerus	R	I	shaft	>75	2	
humerus	L	I	shaft	~50	3	
humerus	I	I	shaft	~25	1	probable identification
femur	R	A	shaft	50-75	20	
not identified	I	I	with lower leg	<25	22	
fibula	I	I	shaft	<25	2	
not identified	I	I		<25	6	possibly lower arm fragments
rib	I	I	shaft	<25	14	probable identification
tibia	I	I	shaft	<25	2	2 refit. Multiple fragments are right tibia
not identified	I	I	many are limb fragments	<25	47	
limb	I	I	limb shaft	<25	2	
not identified	I	I	shafts fragments	<25	4	includes probable metatarsal shaft
limb	I	I	limb shaft	<25	2	refit
not identified	I	I	mostly limb shafts	<25	300	approximate count. Preservation is highly variable. Some surfaces are well-preserved and others very worn and eroded.

3b. Blackman Eddy Str. A4: Burial 2 Op. 2c

One individual is represented by 113 bone fragments that include two humeri, two clavicles, an incomplete and fragmentary skull, vertebrae, scapulae, and fragments of a tibia (Table A15). Some of the bones were intermingled with those in Burial 3 and are described below. It is not possible to estimate sex, but an age can be assigned based on the presence of two permanent molars that were not fully developed at the time of death. These suggest an age of 3.6 - 6.4 years.

Each of the bones is represented by only a partial diaphysis, so age is estimated using the size and development of the clavicles and the radius, which suggest a subadult individual. However using long bones to estimate age in this burial context is problematic because it appears that the bones from Burials 2 and 3 are comingled. For example, the left tibia and right femur in Burial 2 are larger than other elements, and it seems likely that they do not belong to this individual. This is important because the bones were used for collagen and apatite assays, although the isotope values for both burials are sufficiently similar that interpretations should not be affected by potential sampling confusion.

Table A15. Osteological inventory for Blackman Eddy Str. 4A: Burial 2 Op. 2c.

Element	Side	Age and sex	Detail	% complete	# bones	Notes
ulna	L	I	shaft	25-50	3	
radius	L	I	proximal shaft, radial tuberosity	<25	2	
limb shaft	I	I	shaft	<25	9	these were included in radius bag: one is likely not limb shaft
not identified	I	I	not identified	<25	1	these were included in radius bag: one is manual phalanx
limb	I	I	shaft	<25	41	three fragments refit
femur	L	I	shaft	25-50	25	multiple fragments refit
metatarsal	I	I	shaft	25-50	1	probable identification
limb shaft	I	I	shaft	<25	11	
not identified	I	I	includes vertebrae	-	50	
first lower molar	R	C	complete	100	1	LARCH sample number F5906. Roots 3/4 developed
first upper molar	R	C	complete	100	1	no wear. Roots 1/2 developed
not identified	I	I	not identified	<25	0	
tibia	L	I	shaft	50-75	12	4 fragments refit.
femur	R	I	shaft	50-75	2	surface heavily eroded
not identified	I	I	not identified	-	5	
clavicle	L	I	shaft	50-75	2	both fragments refit
clavicle	R	I	shaft	50-75	2	both fragments refit
rib	R	I	shaft	<25	1	
rib (first)	L	I	shaft	<25	1	
rib	I	I	shaft	<25	2	
temporal	R	I	EAM, petrous pyramid	-	2	both fragments refit
cranial	I	I	various	<25	35	2 fragments refit. Bag labeled ‘skull’

3c. Blackman Eddy Str. A4: Burial 3 Op. 2c

One individual is represented by 303 bone fragments, which comprise a partially-preserved skeleton that likely was the burial of a complete individual (Table A16). The bones identified as Burial 3 include elements of the cranium, ribs, right ilium, left upper arm, and both lower arms and legs. An assignment of sex was not made due to the poor preservation, incomplete nature of the bones, and the likely mixing of elements between Burials 2 and 3. For example, two left humeri shafts are present: one is a poorly preserved adult-sized bone, and the other a well-preserved, child-sized shaft that is nearly complete and probably belongs with Burial 2. The left radius is larger than that of Burial 2, as is one left ulna. Like the two distinct humeri, the larger left ulna has an eroded surface that contrasts with the shaft surface of the smaller one.

The age estimation, as in Burial 2, is based on the development and wear of the two teeth present in the burial. Both are fully developed and have minimal wear. Almost none is visible in on the premolar, and slight wear on the second mandibular incisor suggests bracketing age categories of adolescent to young adult (Ubelaker 1989 in White 2000).

Table A16. Osteological inventory for Blackman Eddy Str. 4A: Burial 3 Op. 2c.

Element	**Side**	**Age and sex**	**Detail**	**% complete**	**# bones**	**Notes**
Ribs	I	I	shaft	<25	20	less than 1 rib
Ilium	R	I	-	<25	15	
cranial	I	I	-	<25	40	
vertebrae	A	I	-	25-50	26	minimum of 4 vertebrae
not identified	I	I	Not identified	<25	12	
radius	L	A	proximal shaft	50-75	2	
radius	R	I	shaft	50-75	8	
fibula	I	I	shaft	50-75	10	bag marked as fibula
not identified	I	I	not identified	<25	34	many limb shaft fragments
ulna	L	I	shaft	25-50	7	from bag marked as right ulna. Larger than the other ulna and comes from different individual
limb	I	I	shaft	<25	2	

ulna	L	I	proximal shaft	25-50	11	this is a smaller individual. Bone is well preserved, including the surface.
humerus	L	I	shaft	25-50	9	bone is from a larger and more muscular individual than the other humerus of the same side
humerus	L	I	shaft	25-50	8	This is the smaller individual with the size of the bone suggesting age of child.
femur	L	I	shaft	50-75	18	
femur	R	I	shaft	25-50	1	
tibia	R	I	shaft and other	<25	46	
tibia	L	I	shaft	25-50	32	central shaft at anterior crest
second incisor	L	A	lower	100	1	
fourth premolar	L	A	lower	100	1	LARCH sample F5905

D. Curation

Curation of skeletal materials is not normally discussed in publications. It more frequently forms part of the discourse in museum studies, but remains a side note in the archaeological literature, if it is mentioned at all. The main focus during fieldwork is on collecting data within short timeframes and with limited budgets, followed by analysis and publication that have to fit into already crowded academic calendars. Curation merits more attention than it receives. Not only did it form an important part of this study, but the burials excavated by multiple projects at more than 17 distinct sites in Belize Valley provide a snapshot of curation practices in Maya archaeology today. The condition of the nearly 200 burials observed during this study show how storage needs in tropical environments present special challenges for which few guidelines exist.

In fact, it is important for Mayanists to begin a formal discourse about curation practices. Not only because poor handling and care of human remains might limit DNA and other scientific analyses in the Maya region (Wright 2006), but because there is growing indigenous concern over care and control of archaeological heritage in Latin America. Most controversy about ownership of cultural patrimony revolves around the antiquities trade and looting, but reclamation and reuse of ancient sites by modern Maya is becoming more commonplace (e.g., Dart 2010). Careful stewardship of human remains is a critical investment for the future of archaeology in Latin America, not only to ensure that the collections are preserved for ongoing studies, but as an ethical principle that archaeologists agree to when joining professional organizations, like the Society for American Archaeology.

The return of looted objects from museums is an ongoing concern, but debate over ownership of cultural knowledge and sacred objects is gaining momentum. One example is the return, or repatriation, of a decades-old ethnography to the Jakaltek Maya (Montejo 1999). For the most part, indigenous concerns reflected in NAGPRA and similar legislation in North America are not currently contested political issues between archaeologists and Maya communities. However, a proposed sacred sites law (Dirección Legislativa Número de Registro 3835) in Guatemala has potentially broad implications. According to Linda Brown (personal communication 2010; Maxwell n.d.), its implications could be broad, extending to both private and public land, and including constructed and natural areas where the remains of the ancestors are buried. Archaeologists must avoid the appearance of neglect and show that we are responsible caretakers of these scarce and valued resources.

1. Principles of curation: the theory and practice of preservation, conservation and restoration

Any plan for care of artifacts must consider storage materials, treatment of the artifacts, storage and access, and recordkeeping. Archaeologists must devise plans that include multiple stages, including field laboratory, storage, and research facilities in more than in country or continent. Three basic principles govern each of these stages (e.g., Sease 1994). First, handle the objects carefully. Second, minimize handling of the objects. And third, use the minimal treatment possible and make a record of it. At first glance, these ideas seem simplistic to the point of stating the obvious. But many projects fail to meet at least two of the three basic guidelines.

Sease (1994) recommends that projects have a conservator, but in reality, this is not financially feasible for most projects. However, simple mishandling of fragile remains may be the most common problem (Ward 1989). For example, fragile items should be transported using methods that prevent further deterioration (Sease 1994). Bones transported from the field with heavy ceramics and lithics causes immediate damage. Objects also are often handled multiple times, including screening, washing, sorting, and initial counting and weighing, before fragile items are given special treatment. Objects like beads and bones are easily damaged at each of these stages if not separated when initially discovered.

While most scholars attempt to use treatments they consider reversible, this is not possible if future researchers are not aware of what needs to be reversed. In fact, no treatment is fully reversible (Ward 1989). All leave either some trace after removal or react with the original material and cause permanent change (Ward 1989). Chemical assays are becoming more common and the effects of even the most standard chemical applications are not fully understood. Archaeologists excel at recording data, but rarely keep records of treatment applied to bone during preservation or reconstruction efforts, during excavation and/or laboratory analysis. Nor are copies of records maintained with the collection.

Tropical environments present special curation challenges. They include nearly all of the most common factors that contribute to deterioration of organic objects, including acidic soils, strong light, high temperatures and humidity, as well as damage from mishandling, plants, insects, and animals (e.g., Ogden 2004; Ward 1989). But deterioration is not inevitable, and a relatively simple preventative conservation plan can effectively mitigate some of the problems. A description of basic curation techniques for each stage of analysis is followed by specific details on care of the human remains that formed part of this project.

2. Curation in tropical environments

2a. In the Field

Most projects do not have a full-time conservator and may lack on-site support from a paelobotanist or zooarchaeologist trained to work with perishable items, so the main goal is to arrest deterioration of the artifacts (Sease 1994). This is achieved through careful handling, and by minimizing treatment of artifacts, even reversible ones. Bone may require special conservation procedures in the lab and should be done in consultation with the osteologist or faunal specialist. Conservation, however, differs from restoration. Restoration is repair of damage that already has occurred. It may be undertaken when the object is structurally unstable and should only occur to prevent further deterioration (Chevallier and Dunning 2009; Moreno et al. 2009; Ward 1989). Conservation preserves the object in its existing state.

It is prudent to train staff to refrain from cleaning artifacts in the field. Bone and other fragile objects should be packaged, packed, and transported separate from other objects like ceramic or lithic materials. The use of inner and outer tags for every bag is a safeguard against loss of contextual information, and some projects enclose the inner tag in plastic to prevent moisture damage from obscuring data on provenience. While common sense and the mode of transportation dictates the extent to which secure, shock absorbent packaging is needed, this responsibility is best placed with a supervisor.

If a specialist is not available during the excavation, mapping each bone in burials and special-use contexts can prevent a loss of information between the field and the lab. Taphonomic processes must be considered as part of all research questions, and assumptions that bones are in anatomical position often are incorrect. Excavators often identify complete, but poorly preserved, burials as secondary ones because skull and long bone fragments are easy to identify and portions of the axial skeleton go unrecognized.

2b. In the Lab

Conservation in the field lab is often the only treatment an artifact receives, so artifacts should be prepared for long-term, rather than temporary, storage (Sease 1994). Many artifact classes are analyzed years or decades after the excavations are complete, and are placed in storage facilities that lack both a curator and regular maintenance plan. Curation principles for laboratory processing fall into three main categories: artifact treatment, handling procedures, and packaging.

The general principle is that what is done must be undone. In fact, the most common treatments come undone by themselves, leaving irreversible damage. For example, glues used in reconstruction often break down within just a few years. Duco, a household cement, dries and becomes brittle, breaking bone at the edges of the join. Chemical changes occur in white glues and polyvinyl acetates (PVAc), which are unstable in hot temperatures (Sease 1994). Both result in long-term chemical changes in the bone. This creates a dilemma for lab staff and specialists, who often must process highly fragmented bones that are wrapped in foil, and surrounded by matrix and other organics that will cause further deterioration. The specialist should decide whether the joins can be “mapped” without excessive labeling or loss of information, or whether the piece merits reconstruction despite the eventual damage adhesives cause. If not, measurements can be obtained using temporary fixatives like Parafilm and documented with photos and drawings.

The most basic procedure for bone and other artifacts in the lab is washing, and because it is so common, there is little documentation. Cassman and Odegaard (2007c) note that cleaning is one of the most invasive interventions of artifacts, and is an irreversible action. What is removed should be documented, along with what solvents are potentially added. Even water can alter the chemical structure of the object by bringing salts to the surface during drying, or introducing elements like calcium and magnesium present in groundwater.

The main goal is to ensure that the bone is completely dry before storage, and is as free of dirt and other organic materials as possible (with the exception of unique circumstances like waterlogged or salt-laden materials). A plan for cleaning should be made in consultation with an osteologist who is familiar with the current condition of the materials. Several pieces should then be tested to ensure that brushes do not damage fragile surfaces, and that the bone does not dissolve in water. The fragments should never be fully immersed in water and should be handled as little as possible. Gloves are recommended so that artifacts are not handled with bare hands. Soft brushes (not toothbrushes) can be used if they do not damage the materials. Likewise, even wood tools used instead of metal can leave marks on fragile objects. All materials should be tested because conditions of bones can vary even within the same context.

Foil or paper products used in the field should be replaced with archival quality plastics, as should cheap bags which give off hydrochloric acid in damp conditions and break down rapidly. Likewise, paper products are acidic and encourage the breakdown of organic materials (Sease 1994). Polyethylene 4 mil bags are recommended (Moreno et al. 2009), and 2 mil bags also can be used with additional packaging.

Paper field tags should be replaced with long-lasting material like Tyvek (polyethylene) paper, and markers should be of permanent, archival quality. While some conservationists see labeling individual pieces as a necessity (Cassman and Odegaard 2007b), bones require special consideration. Labels, adhesives, and other additives may be considered inappropriate treatment in many descendant communities (Sadongei and Cash 2009). Safeguards against loss of context include identifying bones by weight or photos, or use of temporary fixatives like parafilm.

Drawers and containers should be lined with protective cushion, like 1/8" polyethlylene padding. While toilet paper or paper towels may be readily available, both disintegrate quickly and are not appropriate for a humid environment. Cotton may serve as a temporary padding, but is perishable and should be used with caution (Odegaard and Cassman 2007). Cotton also catches on the exterior and edges of bones and may cause additional flaking where surfaces are poorly preserved. In addition, small items may be inadvertently damaged or lost during handling when containers are opened and the object becomes entangled in the cotton as it is pulled out.

For example, cotton is often used to wrap items in small plastic containers (e.g., film canisters) that provide a hard protective shell. The artifact(s) should first be placed in a polyethylene bag, and then may be wrapped temporarily with cotton, or preferably with an archival quality padding, within the canister or container. For larger objects, storage mounts are an alternative padding and should replace newspaper and other perishable items often used to wrap stone or ceramic objects. Other less frequently used storage materials, like glass, pose the obvious danger of breakage and loss of context. These are more frequently found in storage of older excavation materials, but can be replaced with snap-top polyethylene plastic vials for long-term storage.

Acid-free papers, cloth, and boxes are the norm in climate-controlled storage that is monitored for pests and other environmental damage. However, they not only break down quickly in tropical environments, but provide no protection if flooding occurs and do not prevent the damage by mold or animals. Plastic air-tight containers provide the safest storage.

Finally, it is common for field or lab staff to run short of time and leave artifacts to be processed during the following field season. Allowing extra time for lab work is a good preventative measure, as is prioritizing processing of perishables. Damp bone, even packed in breathable fabric or bags, will attract mold and other pests, which may cause permanent damage and the deterioration of the bags, labels, and contextual information. Less damage may occur if the object is left for excavation during the following field season.

2c. Storage facilities

Establishing appropriate facilities is a challenge where money is limited, but creating stable micro-environments for sensitive material is a realistic possibility. Simple modifications to existing storage facilities provide alternatives to climate controlled environments. First, storage specific relative humidity (RH) is essential for organics. Relative humidity should be between 30-55%, fluctuating less than 15% (Storch 2004). At a relative humidity of >65%, mold can grow and cause irreparable damage, with an ideal temperature of 68 degrees $\pm$ 3 degrees

(Ambrose and Payne 2007). Objects should not be placed directly on floors to avoid damp conditions, and adequate ventilation can include use of window fans. Storing objects away from heat and light sources also prevents localized environmental fluctuations (Ambrose and Payne 2007; Moreno et al. 2009). The goal is to stabilize temperature and relative humidity, which can be monitored using a simple hygrometer that costs $7 (Cassman and Odegaard 2007a; Ward 1989).

2d. Maintenance and use of collections

Periodic condition assessments are needed to track changes in condition that may require intervention to arrest further deterioration. Assessing the current state of burials, however, is distinct from undertaking research or the basic processing performed in field laboratories (Cassman and Odegaard 2007a). Three types of deterioration processes can affect bone: 1) physical stressors such as breakage or animal damage, 2) chemical processes, like temperature and humidity fluctuations or conservation/restoration treatment processes, or 3) biological ones like growth of bacteria, mold or insects. The frequency of assessments depends on storage conditions and the amount of artifact handling that occurs. While not all problems can be immediately mitigated, the assessment will help to set priorities for future care and treatment.

Storage space also can serve to facilitate research needs. Adequate access is part of permanent curation planning, as is centralized recordkeeping, including a permanent lab facility (Chevallier and Dunning 2009; Green and Meister 2009). In addition, clear plastic bags with clear labeling can minimize damage caused by handling.

2e. Destructive analysis

Despite the extensive discussion of artifact preservation, isotopic analyses are destructive. Therefore multiple strategies are needed to retain as much of the data as possible because future researchers may have very different research questions. This includes close collaboration with project directors, osteologists, and lab managers, as well as collection of morphometric data, creation of visual and physical records like photographs and dental impressions, and use of procedures that minimize damage to the tooth during the sampling process. Each of these steps preserves extra information, but also may cause additional damage to the tooth.

In addition to museum and/or project records of the samples selected for analysis, a Tyvek tag should replace the sample removed, clearly describing the sample, researcher name and affiliation, and date. Other changes, like replacing bags or tags during the curation process, can be documented in a similar manner.

3. Curation of human remains in Belize

Human remains included in this project were affected by nearly every factor that can contribute to deterioration of bone, including flooding, moisture, mold, bats, birds, insects, acidic storage, and deteriorating storage materials. In some cases, temporary packaging, like use of foil to preserve the anatomical features of a bone, became permanent storage material. As a result, burials in broken bags and foil became mixed, and bones left in contact with dirt deteriorated or grew mold, as did those that had not completely dried before being packaged.

Animal pests also were a problem. Damage by bats was minimized through use of well-sealed buckets and high-quality plastic bags that create stable micro-environments that kept out animal pests as well as humidity. However, maintenance efforts are ongoing, and include rehousing materials as storage containers wear out and consolidating burials in a single location. Developing a centralized recordkeeping system to track ongoing curation and research is a logical next step.

This study included informal evaluations of curation conditions for Xunantunich, San Lorenzo, and Chaa Creek burials from the Xunantunich Archaeological Project (XAP) and the Tourism Development Project (TDP). All deteriorating materials were replaced, and the containers were cleaned. Some crania are still stored with associated matrix, but the condition appears stable until another condition evaluation can take place. In addition, some Cahal Pech and Baking Pot burials were rehoused on an as-needed basis. This work was done in conjunction with Jennifer Piehl, with the kind permission of Dr. Jaime Awe and the Belize Institute of Archaeology staff, as well as Cahal Pech Museum staff. Additional curation activities are ongoing.

E. Conclusion

Archaeology results in both the destruction of the contexts excavated and the preservation and dissemination of knowledge about the past. As new methods are developed to obtain information using perishable materials, it is especially important to preserve what is a non-renewable resource. Curation is an important aspect of archaeological research, but one that receives less attention than it deserves. Data from large excavations might not be analyzed for more than a decade, so planning for new projects needs to include permanent plans to maintain and conserve the materials.

Burials present an especially sensitive question. However, proper treatment is not just a question of ethics, but one of practicality. Many recent archaeological innovations entail analysis of the human body, including DNA and bone chemistry, and data can only be retrieved from well-handled specimens. In some areas, like North America, studies of human remains increasingly rely on existing collections. Multiple studies of the same materials will augment the need for proper handling and recordkeeping policies that minimize damage to the materials.

Handling of human remains, however, is also an ethical concern. Archaeologists often are welcomed into descendant communities, and their responsibility to curate materials does not end once the paper or dissertation is published. Human remains are not just specimens or artifacts: they were people. Treating the skeletal materials with care is part of the ethical obligation of the biological anthropologist (Alfonso and Powell 2007), and while the current social context of archaeology varies, a researcher's ethical responsibilities do not.

Appendix B Strontium Isotope Baseline Values of Fauna and Plants

Table B1. Strontium isotope plant and animal sample values and collection information: detailed descriptions of the sites and strontium zones in the study are provided in Chapter 4.

Strontium zone	Collection location	$^{87}Sr/^{86}Sr$	Sample description	LARCH lab number	Location detail (zone 16)
Central / Southern Lowlands	Southern Belize Blue Creek (modern town)	0.707444	river snail shell *(Pachychilus indiorum)*	F4524	281698, 1792066
Belize River	Central Belize Valley, south of Saturday Creek (archaeological site)	0.707572	shell (terrestrial species)	F4939	308073, 1913386
Central Lowlands	Vaca Plateau Caracol (archaeological site)	0.707630	land snail shell *(Neocyclotus* sp.*)*	F4521	273753, 1854383
Central Lowlands	Vaca Plateau Caracol Road	0.707712	iguana bone (Iguanidae)	F1755	280732, 1862863
Central Lowlands	Cretaceous limestone at Roaring Creek	0.707768	river snail shell *(Pachychilus indiorum)*	F3384	303043, 1894443
Central Lowlands	Vaca Plateau San Antonio (modern town)	0.707863	opossum bone (Didelphidae)	F1754	284791, 1889275
Belize River	Upper Belize Valley western highway, near San Lorenzo and Chaa Creek (archaeological sites)	0.708208	shell (terrestrial species)	F5276	276023, 1892227
Belize River	Central Belize Valley, Western Highway	0.708219	toad (Bufonidae)	F5278	305063, 1905607
Belize River	San Pedro Siris (archaeological site)	0.708252	land snail shell *(Neocyclotus* sp.*)*	F4525	288402, 1920784
Belize River	Upper Belize Valley Buenavista (archaeological site)	0.708285	cow tooth enamel *(Bos taurus)*	F4526	1895200, 273250
Belize River	Upper Belize Valley Cristo Rey (modern town)	0.708320	opossum bone (Didelphidae)	F4527	282102, 1895200
Belize River	Upper Belize Valley Arenal (archaeological site)	0.708342	lizard bone *(Basiliscus vittatus)*	F4941	276836, 1882948
Belize River	Caves Branch (archaeological site/modern resort)	0.708366	land snail shell *(Neocyclotus* sp.*)*	F4520	321643, 1900085
Belize River	Central Belize Valley, Western Highway	0.708380	snake bone (*Spilotes pullatus)*	F5274	298473, 1905421
Belize River	Central Belize Valley, Caracol Farms, on Western Highway	0.708397	opossum bone (Didelphidae)	F1751	286372, 1902758
Belize River	Upper Belize Valley Succotz (modern town)	0.708477	iguana bone (Iguanidae)	F1753	272103, 1890417
Belize River	Upper Belize Valley Western Highway	0.708527	toad bone (Bufonidae)	F5277	284804, 1900796
Belize River	Spanish Creek	0.708615	Anura bone	F4938	327614, 1939737
Belize River	Upper Belize Valley San Lorenzo (archaeological site)	0.708629	land snail shell *(Neocyclotus* sp.*)*	F5275	273316, 1891806

Strontium zone	**Collection location**	**$^{87}Sr/^{86}Sr$**	**Sample description**	**LARCH lab number**	**Location detail (zone 16)**
Belize River	Upper Belize Valley Trek Stop (business near modern town of Succotz)	0.708719	armadillo bone *(D. novemcinctus)*	F1752	272103, 1890417
Belize River	Central Belize Valley, south of Saturday Creek (archaeological site)	0.708820	rabbit bone *(Sylvilagus* sp.*)*	F4940	0308073, 1913386
Belize River	Ladyville (modern town)	0.708912	iguana bone (Iguanidae)	F1750	362966, 1941958
Macal River	Lower Macal Valley Chaa Creek (archaeological site)	0.708942	land snail shell *(Neocyclotus* sp.*)*	F5272	277612, 1892312
Belize River	Central Belize Valley Saturday Creek (archaeological site)	0.709077	opossum bone (Didelphidae)	F5273	310807, 1914565
Macal River	Lower Macal Valley Chaa Creek (archaeological site)	0.710373	land snail shell *(Neocyclotus* sp.*)*	F5271	277949, 1892212
Macal River	Lower Macal Valley Martz Farm	0.710653	land snail shell *(Neocyclotus* sp.*)*	F4943	281103, 1881143
Maya Mountains	Blue Hole	0.711136	land snail shell *(Neocyclotus* sp.*)*	F4942	320884, 1899551
Maya Mountains	Upper Macal Valley Guacamayo Bridge	0.711414	river snail shell *(Pachychilus indiorum)*	F4523	282759, 1865966
Maya Mountains	Upper Macal Valley Guacamayo Bridge	0.711755	river snail shell *(Pachychilus indiorum)*	F3385	282759, 1865966
Maya Mountains	Roaring Creek	0.713917	river snail shell *(Pachychilus indiorum)*	F4522	303043, 1894443
Maya Mountains	Hummingbird Community (modern town)	0.715170	tree seed pod (species not identified)	F4933	0331818, 1886422
Maya Mountains	Mountain Pine Ridge	0.716212	toad bone (Bufonidae)	F4934	292650, 1886003
Maya Mountains	St. Margaret (modern town)	0.716847	opossum bone (Didelphidae)	F4932	327536, 1890212
Maya Mountains	Mountain Pine Ridge	0.724951	toad bone (Bufonidae)	F4935	290381, 1879762
Maya Mountains	Mountain Pine Ridge logging road	0.725520	pine cone (species not identified)	F4936	293619, 1879712
Maya Mountains	Mountain Pine Ridge logging road	failed	pine cone (species not identified)	F4937	298980, 1880074

Strontium zone	Location	$^{87}Sr/^{86}Sr$	Sample	LARCH	Location detail (zone 15)
No zone defined	Chiapas Highlands San Cristobal de las Casas	0.707394	shell (terrestrial species)	F2964	538773, 1848614
No zone defined	Chiapas Highlands San Cristobal de las Casas	0.707651	shell (terrestrial species)	F2966	538773, 1848614
No zone defined	Chiapas Highlands San Cristobal de las Casas	0.707747	shell (terrestrial species)	F2965	538773, 1848614
No zone defined	Central Depression, Chiapas Chiapa de Corzo	0.706584	river snail shell *(Pachychilus indiorum)*	F2971	498951, 1847289
No zone defined	Central Depression, Chiapas Chiapa de Corzo	0.707363	river snail shell *(Pachychilus indiorum)*	F2970	498951, 1847289
No zone defined	Central Depression, Chiapas Chiapa de Corzo	0.707392	river snail shell *(Pachychilus indiorum)*	F2972	498951, 1847289
No zone defined	Central Depression, Chiapas Chiapa de Corzo	0.707481	river snail shell *(Pachychilus indiorum)*	F2976	498951, 1847289
No zone defined	Central Depression, Chiapas Mirador, Chiapas (archaeological site)	0.707177	river snail shell *(Pachychilus indiorum)*	F3360	461224, 1824404
No zone defined	Central Depression, Chiapas Mirador, Chiapas (archaeological site)	0.707201	river snail shell *(Pachychilus indiorum)*	F3361	461224, 1824404
Western lowlands	Western lowlands Yaxchilan (archaeological site)	0.708188	land snail shell *(Neocyclotus sp.)*	F3288	715498, 1871905
Western lowlands	Western lowlands Yaxchilan (archaeological site)	0.708222	land snail shell *(Neocyclotus sp.)*	F3287	715498, 1871905
Western lowlands	Western lowlands Bonampak (archaeological site)	0.707701	river snail shell *(Pachychilus indiorum)*	F3290	676454, 1862225
Western lowlands	Western lowlands Bonampak (archaeological site)	0.707727	river snail shell *(Pachychilus indiorum)*	F3289	687899, 1870348
Pacific Coast	Pacific Coast, Chiapas Ojo de Agua (archaeological site)	0.704628	cow tooth enamel *(B. taurus)*	F2980	565331, 1647413
Pacific Coast	Pacific Coast, Chiapas Izapa (archaeological site)	0.704663	Caprinae tooth enamel	F2979	589693, 1647549
Pacific Coast	Pacific Coast, Chiapas Paso de la Amada (archaeological site)	0.704771	cow rib *(B. taurus)*	F2978	555949, 1646180
Pacific Coast	Pacific Coast, Chiapas Chilo (archaeological site)	0.705100	shell (terrestrial species)	F2977	555492, 1649375
No zone defined	Pacific Coast, Chiapas Pijijiapan (modern town)	0.707213	dog tooth enamel *(C. familiares)*	F2975	477416, 1735555
No zone defined	Pacific Coast, Chiapas Pijijiapan (modern town)	0.707680	dog bone *(C. familiares)*	F2974	477416, 1735555
No zone defined	Pacific Coast, Chiapas Pijijiapan (modern town)	0.707759	dog bone *(C. familiares)*	F2973	477416, 1735555

Appendix C Isotope Values from Human Tooth Enamel and Bone

Table C1: Isotope values from human tooth enamel and bone

KEY

Burial: The abbreviated designation as listed in site reports and publications

Sex: M (male), F (female), M? (probable male), F? (probable female), I (sex not estimated, or remains not yet analyzed)

Age: I (infant, birth to 3 years), C (child, 3 - 12 years), Ao (12 – 20 years), A (adult, >20 years), Yad (young adult 20-35 years), Y-Mad (young to mid-age adult 20-50 years), Mad (mid-age adult 35-50 years), M-Oad (mid- to old-age adult 35 years or older), Oad (old adult ~50 years or older), J (juvenile, child, or adolescent), I (not determined or not yet analyzed). Age classes follow Ubelaker and Buikstra (1994).

UW Lab#: UW-Madison Laboratory for Archaeological Chemistry sample number

Tooth: Tooth sampled for strontium $^{87}Sr/^{86}Sr$, carbon $^{13}C/^{12}C$, and oxygen $^{18}O/^{16}O$ isotope analysis: I (incisor), C (canine), P (premolar), M (molar). Example: LRM1 is lower right first molar. URM1-2 is the upper right first or second molar. δ^{13}Cco, ^{13}Cap and δ^{15}N sampled from bone from the same individual for some burials.

$^{87}Sr/^{86}Sr$: The strontium isotope ratio. Only values resulting from this study are included.

δ^{13}C tooth: $^{13}C/^{12}C$ carbon isotope value of tooth enamel. Only values resulting from this study are included.

δ^{18}O tooth: $^{18}O/^{16}O$ oxygen isotope value of tooth enamel. Only values resulting from this study are included.

δ^{13}Cco bone: $^{13}C/^{12}C$ carbon isotope value of bone collagen. *Information from Piehl (2006) and Gerry (1993) are shown in italics.*

δ^{13}Cap bone: $^{13}C/^{12}C$ carbon isotope value of bone apatite. *Information from Piehl (2006) and Gerry (1993) are shown in italics.*

δ^{15}N bone: $^{15}N/^{14}N$ nitrogen isotope ratio value of bone collagen. *Information from Piehl (2006) and Gerry (1993) are shown in italics.*

Date: Provides the date of the burial (when available).

Reference: Sources of osteological, contextual, or isotopic information cited in this study.

Site Burial/Individual	Sex	Age in years	UW Lab #	Tooth	$^{87}Sr/^{86}Sr$	δ^{13}C tooth	δ^{18}O tooth	δ^{13}C co	δ^{13}C ap	δ^{15}N	Date	Reference
Baking Pot Str. B1 B1	I	I	F4548	LRM1	.708831	-	-	-	-	-	AD780-900	Audet 2006; Tiesler personal communication 2009
Baking Pot B1-9 crypt	F?	Oad	F4549	UM1-2	.708574	-	-	-	-	-	Spanish Lookout	Piehl 2006

Site Burial/Individual	Sex	Age in years	UW Lab #	Tooth	$^{87}Sr/^{86}Sr$	$\delta^{13}C$ tooth	$\delta^{18}O$ tooth	$\delta^{13}C$ co	$\delta^{13}C$ ap	$\delta^{15}N$	Date	Reference
Baking Pot Group 1 Plaza 2 B1	I	Yad <23	F5421	URM2	.708283	-	-	-	-	-	AD590-680	Audet 2006
Baking Pot Group 1 Plaza 2 B1 Ext.	I	Yad <23	F5844	LLM1	.708349	-	-	-	-	-	AD590-680	
Baking Pot Str. E B1	I	A	F5845	LLM1	.709088	-	-	-	-	-	AD580-690	Audet and Awe 2005
Baking Pot Str. 96-1	M	Y-Mad	F5854	ULM1	.708778	-	-	-	-	-	Late – Terminal Classic	Hoggarth personal communication 2010; Piehl personal communication 2010
Baking Pot Str. 96-2	I	Oad	F5853	ULM1	.708796	-	-	-	-	-	Late Classic	
Baking Pot Str. 96-3	F	Oad	F5852	ULM1	.708632	-	-	-	-	-	Late Classic	
Baking Pot Str. 102 B1	I	>60	F5847	URM1	.708246	-	-	*-11.4*	*-5.2*	*9.3*	Late Classic	Piehl 2006
Baking Pot Str. 112-1-1	F	Mad	F5855	URI1	.709155	-	-	-	-	-	Early Classic	Hoggarth personal communication 2010; Piehl personal communication 2010
Baking Pot Str. 112-1-2	M	A	F5856	LRP3	.708916	-	-	-	-	-	Early Classic?	
Baking Pot Str. 190 B3	M	A	F5849	ULM1	.708514	-	-	-	-	-	Late Classic I	Audet 2006; Piehl and Awe 2009

Site Burial/Individual	Sex	Age in years	UW Lab #	Tooth	$^{87}Sr/^{86}Sr$	$\delta^{13}C$ tooth	$\delta^{18}O$ tooth	$\delta^{13}C$ co	$\delta^{13}C$ ap	$\delta^{15}N$	Date	Reference
Baking Pot Str. 190 B5	M	Late Ao	F5850	URP3	.708174	-	-	-	-	-	Late Classic I	Audet 2006; Piehl and Awe 2009; Piehl personal communication 2010
Baking Pot Str. 198 B1	I	Infant 3±1	F5838	Upper left dm2	.708636	-	-	-	-	-	Late Preclassic	Audet 2006; Piehl personal communication 2010
Baking Pot Str. 198 B2	I	Infant 3±1	F5839	Lower right dm2	.708626	-	-	-	-	-	Late Classic	Audet 2006
Baking Pot Str. 209 B1	M	Oad	F5836	LRM1	.708827	-	-	-	-	-	AD800-900	Audet 2006; Piehl personal communication 2010
Baking Pot Str. 209 B2	I	Yad 19-23	F5835	LLM2 ?	.708657	-	-	-	-	-	AD550-650	
Baking Pot Str. 209 B3	F	Oad >55	F5837	LLM1	.708856	-	-	-	-	-	AD650-900	Audet 2006; Tiesler personal communication 2009
Baking Pot Str. 215 B1	I	I	F5840	LLM1	.708578	-	-	-	-	-	Not available	McRae 2004
Baking Pot Str. 215 B2	I	I	F5841	ULP3	.708852	-	-	-	-	-	Not available	
Baking Pot Str. 215 B4	I	I	F5842	LLM	.709549	-	-	-	-	-	Not available	McRae 2004; Piehl personal communication 2010

Site Burial/Individual	Sex	Age in years	UW Lab #	Tooth	$^{87}Sr/^{86}Sr$	$\delta^{13}C$ tooth	$\delta^{18}O$ tooth	$\delta^{13}C$ co	$\delta^{13}C$ ap	$\delta^{15}N$	Date	Reference
Baking Pot Str. 215 B6	I	I	F5843	ULP3	.709078	-	-	-	-	-	Not available	McRae 2004
Baking Pot Atalaya B1B	F?	Mad	F5846	URM1	.709259	-	-	*-11.2*	*-6.3*	*9.0*	Late Classic	Piehl 2006
Baking Pot Mound G Burial 3 61487	I	Oad >40	F5858	LLM1	.708425	-	-	*-11.7*	*-7.0*	*11.3*	Late Early Classic – Late Classic	Helmke personal communication 2010; Tiesler personal comunication 2009; Ricketson 1931
Baking Pot Mound G Burial 7 61485	M	A	F5862	ULM1	.708201	-	-	*-11.6*	-	*9.0*	Late Early Classic – Late Classic	
Baking Pot Mound G Burial 9 61486	F?	A	F5859	URM1	.708674	-	-	*-8.9*	-	*8.5*	Late Early Classic – Late Classic	
Baking Pot Mound G Burial 11 61478	M	A	F5857	ULM1	.708836	-	-	*-11.5*	-	*9.2*	Late Early Classic – Late Classic	
Baking Pot Mound G Burial 15 61484	I	I	F5861	LLM2	.708510	-	-	*-9.5*	*-6.5*	*10*	Late Early Classic	Helmke personal communication 2010; Ricketson 1931
Baking Pot Excava-tion 9 61663	I	A	F5860	ULM1	.707289	-3.07	-4.27	-	-	-	Not known	Tiesler personal communication 2009; Ricketson 1931
Barton Ramie BR-1 B6 N8857.36	I	A?	F5872	LLM1	.708575	-	-	*-13.0*	-	*8.1*	Spanish Lookout AD700-900	Gerry 1993; Willey et al. 1965

Site Burial/Individual	Sex	Age in years	UW Lab #	Tooth	$^{87}Sr/^{86}Sr$	$\delta^{13}C$ tooth	$\delta^{18}O$ tooth	$\delta^{13}C$ co	$\delta^{13}C$ ap	$\delta^{15}N$	Date	Reference
Barton Ramie BR-1 B10 N8857.141	M	M-Oad 40-60	F5881	URC	.708641	-	-	-10.1	-6.9	8.8	Spanish Lookout AD700-900	Tiesler personal communication 2009; Willey et al. 1965
Barton Ramie BR-1 B25 N8857.142	I	Ao 14-18	F5882	LRM1	.708746	-	-	-	-	-	Spanish Lookout AD700-900	
Barton Ramie BR-75 B2 N8857.127	M?	A	F5878	URM1	.708601	-	-	*-10.0*	*-6.1*	*8.8*	Spanish Lookout AD700-900	Gerry 1993; Tiesler personal communication 2009; Willey et al. 1965
Barton Ramie BR-123 B3 N8857.90	F	A	F5877	URM (3?)	.708958	-	-	*-11.1*	*-6.8*	*8.7*	Spanish Lookout AD700-900	Gerry 1993; Willey et al. 1965
Barton Ramie BR-123 B5 N8857.25	F?	A	F5869	ULM (1?)	.708697	-	-	-	-	-	Spanish Lookout AD700-900	Tiesler personal communication 2009; Willey et al. 1965
Barton Ramie BR-123 B8 N8857.32	M	A	F5873	LLM2	.708699	-	-	*-13.3*	*-7.2*	*8.9*	Spanish Lookout AD700-900	Gerry 1993; Tiesler personal communication 2009; Willey et al. 1965

Site Burial/Individual	Sex	Age in years	UW Lab #	Tooth	$^{87}Sr/^{86}Sr$	$\delta^{13}C$ tooth	$\delta^{18}O$ tooth	$\delta^{13}C$ co	$\delta^{13}C$ ap	$\delta^{15}N$	Date	Reference
Barton Ramie BR-123 B9 N8857.33	F	M-Oad >45	F5871	LLM1	.709584	-	-	*-13.3*	*-7.9*	*8.8*	Spanish Lookout AD700-900	Gerry 1993; Tiesler personal communication 2009; Willey et al. 1965
Barton Ramie BR-123 B11 N8857.83	I	C	F5875	URP3	.708535	-	-	-	-	-	Spanish Lookout AD700-900	Tiesler personal communication 2009; Willey et al. 1965
Barton Ramie BR-123 B12 N8857.84	F?	A	F5876	URM1	.708262	-	-	*-12.8*	*-7.4*	*8.2*	Spanish Lookout AD700-900	Gerry 1993; Tiesler personal communication 2009; Willey et al. 1965
Barton Ramie BR-123 B18 N8857-7	M?	A	F5864	LLM2	.709160	-	-	*-11.4*	*-7.0*	*9.5*	Spanish Lookout AD700-900	
Barton Ramie BR-123 B22 N8857-8	I	C 4-5	F5863	Ldm2	.708578	-	-	-	-	-	Spanish Lookout AD700-900	Tiesler personal communication 2009; Willey et al. 1965
Barton Ramie BR-123 B23 N8857.42	M?	Ao 12-18	F5870	LRM1	.708560	-	-	*-10.6*	*-6.5*	*9.2*	Spanish Lookout? AD700-900	Gerry 1993; Tiesler personal communication 2009; Willey et al. 1965

Site Burial/Individual	**Sex**	**Age in years**	**UW Lab #**	**Tooth**	**$^{87}Sr/^{86}Sr$**	**$\delta^{13}C$ tooth**	**$\delta^{18}O$ tooth**	**$\delta^{13}C$ co**	**$\delta^{13}C$ ap**	**$\delta^{15}N$**	**Date**	**Reference**
Barton Ramie BR-123 B25 N8857.55	M	A	F5874	URP3	.708733	-	-	*-11.1*	*-7.7*	*8.9*	Spanish Lookout AD700-900	Gerry 1993; Tiesler personal communication 2009; Willey et al. 1965
Barton Ramie BR-123 B28 N8857.134	I	Yad 20-35	F5879	LLM1	.708481	-	-	*-12.3*	*-7.6*	*8.6*	Spanish Lookout? AD700-900	
Barton Ramie BR-130 B5 N8857.17	M?	A	F5865	LRM1	.708771	-	-	-	-	-	Spanish Lookout AD700-900	Tiesler personal communication 2009; Willey et al. 1965
Barton Ramie BR-144 B1 N8857.21	F?	A	F5866	LRM1	.708745	-	-	-	-	-	Spanish Lookout or New Town	
Barton Ramie BR-144 B2 N8857.22	M?	A	F5867	LRM1 ?	.707650	failed	failed	-10.8	-8.3	9.3	Spanish Lookout or New Town	
Barton Ramie BR-144 B3 N8857.23	M	A	F5868	LLM1	.708753	-	-	*-11.8*	-	*8.9*	Spanish Lookout or New Town	Gerry 1993
Barton Ramie BR-155 B3 N8857.137	M	M-Oad 40-50	F5880	LLM1	.708675	-	-	*-12.0*	*-6.9*	*9.4*	Spanish Lookout or earlier?	Gerry 1993; Tiesler personal communication 2009; Willey et al. 1965
Black-man Eddy Str. A-4 2C-B1	I	A	F5907	LRM1	.708483	-	-	*-9.0*	-	*7.9*	Late Classic	Piehl 2006; Appendix A
Black-man Eddy Str. A-4 2C-B2	I	C	F5906	LRM1	.708612	-	-	*-8.4*	*-6.5*	*7.9*	Late Classic	
Black-man Eddy Str. A-4 2C-B3	I	Ao-Yad	F5905	LLP4	.708581	-	-	*-8.3*	*-6.7*	*7.4*	Late Classic	

Site Burial/Individual	**Sex**	**Age in years**	**UW Lab #**	**Tooth**	**$^{87}Sr/^{86}Sr$**	**$\delta^{13}C$ tooth**	**$\delta^{18}O$ tooth**	**$\delta^{13}C$ co**	**$\delta^{13}C$ ap**	**$\delta^{15}N$**	**Date**	**Reference**
Buenavista Op. 350 B1	I	C 4±1	F5901	dm2	.708113	-	-	-	-	-	Late Preclassic	Peuramaki-Brown 2009
Cahal Pech Str. A2 B1	I	A	F5883	URM1	.708505	-	-	*-8.6*	*-5.2*	*8.4*	AD600-700	Song 1995
Cahal Pech Plaza A Str. A3-1	I	I	F4534	UP	.708558	-	-	-	-	-	Not available	Field label room “#2 l. 2”, no date
Cahal Pech Str. B2-2	I	A	F5884	URM1 ?	.708649	-	-	*-9.3*	-	*9.8*	AD200-450	Field label CP-B2-2, no date; Song 1995
Cahal Pech Plaza B Op. 1g cache 7	I	I	F4533	LRM1	.708597	-	-	-	-	-	Middle Preclassic	Garber et al. 1994
Cahal Pech Str. B4 Burial 1/06	I	I	F4536	Bone	.708624	-	-	-	-	-	Middle Preclassic	Field label 1/06 (Str. B4 Burial 1/06)
Cahal Pech Str. H1 Plaza H Tomb 1	M	A	F4535	LRM1	.708585	-	-	-	-	-	Terminal Classic	Awe 2008
Cahal Pech Zotz 2/B1 1992	M	A	F5885	LRM1	.708731	-	-	*-12.5*	*-8.2*	*9.2*	Late Classic	
Cahal Pech Zotz 2/B3 1992	M	A	F5887	LLM1	.708726	-	-	*- 9.0*	*-2.4*	*11.2*	Late Classic	Piehl 2006; Song 1995
Cahal Pech Zotz 2/B5 1992	I	I	F5888	LRM1	.708892	-	-	*-10.2*	*-5.8*	*9.6*	Late Classic	
Cahal Pech Zotz B7 1991	I	A	F5891	LRM1	.708744	-	-	-	-	-	Late Classic	Song 1995
Cahal Pech Tolok 2-92	I	A	F5886	LLM1	.708311	-	-	*-10.4*	*-7.0*	*8.5*	Late Classic	Piehl 2006 (male); Song 1995 (female)

Site Burial/Individual	Sex	Age in years	UW Lab #	Tooth	$^{87}Sr/^{86}Sr$	$\delta^{13}C$ tooth	$\delta^{18}O$ tooth	$\delta^{13}C$ co	$\delta^{13}C$ ap	$\delta^{15}N$	Date	Reference
Cahal Pech Tolok 4	I	Y-Mad	F5889	C (RU?)	.708311	-	-	*-12.2*	*-7.9*	*8.2*	Late Classic	Piehl 2006; Song 1995 (individual A: I 40+, individual B: M, 25-30)
Cahal Pech Zopilote Tomb 1 B1	M	Yad	F5893	UM	.708852	-	-	-	-	-	AD580-630	Cheetham 2004; Song 1995
Cahal Pech Zopilote Tomb 1 B2	M	Yad	F5892	LLM1	.709418	-	-	-	-	-	AD580-630	
Chaa Creek Op. Q11/12 Q#4	teeth commingled: F Yad M A M Oad >50		F5189	URI1	.709540	-5.04	-3.15	-	-	-	Late Classic II	Adams 1998; Connell 2000
Chaa Creek Op.Q12N#5			F5158	URI1	.709460	-6.05	-2.45	-	-	-		
Chaa Creek Op. Q11/12 #52			F5159	URI1	.709181	-6.62	-2.92	-	-	-		
Chaa Creek Op. 161 XX#11	teeth commingled: Female Oad, Male Mad, Male A		F5160	I	.709178	-8.71	-2.79	-	-	-	LCII-Terminal transition	
Chaa Creek Op. 161 XX#167			F5161	LRM1	.709977	-7.36	-2.90	-	-	-		
Chaa Creek Op. 161 XX#173			F5162	LRM1	.709435	-3.58	-4.48	-	-	-		
Chaa Creek Op. 161 XX/31	I	C 3-5	F5163	UM	.708411	-7.89	-3.06	-	-	-	LCII-Terminal transition	
Chaa Creek Op. 190O B1	M	Oad >50	F5157	LRM1	.708748	-4.66	-4.37	-	-	-	Protoclassic	
Chaa Creek Op. 190P B1 intrusive	M	A	F5166	LRM1	.711200	-6.58	-3.44	-	-	-	Protoclassic	

Site Burial/Individual	Sex	Age in years	UW Lab #	Tooth	$^{87}Sr/^{86}Sr$	$\delta^{13}C$ tooth	$\delta^{18}O$ tooth	$\delta^{13}C$ co	$\delta^{13}C$ ap	$\delta^{15}N$	Date	Reference
Chaa Creek Op. 190P B1disturbed	M	A	F5165	LLM1	.708568	-4.88	-3.73	-	-	-	Protoclassic	Adams 1998; Connell 2000
Chaa Creek Op. 254B B1	M	35-40	F5148	ULM1	.709633	-8.97	-3.10	-	-	-	LCIIb-Terminal transition	
Chaa Creek Chultun 2 Chamber 3	I	I	F5164	P	.709586	-4.39	-4.61	-	-	-	Not available	
Chapat Cave	I	I	F5928	URM1	.708160	-	-	-	-	-	Not available	
Esperanza Str. A4 2b-4-B2?	I	A	F5908	LLM1	.709325	-5.54	-3.21	-	-	-	Late Classic	Appendix A
Esperanza Str. A4 2c-1 B2	I	A	F5910	LLM1	.707961	failed	failed	*-12.4*	*-6.3*	*9.3*	Late Classic	
Esperanza Str. A4 2d-1 B3	M?	A	F5909	LRM1	.709511	*-6.54*	*-3.50*	-	-	-	Late Classic	
Floral Park Str. 2A B2	I	I	F5902	LRM1	.708470	-	-	*-9.4*	-	*8.9*	Late Classic	Piehl 2006; Appendix A
Floral Park Str. 2A B6	I	Yad	F5903	LLM1	.708582	-	-	*-11.0*	-	*9.5*	Late Classic	
Floral Park Str. 2A B9	F	Y-Mad	F5904	M	.710286	-8.49	-3.28	*-13.6*	-	*8.9*	Late Classic	
Franz Harder Cave	I	I	F5929	LRM1	.708239	-	-	-	-	-	Not available	
Pook's Hill Str. 4A LP	I	Yad?	F5919	LUM1	.708524	-	-	-	-	-	AD700	Helmke 2000a

Site Burial/Individual	Sex	Age in years	UW Lab #	Tooth	$^{87}Sr/^{86}Sr$	$\delta^{13}C$ tooth	$\delta^{18}O$ tooth	$\delta^{13}C$ co	$\delta^{13}C$ ap	$\delta^{15}N$	Date	Reference
Pook's Hill Str. 4A-1	M?	Mad	F5920	LRM1	.708929	-	-	-11.7	-6.6	6.4	AD830-950	Helmke et al. 2006; Piehl personal communication 2010
Pook's Hill Str. 4A-2	I	Y-Mad 30-40	F5921	URM1	.708448	-	-	-10.9	-6.6	-7.2	AD500-700	
Pook's Hill Str. 4A-3 B	F?	Yad	F5922	LLM1	.708127	-	-	-	-	-	AD830-950	
Pook's Hill Str. 4A-3 C	M	M-Oad 40-50	F5923	URM1	.708325	-	-	-8.8	-7.1	8.3	AD830-950	
Pook's Hill Str. 4A-3 G	M	Mad	F5924	ULM1	.708238	-	-	-10.3	-7.5	8.2	AD830-950	
Pook's Hill Str. 4A-5 A	M	Mad	F5925	LLM1	.708443	-	-	-10.1	-7.1	8.6	AD830-950	
Pook's Hill Str. 4A-6	M?	Yad	F5926	URM1	.708456	-	-	-11.0	-8.1	8.4	Late-Terminal Classic	
Pook's Hill Str. 4A-7	I	I	F5927	LLM1	.708237	-	-	-10.2	-6.6	8.2	Late-Terminal Classic	
San Lorenzo Op. 71C B1	I	30-50	F5169	LLM1	.708123	-5.11	-2.73	-	-	-	Late Classic I	Adams 1998; Yaeger 2000
San Lorenzo Op. 243U B1	I	Infant 2-4	F5167	Left lower dm1	.708805	-7.06	-3.74	-	-	-	Late Classic	
San Lorenzo Op. 243LL B1	F	35-45	F5168	ULM1	.709384	-6.07	-2.20	-	-	-	Late Classic	
Saturday Creek Str. SC-18 B2	M?	Ao 14-20	F5418	M	.708605	-	-	-	-	-	AD800-900	Piehl 2002, 2006
Saturday Creek Str. SC-18 B5	I	M-Oad 40-50	F5411	ULM1	.709123	-	-	*-10.4*	*-7.0*	*8.8*	AD400-600	

Site Burial/Individual	Sex	Age in years	UW Lab #	Tooth	$^{87}Sr/^{86}Sr$	$\delta^{13}C$ tooth	$\delta^{18}O$ tooth	$\delta^{13}C$ co	$\delta^{13}C$ ap	$\delta^{15}N$	Date	Reference
Saturday Creek Str. SC-18 B7	F	Yad 20-30	F5412	LRM1	.709024	-	-	*-11.4*	*-6.5*	*9.0*	AD700-800	Piehl 2002, 2006
Saturday Creek Str. SC-85 B1	F	Yad 24-30	F5413	M	.709273	-	-	*-11.1*	-	*9.0*	AD700-900	
Saturday Creek Str. SC-85 B3	I	Ao 10-12	F5414	LRM1	.708629	-	-	*- 8.9*	*-6.7*	*9.1*	AD600-700	
Saturday Creek Str. SC-85 B4	I	Infant 1-4	F5417	LRM1	.708880	-	-	-	-	-	AD800-900	
Saturday Creek Str. SC-85 B6	M	Yad 18-25	F5416	ULM1	.708402	-	-	*-10.0*	*-6.6*	*8.9*	AD400-600	
Saturday Creek Str. SC-85 B8	M	Yad 24-30	F5415	LRM1	.708567	-	-	*-10.2*	*-6.4*	*8.5*	AD700-900	
Xunantunich Str. A-11 Op. 302 B1	M	Yad 20-23	F4530	LRM1	.707969	-2.85	-0.32	-	-	-	Late Classic	
Xunantunich Str. A-4 B1 skull 4	I	Ao 10-12	F4531	UM1	.707936	-3.36	-1.73	-	-	-	Late Classic	Piehl personal communication 2010
Xunantunich Str. A-4 B1 head 1	I	A?	F4528	ULI2	.707960	-2.40	-2.36	-	-	-	Late Classic	
Xunantunich Str. A-4 B1 mandible D	F	Ao 16-18	F5420	LLP3	.707982	-5.83	-1.84	-	-	-	Late Classic	
Xunantunich Str. A-4 B1mand- ible B	I	A	F4532	LRM1 -2	.708431	-7.71	-3.16	-	-	-	Late Classic	
Xunantunich Str. A-4 B1mand- ible A	I	A	F5150	LLM2	.709140	-6.72	-2.40	-	-	-	Late Classic	
Xunantunich Str.A-4 B1 cist	I	I	F5151	LRP3?	.708720	-5.80	-2.89	failed	-5.0	failed	Late Classic	

Site Burial/Individual	Sex	Age in years	UW Lab #	Tooth	$^{87}Sr/^{86}Sr$	$\delta^{13}C$ tooth	$\delta^{18}O$ tooth	$\delta^{13}C$ co	$\delta^{13}C$ ap	$\delta^{15}N$	Date	Reference
Xunantunich Str. A-4 B1 extension	M?	A?	F5152	URM1	.708423	-4.16	-3.18	-	-	-	Late Classic	
Xunantunich Str. A-32 Op. 247 B1	M?	A	F5146	LRM1	.708004	-4.91	-0.60	-9.6	-5.4	9.0	Late Classic?	
Xunantunich Str. A-17 Op.141CB1	I	C 6-10	F5141	UM1	.708578	-6.99	-2.65	-	-	-	Late Classic?	Adams 1998
Xunantunich Group B B1 Op. 211K	F	A	F5153	LLM1	.708196	-2.65	-0.91	-9.1	-4.6	8.7	Late Classic II?	
Xunantunich Str. D-6 Op. 74R B1	I	A	F5147	LLM1	.708648	-5.36	-2.76	-12.8	-6.8	9.0	Late Classic	
Xunantunich Str. D-6 Op. 74JJ B1	M	Y-Mad 30-40	F5140	LLM1	.708991	-5.91	-3.41	failed	-8.5	failed	Late Classic	
Xunantunich Str. D-7 Op. 22F B1	I	Infant 2-4	F5142	Ldm2	.708818	-4.50	-3.98	-	-	-	Late Classic II	
Xunantunich Group D Op. 21B B1	I	A	F5143	P	.708369	-4.18	-3.01	-12.1	-8.3	8.2	Terminal Classic	Adams 1998; Braswell 1998
Xunantunich Group D Op. 21C B1 Ind. #1	M	Yad 25-29	F5144	UP	.709031	-5.98	-1.41	-12.2	-9.6	7.9	Terminal Classic?	
Xunantunich Group D Op. 21C B1 Ind. #2	M	Oad >50	F5145	LRM1	.710463	-5.90	-3.47	-12.7	-9.1	6.8	Terminal Classic?	
Xunantunich Group D Op. 21D B1	M?	Mad >35	F5149	P	.711112	-6.05	-3.33	failed	see next	failed	Terminal Classic?	

Site Burial/Individual	Sex	Age in years	UW Lab #	Tooth	$^{87}Sr/^{86}Sr$	$\delta^{13}C$ tooth	$\delta^{18}O$ tooth	$\delta^{13}C$ co	$\delta^{13}C$ ap	$\delta^{15}N$	Date	Reference
Xunantunich Group D Op. 5J B1	I	C 7-8	F5419	LRM1	.708222	-3.52	-2.78	-	-	-	Late Classic	Adams 1998; Braswell 1998
Zubin Str. A1-B1	I	A?	F5900	LLM1	.708658	-	-	-	-	-	AD675-750	
Zubin Str. A1-B3 #1	M	Y-Mad 30-45	F5897	LRM1 -2	.708661	-	-	-	-	-	AD675-750	
Zubin Str. A1-B3 #3	M	Y-Mad	F5898	URM1	.709816	-	-	-	-	-	AD675-750	
Zubin Str. A1-B3 #2	F	Y-Mad	F5851	LLM1	.708700	-	-	-	-	-	AD675-750	
Zubin Str. A1-B3 #4	M	Yad 20	F5899	UM1	.708660	-	-	-	-	-	AD675-750	Iannone 1996
Zubin Str. A1-B6	I	I	F5896	C	.709500	-	-	-	-	-	AD675-750	
Zubin Str. A1-B9	I	Y-Mad 27-40	F5894	LRM1	.708708	-	-	-	-	-	AD200-300	
Zubin Str. A1-B10	I	C 4-5	F5895	LLM1	.708387	-	-	-	-	-	AD100-350	
Zubin Str. C9-B1	I	I	F5890	LLM1	.708455	-	-	-	-	-	650-350BC	

DATA FROM OTHER REGIONS

Site Burial/Individual	Sex	Age in years	UW Lab #	Tooth	$^{87}Sr/^{86}Sr$	$\delta^{13}C$ tooth	$\delta^{18}O$ tooth	$\delta^{13}C$ co	$\delta^{13}C$ ap	$\delta^{15}N$	Date	Reference
Caracol CD4C/14 3rd plaza	I	C	F4537	LRdm2	.70769	-3.26	-3.70	-	-	-	-	Gibbs personal communication 2009
Caracol CD4C/13	I	C	F4538	Rdc	.707781	-	-	-	-	-	-	
Caracol Str. D7 C88	I	I	F4539	LRM1	.707800	-5.56	-2.82	-	-	-	-	
Caracol Str. D7 CD20	I	I	F4540	LRP4	.707978	failed	failed	-	-	-	-	Gibbs personal communication 2009
Caracol Str. A6 CD9I/4g	I	I	F4541	ULP4?	.707563	-3.38	-4.35	-	-	-	-	
Caracol CD4C/14 centro	I	I	F4542	LRM1	.709555	failed	failed	-	-	-	-	
Caracol CD4/B26	M?	Ao	F4543	LLM1	.708121	-4.14	-4.03	-	-	-	-	
Caracol CD3 A/17	I	I	F4544	LRP3	.707766	-4.35	-3.13	-	-	-	Terminal Classic	Awe and Piehl 2009
Caracol CD14 B/1 and 2	I	I	F4545	URP	.707238	-3.64	-3.27	-	-	-	Late-Terminal Classic	Gibbs personal communication 2009
Caracol Str. D7 CD20 a/7	I	Sub-adult	F4546	LLM1	.707671	-	-	-	-	-	-	
Caracol CD27 B/2 burial 1	I	I	F4547	LRM1	.707833	-3.88	-2.55	-	-	-	-	
Ramonal B005 #3	I	A	F4573	UM3	.716369	-5.33	-4.44	-	-	-	-	Awe et al. 2005; Nash personal communication 2008

Site Burial/Individual	Sex	Age	UW Lab #	Tooth	$^{87}Sr/^{86}Sr$	$\delta^{13}C$ tooth	$\delta^{18}O$ tooth	$\delta^{13}C$ co	$\delta^{13}C$ ap	$\delta^{15}N$	Date	Reference
Ramonal B005 #16	I	A	F4572	lower M1	.713463	-4.33	-3.12	-	-	-	-	Awe et al. 2005; Nash personal communication 2008
Ramonal B005 #55	I	A	F4574	URM3	.715127	failed	failed	-	-	-	-	
Ramonal B005 #12	I	A	F4575	lower M1	.712173	-	-	-	-	-	-	
Ramonal B005 #138	I	A	F4576	lower M1	.711277	-5.16	-3.40	-	-	-	-	
Ramonal B003 #75	I	A	F4577	ULM1	.714609	-6.10	-4.14	-	-	-	-	
Ramonal B003 #21	I	A	F4578	URM1	.714997	-4.31	-2.87	-	-	-	-	
Bajo del Lago B001 #20	I	I	F4579	LLM2	.713474	-4.27	-3.24	-	-	-	-	
Peligroso B008 cluster D #32	I	A	F4581	ULM1-2	.715075	-3.76	-3.11	-	-	-	Early-Late Classic transition	Awe et al. 2005; Nash personal communication 2008
Peligroso B008 cluster A #22	I	A	F4529	URM2	.714818	failed	failed	-	-	-	Early-Late Classic transition	Awe et al. 2005; Nash personal communication 2008
Peligroso B008 cluster A vessel 17	I	A	F4580	LRM2-3	.71464	-4.69	-4.06	-	-	-	Early-Late Classic transition	Awe et al. 2005; Nash personal communication 2008

Table C2. Isotope values and sample information for bone collagen and apatite samples: This chart presents detailed information on bone collagen samples and includes only burials with carbon, oxygen or nitrogen values (in addition to strontium isotope ratios). Strontium isotope values from the Laboratory for Archaeological Chemistry at UW-Madison are assigned lab numbers (F#) for tooth enamel samples. Bone samples from the same individual also receive a University of Illinois at Urbana-Champaign laboratory number (UIA#). Data in italics are from Piehl (2006) and Gerry (1993). Procedures 1 and 2 for UIA#s are described in Chapter 4.

Site and Burial	**Sex and Age**	**UW Lab #**	**Tooth**	**$^{87}Sr/^{86}Sr$**	**$^{13}C/^{12}C$**	**$^{18}O/^{16}O$**	**UIA Lab #**	**Bone sample**	**$^{18}O/^{16}O$ smow**	**$^{13}C/^{12}C$ apatite**	**UIA Lab #**	**$^{13}C/^{12}C$ collagen**	**$^{15}N/^{14}N$**	**C:N**
Baking Pot														
Str. 102 B1	I >60	F5847	URM1	.708246	-	-	-	-	-	*-5.2*	-	*-11.4*	*9.3*	-
Atalaya B1B	F? Mad	F5846	URM1	.709259	-	-	-	-	-	*-6.3*	-	*-11.2*	*9.0*	-
Mound G Burial 3 61487	I Oad >40	F5858	LLM1	.708425	-	-	-	-	-	*-7.0*	-	*-11.7*	*11.3*	-
Mound G Burial 7 61485	M A	F5862	ULM1	.708201	-	-	-	-	-	-	-	*-11.6*	*9.0*	-
Mound G Burial 9 61486	F? A	F5859	URM1	.708674	-	-	-	-	-	-	-	*-8.9*	*8.5*	-
Mound G Burial 11 61478	M A	F5857	ULM1	.708836	-	-	-	-	-	-	-	*-11.5*	*9.2*	-
Mound G Burial 15 61484	I	F5861	LLM2	.708510	-	-	-	-	-	*-6.5*	-	*-9.5*	*10*	-

Site and Burial	Sex and Age	UW Lab #	Tooth	$^{87}Sr/^{86}Sr$	$^{13}C/^{12}C$	$^{18}O/^{16}O$	UIA Lab #	Bone sample	$^{18}O/^{16}O$ smow	$^{13}C/^{12}C$ apatite	UIA Lab #	$^{13}C/^{12}C$ collagen	$^{15}N/^{14}N$	C:N
Baking Pot (continued)														
Excavation 9 61663	A	F5860	ULM1	.707289	-3.07	-4.27	-	-	-	-	-	-	-	-
Barton Ramie														
BR-1 B6 N8857.36	A?	F5872	LLM1	.708575	-	-	-	-	-	-	-	*-13*	*8.1*	-
BR-1 B10 N8857.141	M 40-60	F5881	URC	.708641	-	-	18884 BPCF22	left femur: proc#1	27.53	-6.91	18915 BPCF21	-10.13	8.84	3.26
BR-1 B10 N8857.141	M 40-60	F5881	URC	.708641	-	-	18855 BPCF59	left femur: proc#2	26.55	-6.90	-	-	-	-
BR-75 B2 N8857.127	M? A	F5878	URM1	.708601	-	-	-	-	-	*-6.1*	-	*-10.0*	*8.8*	-
BR-123 B3 N8857.90	F A	F5877	URM (3?)	.708958	-	-	-	-	-	*-6.8*		*-11.1*	*8.7*	-
BR-123 B8 N8857.32	M A	F5873	LLM2	.708699	-	-	-	-	-	*-7.2*	-	*-13.3*	*8.9*	-
BR-123 B9 Nx8857.33	F >45	F5871	LLM1	.709584	-	-	-	-	-	*-7.9*	-	*-13.3*	*8.8*	-
BR-123 B12 N8857.84	F? A	F5876	URM1	.708262	-	-	-	-	-	*-7.4*	-	*-12.8*	*8.2*	-
BR-123 B18 N8857-7	M? A	F5864	LLM2	.709160	-	-	-	-	-	*-7.0*	-	*-11.4*	*9.5*	-
BR-123 B23 N8857.42	M? 12-18	F5870	LRM1	.708560	-	-	-	-	-	*-6.5*	-	*-10.6*	*9.2*	-

Site and Burial	Sex and Age	UW Lab #	Tooth	$^{87}Sr/^{86}Sr$	$^{13}C/^{12}C$	$^{18}O/^{16}O$	UIA Lab #	Bone sample	$^{18}O/^{16}O$ smow	$^{13}C/^{12}C$ apatite	UIA Lab #	$^{13}C/^{12}C$ collagen	$^{15}N/^{14}N$	C:N
Barton Ramie (continued)														
BR-123 B25 N8857.55	M A	F5874	URP3	.708733	-	-	-	-	-	*-7.7*	-	*-11.1*	*8.9*	-
BR-123 B28 N8857.134	I 20-35	F5879	LLM1	.708481	-	-	-	-	-	*-7.6*	-	*-12.3*	*8.6*	-
BR-144 B2 N8857.22	M? A	F5867	LRM1 ?	.707650	-	-	18883 BPCF20	right femur	27.85	-8.44	18910 BPCF19	-10.77	9.37	3.33
BR-144 B2 N8857.22	M? A	F5867	LRM1 ?	.707650	-	-	18854 BPCF58	right femur	27.33	-8.25	18914 BPCF19 replicate	-10.81	9.26	3.29
BR-144 B3 N8857.23	M A	F5868	LLM1	.708753	-	-	-	-	-	-	-	*-11.8*	*8.9*	-
BR-155 B3 N8857.137	M 40-50	F5880	LLM1	.708675	-	-	-	-	-	*-6.9*	-	*-12.0*	*9.4*	-
Blackman Eddy														
Str. A4 2C-B1	I A	F5907	LRM1	.708483	-	-	-	-	-	-	-	*-9.0*	*7.9*	-
Str. A4 2C-B2	I C	F5906	LRM1	.708612	-	-	-	-	-	*-6.5*	-	*-8.4*	*7.9*	-
Str. A4 2C-B3	I Ao-Yad	F5905	LLP4	.708581	-	-	-	-	-	*-6.7*	-	*-8.3*	*7.4*	-

Site and Burial	Sex and Age	UW Lab #	Tooth	$^{87}Sr/^{86}Sr$	$^{13}C/^{12}C$	$^{18}O/^{16}O$	UIA Lab #	Bone sample	$^{18}O/^{16}O$ smow	$^{13}C/^{12}C$ apatite	UIA Lab #	$^{13}C/^{12}C$ collagen	$^{15}N/^{14}N$	C:N
Cahal Pech														
Str. A2 B1	I A	F5883	URM1	.708505	-	-	-	-	-	*-5.2*	-	*-8.6*	*8.4*	-
Str. B2-2	I A	F5884	URM1 ?	.708649	-	-	-	-	-	-	-	*-9.3*	*9.8*	-
Zotz 2/B1 1992	M A	F5885	LRM1	.708731	-	-	-	-	-	*-8.2*	-	*-12.5*	*9.2*	-
Zotz 2/B3 1992	M A	F5887	LLM1	.708726	-	-	-	-	-	*-2.4*	-	*- 9.0*	*11.2*	-
Zotz 2/B5 1992	I	F5888	LRM1	.708892	-	-	-	-	-	*-5.8*	-	*-10.2*	*9.6*	-
Tolok 2-92	I A	F5886	LLM1	.708311	-	-	-	-	-	*-7.0*	-	*-10.4*	*8.5*	-
Tolok 4	I Y-Mad	F5889	C (RU?)	.708311	-	-	-	-	-	*-7.9*	-	*-12.2*	*8.2*	-
Chaa Creek														
Op. Q11/12 Q#4	F Yad, M A, M >50	F5189	URI1	.709540	-5.04	-3.15	-	-	-	-	-	-	-	-
Op. Q12 N#5		F5158	URI1	.709460	-6.05	-2.45	-	-	-	-	-	-	-	-
Op. Q11/12 #52		F5159	URI1	.709181	-6.62	-2.92	-	-	-	-	-	-	-	-

Site and Burial	Sex and Age	UW Lab #	Tooth	$^{87}Sr/^{86}Sr$	$^{13}C/^{12}C$	$^{18}O/^{16}O$	UIA Lab #	Bone sample	$^{18}O/^{16}O$ smow	$^{13}C/^{12}C$ apatite	UIA Lab #	$^{13}C/^{12}C$ collagen	$^{15}N/^{14}N$	C:N
Chaa Creek (continued)														
Op. 161 XX#11	F Oad, M Mad, M A	F5160	I	.709178	-8.71	-2.79	-	-	-	-	-	-	-	-
Op. 161 XX#167		F5161	LRM1	.709977	-7.36	-2.90	-	-	-	-	-	-	-	-
Op. 161 XX#173		F5162	LRM1	.709435	-3.58	-4.48	-	-	-	-	-	-	-	-
Op. 161 XX/31	I 3-5	F5163	UM	.708411	-7.89	-3.06	-	-	-	-	-	-	-	-
Op. 190 O B1	M >50	F5157	LRM1	.708748	-4.66	-4.37	-	-	-	-	-	-	-	-
Op. 190 P B1 intrusive	M A	F5166	LRM1	.71120	-6.58	-3.44	-	-	-	-	-	-	-	-
Op. 190 P B1 disturbed	M A	F5165	LLM1	.708568	-4.88	-3.73	-	-	-	-	-	-	-	-
Op. 254 B B1	M 35-40	F5148	ULM1	.709633	-8.97	-3.10	-	-	-	-	-	-	-	-
Chultun 2 Chamber 3	I	F5164	P	.709586	-4.39	-4.61	-	-	-	-	-	-	-	-
Esperanza														
Str. A4 2c-1 B2	I A	F5910	LLM1	.707961	failed	failed	-	-	-	*-6.3*	-	*-12.4*	*9.3*	-
Str. A4 2d-1 B3	M? A	F5909	LRM1	.709511	-6.54	-3.50	-	-	-	-	-	-	-	-
Str. A4 2b-4-B2?	I A	F5908	LLM1	.709325	-5.54	-3.21	-	-	-	-	-	-	-	-

Site and Burial	Sex and Age	UW Lab #	Tooth	$^{87}Sr/^{86}Sr$	$^{13}C/^{12}C$	$^{18}O/^{16}O$	UIA Lab #	Bone sample	$^{18}O/^{16}O$ smow	$^{13}C/^{12}C$ apatite	UIA Lab #	$^{13}C/^{12}C$ collagen	$^{15}N/^{14}N$	C:N
Floral Park														
Str. 2A B2	I	F5902	LRM1	.708470	-	-	-	-	-	-	-	*- 9.4*	*8.9*	-
Str. 2A B6	I Yad	F5903	LLM1	.708582	-	-	-	-	-	-	-	*-11.0*	*9.5*	-
Str. 2A B9	F Y-Mad	F5904	M	.710286	-8.49	-3.28	-	-	-	-	-	*-13.6*	*8.9*	-
Pook's Hill														
Str. 4A LP	Yad?	F5919	LUM1	.708524	-	-	-	-	-	-	-	-	-	
Str. 4A-1	M? Mad	F5920	LRM1	.708929	-	-	18885 BPCF24	right femur: proc#1	27.76	-6.60	18916 BPCF23	-11.72	6.40	3.04
Str. 4A-2	30-40	F5921	URM1	.708448	-	-	18888 BPCF30	left femur: proc#1	27.84	-6.34	18919 BPCF29	-10.92	7.18	3.35
Str. 4A-2	30-40	F5921	URM1	.708448	-	-	18858 BPCF62	left femur: proc#2	27.78	-6.79	-	-	-	-
Str. 4A-3 B	F? Yad	F5922	LLM1	.708127	-	-	-	-	-	-	-	-	-	-

Site and Burial	Sex and Age	UW Lab #	Tooth	$^{87}Sr/^{86}Sr$	$^{13}C/^{12}C$	$^{18}O/^{16}O$	UIA Lab #	Bone sample	$^{18}O/^{16}O$ smow	$^{13}C/^{12}C$ apatite	UIA Lab #	$^{13}C/^{12}C$ collagen	$^{15}N/^{14}N$	C:N
Pook's Hill (continued)														
Str. 4A-3 C	M 40-50	F5923	URM1	.708325	-	-	18886 BPCF26	left femur: proc#1	28.30	-7.09	18917 BPCF25	-8.79	8.30	3.36
Str. 4A-3 C	M 40-50	F5923	URM1	.708325	-	-	18856 BPCF60	left femur: proc#2	28.00	-7.09	-	-	-	-
Str. 4A-3 C	M 40-50	F5923	URM1	.708325	-	-	18896 BPCF26	left femur: proc#1	28.16	-7.18	-	-	-	-
Str. 4A-3 G	M Mad	F5924	ULM1	.708238	-	-	18887 BPCF28	right femur: proc#1	28.22	-7.42	18918 BPCF27	-10.34	8.23	3.35
Str. 4A-3 G	M Mad	F5924	ULM1	.708238	-	-	18857 BPCF61	right femur: proc#2	27.69	-7.63	-	-	-	-
Str. 4A-5 A	M Mad	F5925	LLM1	.708443	-	-	18889 BPCF32	left femur: proc#1	28.18	-7.14	18920 BPCF31	-10.11	8.57	3.34
Str. 4A-5 A	M Mad	F5925	LLM1	.708443	-	-	18860 BPCF63	left femur: proc#2	27.51	-7.08	-	-	-	-
Str. 4A-6	M? Yad	F5926	URM1	.708456	-	-	18890 BPCF34	right femur: proc#1	28.03	-8.10	18921 BPCF33	-10.95	8.39	3.38

Site and Burial	Sex and Age	UW Lab #	Tooth	$^{87}Sr/^{86}Sr$	$^{13}C/^{12}C$	$^{18}O/^{16}O$	UIA Lab #	Bone sample	$^{18}O/^{16}O$ smow	$^{13}C/^{12}C$ apatite	UIA Lab #	$^{13}C/^{12}C$ collagen	$^{15}N/^{14}N$	C:N
Pook's Hill (continued)														
Str. 4A-6	M? Yad	F5926	URM1	.708456	-	-	18861 BPCF64	right femur: proc#2	27.65	-8.16	-	-	-	-
Str. 4A-7	I	F5927	LLM1	.708237	-	-	18891 BPCF36	right femur: proc#1	27.68	-6.58	18922 BPCF35	-10.24	8.15	3.25
Str. 4A-7	I	F5927	LLM1	.708237	-	-	18862 BPCF65	right femur: proc#2	failed	failed	-	-	-	-
Str. 2A-2	-	F6062	-	-	-	-	18838 BPCF38	left femur: proc#1	27.45	-5.74	18923 BPCF37	-11.36	7.68	3.33
Str. 2A-2	-	F6062	-	-	-	-	18863 BPCF63	left femur: proc#2	27.52	-5.57	18927 BPCF37 replicate	-11.37	7.52	3.33
Str. 2A-2	-	F6062	-	-	-	-	18935 BPCF38	left femur: proc#1	27.69	-5.52	-	-	-	-
Str. 2A-2	-	F6062	-	-	-	-	18893 BPCF40	left femur: proc#2	27.93	-5.37	-	-	-	-
Str. 2A-1	-	F6064	-	-	-	-	18839 BPCF38	left femur: proc#1	27.75	-5.77	18928 BPCF39	-9.99	8.43	3.34
Str. 2A-1	-	F6064	-	-	-	-	18880 BPCF40	left femur: proc#1	27.73	-5.95	-	-	-	-

Site and Burial	Sex and Age	UW Lab #	Tooth	$^{87}Sr/^{86}Sr$	$^{13}C/^{12}C$	$^{18}O/^{16}O$	UIA Lab #	Bone sample	$^{18}O/^{16}O$ smow	$^{13}C/^{12}C$ apatite	UIA Lab #	$^{13}C/^{12}C$ collagen	$^{15}N/^{14}N$	C:N
Pook's Hill (continued)														
Str. 2A-1	-	F6064	-	-	-	-	18864 BPCF67	left femur: proc#2	27.58	-5.74	-	-	-	-
Str. 4A-3 E	-	F6068	-	-	-	-	18841 BPCF44	right femur: proc#1	28.54	-8.09	18930 BPCF43	-11.30	7.98	3.25
Str. 4A-3 E	-	F6068	-	-	-	-	18866 BPCF69	right femur: proc#2	27.81	-7.90	-	-	-	-
Str. 2A-3	-	F6066	-	-	-	-	18865 BPCF68	left femur: proc#2	27.98	-7.63	18929 BPCF41	-11.92	7.71	3.34
Str. 2A-3	-	F6066	-	-	-	-	18936 BPCF42	left femur: proc#1	28.19	-7.84	-	-	-	-
Str. 4A-3 A	-	F6069	-	-	*33-*	-	18842 BPCF46	right femur: proc#1	28.02	-7.22	18931 BPCF45	-9.71	8.56	3.36
Str. 4A-3 A	-	F6069	-	-	-	-	18895 BPCF70 replicate	right femur: proc#2	27.80	-7.17	-	-	-	-
Str. 4A-3 A	-	F6069	-	-	-	-	18867 BPCF70	right femur: proc#2	27.80	-7.18	-	-	-	-

Site and Burial	Sex and Age	UW Lab #	Tooth	$^{87}Sr/^{86}Sr$	$^{13}C/^{12}C$	$^{18}O/^{16}O$	UIA Lab #	Bone sample	$^{18}O/^{16}O$ smow	$^{13}C/^{12}C$ apatite	UIA Lab #	$^{13}C/^{12}C$ collagen	$^{15}N/^{14}N$	C:N
San Lorenzo														
Op. 71C B1	30-50	F5169	LLM1	.708123	-5.11	-2.73	-	-	-	-	-	-	-	-
Op. 243U B1	I 2-4	F5167	Left lower dm1	.708805	-7.06	-3.74	-	-	-	-	-	-	-	-
Op. 243LL B1	F 35-45	F5168	ULM1	.709384	-6.07	-2.20	-	-	-	-	-	-	-	-
Saturday Creek														
Str. SC-18 B2	M? 14-20	F5418	M	.708605	-3	-	-	-	-	-	-	-	-	-
Str. SC-18 B5	I 40-50	F5411	ULM1	.709123	-	-	-	-	-	*-7.0*	-	*-10.4*	*8.8*	-
Str. SC-18 B7	F 20-30	F5412	LRM1	.709024	-	-	-	-	-	*-6.5*	-	*-11.4*	*9.0*	-
Str. SC-85 B1	F 24-30	F5413	M	.709273	-	-	-	-	-	-	-	*-11.1*	*9.0*	-
Str. SC-85 B3	I 10-12	F5414	LRM1	.708629	-	-	-	-	-	*-6.7*	-	*- 8.9*	*9.1*	-
Str. SC-85 B4	I 1-4	F5417	LRM1	.708880	-	-	-	-	-	-	-	-	-	-

Site and Burial	**Sex and Age**	**UW Lab #**	**Tooth**	**$^{87}Sr/^{86}Sr$**	**$^{13}C/^{12}C$**	**$^{18}O/^{16}O$**	**UIA Lab #**	**Bone sample**	**$^{18}O/^{16}O$ smow**	**$^{13}C/^{12}C$ apatite**	**UIA Lab #**	**$^{13}C/^{12}C$ collagen**	**$^{15}N/^{14}N$**	**C:N**
Saturday Creek (continued)														
Str. SC-85 B6	M 18-25	F5416	ULM1	.708402	-	-	-	-	-	*-6.6*	-	*-10.0*	*8.9*	-
Str. SC-85 B8	M 24-30	F5415	LRM1	.708567	-	-	-	-	-	*-6.4*	-	*-10.2*	*8.5*	-
Xunantunich														
Str. A-11 Op. 302 B1	M 20-23	F4530	LRM1	.707969	-2.85	-0.32	-	-	-	-	-	-	-	-
Str. A-4 B1 skull 4	I 10-12	F4531	UM1	.707936	-3.36	-1.73	-	-	-	-	-	-	-	-
Str.- A-4 B1 head 1	A?	F4528	ULI2	.707960	-2.40	-2.36	-	-	-	-	-	-	-	-
Str. A-4 B1 mandible D	F 16-18	F5420	LLP3	.707982	-5.83	-1.84	-	-	-	-	-	-	-	-
Str. A-4 B1 mandible B	A	F4532	LRM1 -2	.708431	-7.71	-3.16	-	-	-	-	-	-	-	-
Str. A-4 B1 mandible A	A	F5150	LLM2	.709140	-6.72	-2.40	-	-	-	-	-	-	-	-

Site and Burial	Sex and Age	UW Lab #	Tooth	$^{87}Sr/^{86}Sr$	$^{13}C/^{12}C$	$^{18}O/^{16}O$	UIA Lab #	Bone sample	$^{18}O/^{16}O$ smow	$^{13}C/^{12}C$ apatite	UIA Lab #	$^{13}C/^{12}C$ collagen	$^{15}N/^{14}N$	C:N
Xunantunich (continued)														
Str. A-4 B1 skull 2	F 16-18	F6070	-	-	-	-	18868 BPCF71	left ulna: proc#2	failed	failed	-	-		-
Str. A-4 B1 cist	I	F5151	LRP3?	.708720	-5.80	-2.89	18877 BPCF16	right femur: proc#1	26.67	-5.12	18908 BPCF15	Invalid value		0.62
Str. A-4 B1 cist	I	F5151	LRP3?	.708720	-5.80	-2.89	18852 BPCF56	right femur: proc#2	27.06	-4.81	-	-	-	-
Str. A-4 B1 extension	M? A?	F5152	URM1	.708423	-4.16	-3.18	-	-	-	-	-	-	-	-
Str. A-32 Op. 247 B1	M? A	F5146	LRM1	.708004	-4.91	-0.60	18874 BPCF10	left femur: proc#1	27.64	-5.35	18905 BPCF9	-9.60	9.04	3.05
Str. A-32 Op. 247 B1	M? A	F5146	LRM1	.708004	-4.91	-0.60	18849 BPCF53	left femur: proc#2	27.68	-5.44	-	-	-	-
Str. A-17 Op. 141C B1	6-10	F5141	UM1	.708578	-6.99	-2.65	-	-	-	-	-	-	-	-
Group B Op. 211K B1	F A	F5153	LLM1	.708196	-2.65	-0.91	18878 BPCF18	right ulna: proc#1	28.11	-4.58	18909 BPCF17	-9.07	8.70	3.35
Group B Op. 211K B1	F A	F5153	LLM1	.708196	-2.65	-0.91	18853 BPCF57	right ulna: proc#2	27.92	-4.57	-	-	-	-
Group B Op. 211K B1	F A	F5153	LLM1	.708196	-2.65	-0.91	18894 BPCF57	right ulna: proc#2	27.93	-4.55	-	-	-	-
Str. D-6 Op. 74R B1	A	F5147	LLM1	.708648	-5.36	-2.76	18875 BPCF12	humerus: proc#1	27.80	-6.66	18906 BPCF11	-12.79	8.99	3.30

Site and Burial	Sex and Age	UW Lab #	Tooth	$^{87}Sr/^{86}Sr$	$^{13}C/^{12}C$	$^{18}O/^{16}O$	UIA Lab #	Bone sample	$^{18}O/^{16}O$ smow	$^{13}C/^{12}C$ apatite	UIA Lab #	$^{13}C/^{12}C$ collagen	$^{15}N/^{14}N$	C:N
Xunantunich (continued)														
Str. D-6 Op. 74R B1	A	F5147	LLM1	.708648	-5.36	-2.76	18850 BPCF54	humerus: proc#2	27.63	-6.84	-	-		-
Str. D-6 Op. 74JJ B1	M	F5140	LLM1	.708991	-5.91	-3.41	18869 BPCF2	Left tibia: proc#1	27.41	-8.49	18901 BPCF1	Invalid value		1.63
Str. D-6 Op. 74JJ B1	M 30-40	F5140	LLM1	.708991	-5.91	-3.41	18844 BPCF49	Left tibia: proc#2	27.11	-8.46	-	-	-	-
Str. D-7 Op. 22F B1	2-4	F5142	Ldm2	.708818	-4.50	-3.98	-	-	-	-	-	-	-	-
Group D Op. 21B B1	A	F5143	P	.708369	-4.18	-3.01	18871 BPCF4	right radius: proc#1	27.28	-8.41	18902 BPCF3	-12.13	8.20	3.15
Group D Op. 21B B1	A	F5143	P	.708369	-	-	18845 BPCF50	right radius: proc#2	27.45	-8.28	-	-	-	-
Group D Op. 21C B1 Ind. #1	M 25-29	F5144	UP	.709031	-5.98	-1.41	18872 BPCF6	right femur: proc#1	27.37	-9.67	18903 BPCF5	-12.17	7.86	3.32
Group D Op. 21C B1 Ind. #1	M 25-29	F5144	UP	.709031	-5.98	-1.41	18846 BPCF51	right femur: proc#2	27.32	-9.46	-	-	-	-
Group D Op. 21C B1 Ind. #2	M >50	F5145	LRM1	.710463	-5.90	-3.47	18873 BPCF8	left femur: proc#1	27.60	-9.15	18904 BPCF7	-12.74	6.81	3.25

Site and Burial	Sex and Age	UW Lab #	Tooth	$^{87}Sr/^{86}Sr$	$^{13}C/^{12}C$	$^{18}O/^{16}O$	UIA Lab #	Bone sample	$^{18}O/^{16}O$ smow	$^{13}C/^{12}C$ apatite	UIA Lab #	$^{13}C/^{12}C$ collagen	$^{15}N/^{14}N$	C:N
Xunantunich (continued)														
Group D Op. 21C B1 Ind. #2	M >50	F5145	LRM1	.710463	-5.90	-3.47	18847 BPCF52	Left femur: proc#2	27.92	-9.01	-	-		-
Group D Op. 21D B1	M? >35	F5149	P	.711112	-6.05	-3.33	18876 BPCF14	right femur: proc#1	26.56	-6.39	18907 BPCF13	Invalid value		1.45
Group D Op. 21D B1	M? >35	F5149	P	.711112	-	-	18851 BPCF55	right femur: proc#2	25.71	-9.19	-	-	-	-
Group D Op. 5J B1	7-8	F5419	LRM1	.708222	-3.52	-2.78	-	-	-	-	-	-	-	-

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