

# UC San Diego

## UC San Diego Electronic Theses and Dissertations

### Title

Telling friends from foes : strontium isotope and trace element analysis of companion burials from Pusilhá, Toledo District, Belize

### Permalink

<https://escholarship.org/uc/item/8tx9r1q5>

### Author

Somerville, Andrew D.

### Publication Date

2010

Peer reviewed|Thesis/dissertation

UNIVERSITY OF CALIFORNIA, SAN DIEGO

Telling Friends from Foes: Strontium Isotope and Trace Element Analysis of Companion  
Burials from Pusilhá, Toledo District, Belize

A Thesis submitted in partial satisfaction of the requirements for the degree  
Master of Arts

in

Anthropology

by

Andrew D. Somerville

Committee in charge:

Professor Margaret Schoeninger, Chair  
Professor Geoffrey Braswell  
Professor Paul Goldstein

2010

Copyright  
Andrew D. Somerville, 2010  
All rights reserved

The Thesis of Andrew D. Somerville is approved and it is acceptable in quality and form for publication on microfilm:

---

---

---

Chair

University of California, San Diego

2010

## TABLE OF CONTENTS

Signature Page.....	iii
Table of Contents.....	iv
Acknowledgements.....	v
Abstract.....	vi
Introduction.....	1
Ancestors and Sacrificial Victims .....	3
Pusilhá .....	6
Principles of Strontium Isotopes and Chemical Analyses .....	9
<i>Strontium Isotope Analysis</i> .....	9
<i>Trace-Element Analysis</i> .....	12
Geological Variation and Implications for Defining Local and Foreign .....	15
Materials and Methods .....	19
Results .....	23
<i>Strontium Isotope Results</i> .....	23
<i>Trace-Elements Results</i> .....	26
Discussion .....	29
<i>Companion Burials</i> .....	29
<i>Geographic Origins</i> .....	32
Conclusion .....	37
Appendix .....	40
References .....	49

## ACKNOWLEDGEMENTS

I would like to express my gratitude to Paterno Castillo, Christopher MacIsaac, and Liyan Tian for their generous instruction and patience in the laboratory. Additionally, I thank Sarah Baitzel and Allisen Dahlstedt for their assistance in preparing the samples for analysis. Carolyn Freiwald and Erin Kennedy Thornton kindly offered information on isotope studies in Belize. Finally I thank Margaret Schoeninger and Geoffrey Braswell for their comments and guidance.

ABSTRACT OF THE THESIS

Telling Friends from Foes: Strontium Isotope and Trace Element Analysis of Companion Burials from Pusilhá, Toledo District, Belize

by

Andrew D. Somerville

Master of Arts in Anthropology

University of California, San Diego, 2010

Professor Margaret Schoeninger, Chair

In Maya bioarchaeology, distinguishing the remains of revered ancestors from sacrificial victims often proves difficult due to the frequently poor bone preservation and the similarities of their archaeological contexts. Strontium isotope and trace element analysis are here applied to a population (n=16) of elite Maya from the Late and Terminal Classic Period (600-850 AD) site of Pusilhá, Toledo District, Belize. Three multiple burials in particular were investigated to determine whether the companion figures were

sacrificed enemies or were the curated remains of revered ancestors. The strontium and trace element data find no significant differences between any the principal and companion figures, suggesting that they were not sacrificed enemies or foreigners. One burial pair, however, exhibited nonlocal signals in both individuals.

## INTRODUCTION

During the later half of the 20<sup>th</sup> century, the scholarly perception of the ancient Maya as a society of peaceful theocracies gradually gave way to a more realistic picture of aggressive city-states engaged in practices of warfare, slavery, and human sacrifice. Maya nobles were reinterpreted from their original role as priestly astronomers to practical rulers who struggled to legitimate and maintain their power and authority. Indeed, the Maya elite employed a variety of strategies to reinforce their place within the establish hierarchy. They commissioned stelae that depicted themselves towering over captured enemies (Marcus 1974); they possessed esoteric ritual knowledge that allowed them to communicate with the otherworld (e.g. Schele and Miller 1986:175); they spoke and read an elite language that created social distance from the commoners (Houston, et al. 2000); and they instigated the construction of monumental pyramids, temples, and palaces. Additionally, the Maya elite used human remains in ritual and mortuary contexts as powerful symbols of their right to rule.

Frequently encountered in archaeological investigations, multiple burials from single-interment episodes, or “companion burials” often consist of a principal figure with one to several, often disarticulated or incomplete, secondary individuals. This mortuary practice, in contrast to multiple-episode internments –which likely represent family crypts- has variously been interpreted as representing either the interment of sacrificial victims to accompany the principal figure or as a funerary practice involving the curation of revered ancestor remains. Distinguishing between these two practices has proven problematic elsewhere in Mesoamerica (e.g. Christensen and Winter 1997; Nelson, et al. 1992) and also in the mortuary contexts from complex societies outside of Mesoamerican

(e.g. Tung and Knudson 2008). Overcorrecting for the erroneous notion of a peaceful Maya, scholars may have subsequently attributed human sacrifice to a wide variety of observed mortuary practices, including dismemberment, missing skeletal elements, interment in ritual areas, and secondary burials (Welsh 1988). Yet, as McAnany (1995:60) notes, the remains of revered ancestors were often part of a protracted series of rituals that often led to an incomplete skeleton at its final resting place. This paper addresses the issue of Maya rulership and legitimation by attempting to contribute to the ongoing debate concerning the nature of companion burials and their relationship to their principal figures.

The Late to Terminal Classic Maya site of Pusilhá, located in southern Belize, presents an ideal opportunity to investigate companion burial practices and the methods of elite legitimation. Recent excavations by the Pusilhá Archaeological Project (PUSAP) uncovered the remains of 22 individuals, including three multiple burials, in the ceremonial core of the site. The current project investigates a sample of these individuals by strontium isotope and trace-element analysis in order to determine the childhood location of the sampled individuals. If the results reveal differing signals between the principal and companion figures, then the hypothesis that the companions were captured warriors is supported though not proven, as will be discussed below. If no discernable difference is observed between the individuals, then the companion remains may either belong to revered and curated ancestors, or alternatively, to local, perhaps low status, sacrificial victims ritually offered to the principal figure. Additionally, this paper will contribute to the understanding of the political history of Pusilhá by identifying possible migrants and their regions of origin.

## ANCESTORS AND SACRIFICIAL VICTIMS

Both the use of ancestor remains and the display of sacrificial victims would have been potent symbols of the authority of principal figures. Because ancestor veneration was already a pervasive and fundamental concept to the ancient Maya commoners as early as the Preclassic period (McAnany 1995), the manipulation and display of deceased ancestor remains would have served as powerful, resonant symbols for the elite rulers who appropriated the practice. For the elite Maya, justification for rule was an unbroken chain of succession between themselves and the real or mythical rulers of the past.

Marcus (1992b:262) states that the Maya and other Mesoamerican elites

used their divine ancestors as rationalization for the right to rule, as justification for a whole series of privileges not shared by commoners, and as explanation for skills...that were in fact taught in special school for young nobles.

Thus, through the framework of ancestor veneration, the reign of the living was approved, aided, and sanctified by a connection to the dead. Archaeological,

iconographic, epigraphic, and ethnohistorical sources provide examples of this practice.

Writing in the 16<sup>th</sup> century, Fray Diego de Landa describes a funerary event in which the bones of an ancestor remained in the realm of the living.

Among the ancient lords of the house of the Cocombs they cut off the heads after death, boiled them so as to remove the flesh; then they sawed away the back part of the skull, leaving the front with the cheeks and the teeth, supplying in these half sections of the head the removed flesh by a sort of bitumen, and gave them almost the perfection of what they had been in life. These they kept together with the images, and the ashes, all in the oratorios of their houses among their idols, with great reverence and affection.

(de Landa 1978:57)

Including ancestor bones in funerary rituals would have symbolized the rightful authority of the deceased and, perhaps more importantly, the rightful succession of his or her offspring.

The inclusion of sacrificial victims in funerary contexts, likewise, served as a tactic to legitimate the authority of the Maya elite. Colonial documents and bioarchaeological studies indicate that sacrificial victims were often local low-status Maya, such as criminals, the sick, or children (de Landa 1978:48; Tiesler 2007). Alternatively, they may have resulted from the capture and sacrifice of enemy warriors (Schele and Miller 1986; Tiesler and Cucina 2007). Again, archaeological, iconographic, epigraphic and ethnohistorical data from the Maya region support the actuality of these practices. When the sacrificial victims were local individuals, they may have been dispatched as an offering to the gods or to the principal figure, symbolizing the connection the Maya elite had with the otherworld and their power over the body. Schele and Miller (1986:220) saw the capture and sacrifice of enemy warriors as important not only for building prestige, but also as a fundamental requirement for the office of rulership. Including the remains of sacrificed individuals within the burial would have been a demonstration of power and right to rule.

Although companion burials may have stemmed from very different sources, distinguishing between the two in archaeological contexts often proves difficult, especially in the Maya lowlands where the heat and humidity frequently result in poor bone preservation (Tiesler and Cucina 2007). If cultural markers of violence, such as heart extraction, are obscured due to the lack of preservation, indirect methods for inferring the nature of companion burials are required. Various scholars have attempted

to use indirect indicators, such as burial context, nutrition indices, demographic profiles, and health markers to address this issue (Fowler Jr 1984; McAnany, et al. 1999; Pitcavage 2008; Tiesler 2007; Welsh 1988). Below, I contribute to the ongoing debate concerning the nature of companion burials through an isotopic and chemical investigation of skeletal remains from Pusilhá, Belize.

## PUSILHÁ

Located in the Toledo District of southern Belize, the Maya city of Pusilhá dates to the Late and Terminal Classic periods (600-850 AD) (Figure 1). The city was capital of the regional *Un* (Avocado) polity, situated at the confluence of the Pusilhá and Poité rivers in the southern Maya lowlands (Braswell and Gibbs 2006). Population estimates for the 6 km<sup>2</sup> site suggest a density of 1,100 persons/km<sup>2</sup>, or a total of 6,600 inhabitants, making Pusilhá the most populated Late and Terminal Classic site in the southern Belize region (Volta 2007:39). While the majority of Pusilhá's residential structures lie within the valley between the rivers, the royal palace and elite residences are located on the southern banks of the Pusilhá and are connected to the rest of the site by a unique triple-span stone bridge. Although Pusilhá never boasted monumental architecture on the scale of the largest lowland Maya cities, its most prominent architectural feature, the Gateway Hill Acropolis (Figure 2), contained a series of terraces and ceremonial architecture built atop an impressively modified natural hill. In total, the acropolis reached a height of 79m, making it taller than the Pyramid of the Sun at Teotihuacan (Braswell, et al. 2005; Braswell and Gibbs 2006).

Pusilhá was rediscovered in 1927 by British archaeologists during the British Museum's Expedition to British Honduras and, over the course of four field seasons, it became one of the first systematically excavated sites in Belize (Gruning 1930; Joyce 1929; Joyce, et al. 1927; Joyce, et al. 1928). These early explorations produced the first ceramic sequence for the region and dated the site to the Late Classic period through their analyses of recovered stelae, hieroglyphs, and ceramics (Joyce, et al. 1928). Despite the early interest in Pusilhá, subsequent archaeological research has been sporadic due to its

remote location and difficulty of access. Decades after the British expeditions, Hammond (1975) investigated two caves at Pusilhá as an extension of his larger excavations at Lubaantun. In 1979 and 1980, Levantlhal excavated several test pits, located previously unknown architectural groups, and produced a pace-and-compass map of the site (Levantlhal 1990). The work of Hammond and Levantlhal proved beneficial in that it recognized southern Belize as its own archaeological region or “realm” within the Maya world (Hammond 1975; Levantlhal 1990). During the late 1980s and early 1990s, further exploration of Pusilhá was conducted by Gary Walters who documented several additional architectural groups in a series of unpublished reports (Walters and Weller 1992).

Most recently, extensive research resumed under the banner of the Pusilhá Archaeological Project (PUSAP), directed by Geoffrey Braswell. Interdisciplinary work from 2001 through 2007 consisted of several components, including systematic mapping of the site, test pitting and excavations of major architectural features, architectural consolidation, epigraphic and iconographic analysis, and osteological and artifact analysis (Bill, et al. 2005; Braswell, et al. 2005; Braswell 2001; Braswell and Gibbs 2006; Nickels 2008; Pitcavage 2008; Volta 2007). A primary goal of the PUSAP was to test models of secondary state formation and to understand the political history of Pusilhá in relation to nearby states such as Copan and Tikal. The findings of Braswell and colleagues suggest that Pusilhá, contrary to previous models, was never politically affiliated with its larger neighbors and that secondary state formation in southern Belize may have developed differently than predicted by the dynamic model of state formation by Marcus (1992a) or by the “superstate” model by Martin and Grube (1995).

Although no formal cemetery was discovered during excavations by the PUSAP, 22 burials were uncovered in 17 different funerary contexts (Figure 2; Braswell, et al. 2005; Braswell and Gibbs 2006; for detailed discussion of each burial see Pitcavage 2008). Because of the labor investment in most of these tombs, the nature of their artifact assemblages, and their location within *plazuela* group structures, most burials are assumed to represent high-status individuals. Yet, three burials, Bu 3/1, Bu 3/2, and Bu 8/3, were multiple interments consisting of a primary individual and one or two companions. Recent analysis of Pusilhá dental paleopathology by Pitcavage (2008) suggests that the companion burials lived different lifestyles than the principal individuals and that the companions may have been sacrificial victims. Because maize is a socially valuable yet cariogenic food, individuals of higher status were expected to exhibit a higher rate of caries and dental calculus. Despite the somewhat limited skeletal sample of Pusilhá, Pitcavage (2008) observed a significant difference between the primary and companion individuals, with the primaries exhibiting both higher average rates of caries and higher calculus scores than their companion figures. This indicates a general division in health and status within the multiple burials and suggests that the companion figures were ritually sacrificed individuals disposed of as a means to demonstrate the power and authority of the Maya elite. The present project builds upon the work of Pitcavage and presents data concerning the geographic origins of the companion burials in relation to their primary figures.

## PRINCIPLES OF STRONTIUM ISOTOPES AND CHEMICAL ANALYSES

The radiogenic isotope ratios of strontium in combination with trace-element analysis or other isotopic studies are rapidly becoming an integral part of archaeological investigations, especially in Mesoamerica and the Andes (e.g., Burton, et al. 2003; Knudson and Price 2007; Knudson, et al. 2004; Knudson, et al. 2009; Price, et al. 2008). The chemical and isotopic ratios in bones and teeth reflect dietary, climatological, and geographic information relevant to the life history of the individual under study (Ambrose and Krigbaum 2003; Katzenberg and Harrison 1997; Schoeninger and Moore 1992). Over the past two decades, these analyses have proven extremely useful in Maya bioarchaeology. Strontium isotope ratio analysis and trace-element analysis of strontium and barium are here applied to a sample of the skeletal remains from Pusilhá to investigate the relationship between the principal and companion burials and to identify any possible immigrants within the sampled population.

### *Strontium Isotope Analysis*

Strontium isotope ratios in an ecosystem are a factor of the local geology and these ratios are incorporated into the skeletal tissue of organisms that consume local flora and fauna. Regional strontium isotope values vary depending on the age and nature of the geological sediments. Strontium-87 ( $^{87}\text{Sr}$ ) is the end-product of the decay of rubidium-87 ( $^{87}\text{Rb}$ ), a process by which the radioactive  $^{87}\text{Rb}$  transforms into  $^{87}\text{Sr}$  over time.  $^{86}\text{Sr}$  is a stable isotope and the ratio of  $^{87}\text{Sr}/^{86}\text{Sr}$  is a function of the age of geological deposits. Generally, rocks older than 100 mya that originally had high Rb/Sr ratios are expected to have  $^{87}\text{Sr}/^{86}\text{Sr}$  values  $> 0.710$ . More recent rocks ( $< 1-10$  mya) with low original Rb/Sr

ratios are expected to have  $^{87}\text{Sr}/^{86}\text{Sr}$  values  $< 0.704$  (Bentley 2006; Faure and Powell 1972). Since the variation of  $^{87}\text{Sr}/^{86}\text{Sr}$  values is a function of both time and the original abundance of  $^{87}\text{Rb}$  in the bedrock, isotope values can be quite variable between regions.

Strontium is released from rocks through weathering and enters the biological cycle by being incorporated in plant material. Plants growing in a given area will exhibit similar  $^{87}\text{Sr}/^{86}\text{Sr}$  values to the local geology, and due to the small mass difference between  $^{87}\text{Sr}$  and  $^{86}\text{Sr}$ , strontium does not fractionate as it is metabolized by plants and animals and transported through trophic levels. Like calcium, strontium is a member of the alkaline earth metals and has two valence electrons. Because of their similar atomic radii, strontium occasionally substitutes for calcium during bone and enamel formation (Elias, et al. 1982; Schroeder, et al. 1972). Organisms that consume local plants will exhibit the local  $^{87}\text{Sr}/^{86}\text{Sr}$  values in their skeletal tissue and in a stable local ecosystem, plants, herbivores, and predators will all exhibit the same ratios of  $^{87}\text{Sr}/^{86}\text{Sr}$ . Therefore, the strontium isotope composition of the foods in a given region will be reflected in the skeletal tissue of living organisms. Because bone remodels through time, an individual's skeleton will eventually come to exhibit the same  $^{87}\text{Sr}/^{86}\text{Sr}$  value of a new region after a residential relocation. Enamel, on the other hand, forms during childhood and undergoes no subsequent remodeling. Even if an individual relocated to an isotopically different region, their enamel would retain the  $^{87}\text{Sr}/^{86}\text{Sr}$  ratio of the area during original mineralization. Comparing  $^{87}\text{Sr}/^{86}\text{Sr}$  ratios between different individuals, or between individuals and the local geology, or even between one individual's bone and enamel provides the opportunity to observe past migrations and residential mobilities (Bentley 2006; Price, et al. 1994).

Because  $^{87}\text{Sr}/^{86}\text{Sr}$  values can vary greatly within an individual rock or sediment deposition and because these variations may be transferred to plant material, sampling rocks, soil, or plants may provide unrepresentative baseline signals. Instead, Price et al. (2002) suggest using local animal tissues as proxies for the expected variation in  $^{87}\text{Sr}/^{86}\text{Sr}$  within a given region. Small mammal species consume foods within a finite area and integrate the range of local values within their bones. The integration effect reduces the potential intra-site variability and has proven to provide accurate local baseline values (Knudson and Price 2007; Price, et al. 2000). When small mammal species are not available for baseline sampling, the human values may be used. Archaeological human populations will generally consume similar foods grown in similar locations through time and thus averaging the  $^{87}\text{Sr}/^{86}\text{Sr}$  values from a population of humans may also provide reliable baseline data. Price et al. (2002) propose finding the mean  $^{87}\text{Sr}/^{86}\text{Sr}$  value from either small mammals or from a local human sample and setting a limit of two standard deviations as the expected variation for an archaeological site. According to this line of reasoning, any individuals who exhibit  $^{87}\text{Sr}/^{86}\text{Sr}$  values above or below two standard deviations from the mean should represent immigrants to the site.

An additional factor to consider in establishing local baseline values is the source of strontium for the sampled fauna or humans. As maize was the staple food of the Classic Maya (e.g. White 1999), much of the Sr uptake most likely came from alkaline processing of maize in order to dissolve the outer shell, or pericarp, from the kernels (Wright 2005). Lime processing raises the Ca and Sr content by 10-20 fold and, theoretically, will bias the  $^{87}\text{Sr}/^{86}\text{Sr}$  value towards that of the lime used in processing (Burton and Wright 1995). If a settlement imported their lime, the  $^{87}\text{Sr}/^{86}\text{Sr}$  values of

sampled skeletal elements may represent a false local average. As Pusilhá is situated near, and perhaps partially within, a geological region composed primarily of carbonate breccia (Purdy, et al. 2003), it is not likely that the Classic Period residents would have imported limestone from great distances.

A second variable source of strontium to consider is the intake of sea salt. The modern  $^{87}\text{Sr}/^{86}\text{Sr}$  ratio of seawater has a relatively high value of 0.7092, which is also reflected in the values of salt. Wright (2005:562-563) suggests that the importation of sea salt to Tikal may explain the elevated  $^{87}\text{Sr}/^{86}\text{Sr}$  values in her human samples over the local geology. If the residents of Pusilhá imported large enough quantities of salt from the coast, their  $^{87}\text{Sr}/^{86}\text{Sr}$  values may be affected. Similarly, if seafood, such as small fish, was consumed whole, including the calcium-rich bones, the  $^{87}\text{Sr}/^{86}\text{Sr}$  ratios in human bone and enamel might be raised towards the value of seawater. However, experimental studies demonstrating this phenomenon are lacking.

### *Trace-Element Analysis*

Unlike the isotope analysis, which measures the *ratios* of two isotopes of strontium, trace-elemental analysis is useful in determining the *concentration* of a particular element. Concentrations of strontium and barium in bioapatite were originally used primarily for paleodietary analysis. Based on the principle of biopurification of calcium (Elias, et al. 1982; Schroeder, et al. 1972), strontium to calcium ratios (Sr/Ca) were expected to represent the amount of plant and meat contributions to the diet of an individual (e.g., Schoeninger 1979; Toots and Voorhies 1965). Although strontium substitutes for calcium in bone and enamel, it does not pass through the alimentary canal

wall as efficiently as calcium. This process led researchers to predict that organisms with higher trophic positions would exhibit smaller concentrations of strontium than organisms of lower trophic positions. In controlled ecosystem analyses, carnivores had lower Sr/Ca values than herbivores, and herbivores had lower values than plants (Elias, et al. 1982). These analyses were widely used to determine the degree of meat consumption among human populations and between social classes.

Similarly, barium is also subject to biopurification and Ba/Sr ratios have also been used to gauge the relative contribution of marine foods to the diet of individual organisms (e.g., Ezzo, et al. 1995). Although concentrations of barium and strontium appear to be distributed somewhat evenly in terrestrial environments (Ba/Sr=1), barium levels are much less abundant in seawater relative to strontium (Ba/Sr < 0.001). Consequently, marine organisms exhibit significantly depleted levels of barium in their inorganic tissues, and marine mammals may be easily distinguished from terrestrial mammals by concentrations of barium in their bone and enamel (Burton and Price 1990; Wessen, et al. 1977). These findings suggested that humans exhibiting relatively low ratios of barium to strontium consumed significant amounts of marine food (Burton and Price 1990).

Although experimental studies have demonstrated that Sr/Ca and Ba/Ca of bone and enamel do indeed track dietary Sr/Ca and Ba/Ca, recent research has exposed several problems with strontium and barium as paleodiet indicators (Burton and Price 2000). Principal among these objections is the realization that strontium and barium inputs in bioapatite are biased towards food sources that contain high amounts of calcium. Since plants contain much more calcium than does meat, the use of strontium to test degree of

meat consumption may not be valid. Significant differences in Sr concentrations are indeed observed between pure carnivores and pure herbivores, but omnivorous organisms produce unreliable results as “the dietary Sr/Ca ratio for mixed diets is not linearly related to the plant/meat ratio or even particularly sensitive to it” (Burton and Price 2000:163). Although Sr and Ba in human skeletal tissue do come from dietary sources, they most likely reflect calcium rich botanical inputs, which draw their strontium from the local geology.

An additional problem with using Sr/Ca and Ba/Ca concentrations as paleodiet indicators is the fact that the natural variation in strontium and barium abundances can differ significantly between regions independently of the types of foods consumed. The geological differences between areas can result in variability in strontium and barium abundances that exceeds the variation expected from individual dietary differences (Burton, et al. 2003). Although problematic for dietary research, the regional differences in Sr and Ba concentrations allow Sr/Ca and Ba/Ca to be used as an additional tool for tracking human mobility patterns (Burton, et al. 2003; Knudson and Price 2007). Since Sr and Ba are incorporated into skeletal tissue in proportion to their local abundances, their concentrations in human remains will reflect the profile of the local geology. By comparing the local abundances of strontium and barium to the abundances in human bone and teeth, or by comparing the abundances between individuals, patterns of migration and mobility may be discerned.

## GEOLOGICAL VARIATION AND IMPLICATIONS FOR DEFINING LOCAL AND FOREIGN

Since both strontium isotope and trace element values in human bone vary depending on the geology of a region, here I provide a brief summary of the geological variation of southern Belize and discuss its relevance to the problem of defining “local” and “foreign” individuals within the mortuary population at Pusilhá.

The Toledo District and Pusilhá fall within the larger geological area of the Southern Maya Lowlands, a wide region generally characterized by flat-lying limestone that traverses sections of southern Mexico, Guatemala, and southern Belize. By analyzing rock, water, soil, and plant samples from across the Maya world, Hodell et al. (2004) produced a  $^{87}\text{Sr}/^{86}\text{Sr}$  distribution map with the intent of providing baseline data for future migration studies. Their results demonstrate a general trend of relatively higher  $^{87}\text{Sr}/^{86}\text{Sr}$  ratios in the carbonates of the Northern Lowlands ( $0.7089 \pm 0.0007$ ;  $n=16$ ;  $2\sigma$ ) giving way to the lower values of the Southern Lowlands, which have a  $^{87}\text{Sr}/^{86}\text{Sr}$  range of 0.7071-0.7082 ( $n=86$ ) and exhibit an average  $^{87}\text{Sr}/^{86}\text{Sr}$  value of  $0.7077 \pm 0.0005$  ( $2\sigma$ ) (Hodell, et al. 2004). Within Belize, this trend is interrupted by the Maya Mountains, which have very positive  $^{87}\text{Sr}/^{86}\text{Sr}$  ratios ( $0.7133 \pm 0.0017$ ;  $n=3$ ;  $2\sigma$ ) due to their advanced age. South of Belize, the Volcanic Highlands and Pacific Coast exhibit much higher  $^{87}\text{Sr}/^{86}\text{Sr}$  ratios ( $0.7042 \pm 0.00023$ ;  $n=34$ ;  $2\sigma$ ). Another distinct region, the Metamorphic Province, exhibits widely variable  $^{87}\text{Sr}/^{86}\text{Sr}$  ratios ( $0.7074 \pm 0.0057$ ;  $n=50$ ) and is located southeast of the Southern Lowlands. Although useful for observing macro geological differences within the Maya world, more precision is needed to address specific questions of human migration.

Pusilhá lies within an especially heterogeneous portion of the Southern Lowlands. The city itself is situated mostly within a narrow strip of the Toledo Formation, a patchy geologic region that spans southern Belize into western Guatemala. This formation dates to the Paleocene and Eocene epochs and is characterized by siliciclastic sediments, siltstone and sandstone beds, and hemipelagic clays (Purdy, et al. 2003; Tunich-Nah 2007). However, an older geological zone known as La Cumbre Formation borders Pusilhá, and outskirts of the city may lie on its soils. This formation, a Campanian to early Paleocene carbonate breccia almost completely surrounds Pusilhá and is itself nestled within the Toledo Formation (Purdy et al. 2003). Additionally, patches of recent Quaternary limestone and Late Carboniferous Permian formations lie within walking distance from Pusilhá, adding to the mottled nature of southern Belize geology (Meerman and Clabaugh 2009; Tunich-Nah 2007). As no fine-scaled isotopic or trace-element mapping has been conducted throughout these regions, we must assume that variation of  $^{87}\text{Sr}/^{86}\text{Sr}$  ratios and trace-element concentrations exists within the Pusilhá kingdom and that individuals living in its disperse corners may exhibit differing values.

The geologic heterogeneity within the Pusilhá kingdom has implications for which individuals may be defined as “local” or “foreign.” Local individuals may be viewed from two levels. On one hand, local could describe someone who lived within the larger sphere of the Pusilhá kingdom, which spanned at least two distinct geological formations and, before approximately 750 A.D., might have extended as far north as to include the territories of Lubaantun and Nim li Punit (Geoff Braswell personal communication 2009). Although residents of the kingdom may have identified themselves as part of the Pusilhá sphere, they could have consumed food grown on soils

isotopically and chemically distinct from food grown near the city center. In this situation, an ally or ancestor could be erroneously interpreted as a foreigner or an enemy due to differing isotope or chemical values of their bones or teeth. On the other hand, a stricter definition of local could describe an individual raised within the limits of the Pusilhá settlement. This more constricted definition of local has the advantage of narrowing the potential range of isotopic and chemical variation but runs the risk of labeling an individual as foreign who was in fact closely affiliated with Pusilhá. For the present study, I adopt the tighter definition of local – i.e. individuals who spent their childhood within the limits of the city of Pusilhá proper. Consequently, nonlocal individuals cannot be determined to be captured enemy warriors simply because they spent their childhood in an isotopically or chemically distinct region because, as discussed above, the kingdom of Pusilhá extended over geologically diverse regions and individuals who identified themselves as belonging to the Pusilhá system may appear as foreigners. This tighter definition, since it reduces the possible areas of agriculture to those near the city, allows a more comfortable usage of the method proposed by Price et al. (2002) for identifying nonlocal individuals as those who exhibit values more than two standard deviations from the population mean.

Since the Pusilhá kingdom probably never extended outside of the Southern Lowlands, the definition of foreign, at its broadest, includes any individual with a strontium isotope ratio that falls outside of this regional range, as defined by Hodell et al. (2004). For the present study, individuals who exhibit Sr isotope and trace-element values more than two standard deviations from the mean will also be considered nonlocal, though they will not necessarily be assumed to be captured enemy warriors. Sampled

individuals that do exceed the local two-sigma range but fall within the  $^{87}\text{Sr}/^{86}\text{Sr}$  range of the Southern Lowlands will be discussed and possible origins will be hypothesized, but this will be done with the above-described caveats in mind.

## MATERIALS AND METHODS

Sixteen of the 22 burials recovered from excavations by the Pusilhá Archaeological Project (PSAP) were sampled for the present study. Three sets of principal individuals and their companion burials were included to test their relationship to each other. Because enamel has been shown to preserve a biogenic signal far longer than bone (Kohn, et al. 1999; Lee-Thorp and Sponheimer 2003), perhaps as far back as the Triassic (Botha, et al. 2005), only teeth samples were selected for the present study. Enamel has much larger hydroxyapatite crystals than bone, resulting in less surface area available for diagenetic exchange to occur. Also in comparison to bone, enamel contains very little organic material (approximately 2%) making it much more resistant to post-depositional contamination (Hillson 1996). The selected teeth represent similar developmental stages in the lives of the sampled individuals. The crown of the second molar mineralizes between ages 3 and 7 (Hillson 1996). Since this tooth was represented in greater frequency than the other molars and is not likely to contain a weaning signal, it was preferentially selected for analysis. Other teeth used in this study were permanent first molars, the crowns of which begin mineralizing *in utero*, permanent third molars, which mineralize between ages 7 through 12, and a permanent canine, which begins to mineralize at approximately 4 months and finishes at around 6 years (Hillson 1996:123). Deciduous molars were selected from the two sub-adults of the sample. Hence, all enamel specimens represent the isotopic and trace element signal, and therefore geographical location, of the sampled individuals during their childhood years.

All teeth samples were mechanically cleaned in Margaret Schoeninger's Paleodiet Laboratory at the University of California, San Diego. The enamel surface of each tooth

was ablated with a Dremel rotating saw equipped with a carbide burr in order to remove dirt and surface enamel. A section of enamel spanning the crown to cervix (~30-40 mg) was removed using a Dremel diamond cutting wheel. Removing a vertical segment of enamel ensures that the sample will represent an average isotope ratio and trace element concentration signal from the duration of the crown's formation and will not bias the analysis towards any particular temporal episode. Because studies have conclusively demonstrated that dentin is much more prone to diagenesis than enamel (Budd, et al. 2000), all dentin adhering to the enamel wedge was removed by further drilling with a carbide burr. Remaining enamel pieces were powdered in an agate mortar and pestle and separated into mini-centrifuge tubes for strontium and trace elemental analyses.

Although proven to be very resistant to contamination, enamel is not completely immune from diagenetic processes. Enamel is composed of approximately 96% calcium phosphate hydroxyapatite [ $\text{Ca}_{10}(\text{PO}_4)_6(\text{OH})_2$ ] by weight, with water and organic matter comprising the remaining 4% (Hillson 1996:218). Elements such as fluorine, uranium, and the rare earth elements (REE) can readily substitute for OH and Ca in hydroxyapatite and are thousands of times greater in fossil enamel than in modern enamel (Kohn, et al. 1999; Trueman and Tuross 2002). Similarly, Sr and Ba from the burial environment may substitute for Ca in the calcium phosphate of teeth. If this substitution occurs during diagenesis, isotopic and trace element analyses may produce erroneous data; Sr and Ba concentrations may increase and  $^{87}\text{Sr}/^{86}\text{Sr}$  values in enamel may shift to resemble the ratios of the local burial environment, obscuring any evidence of residential mobility.

In order to test for diagenetic contamination, all samples were analyzed for concentrations of U and the REE. These elements are the most appropriate for detecting

post-depositional contamination of bioapatite because, like Sr, they substitute for Ca in hydroxyapatite, are readily analyzed, and occur in extremely low abundances in modern teeth (Kohn, et al. 1999:2744). Approximately 4 to 6 mg of powdered enamel were dissolved in 4 M nitric acid ( $\text{HNO}_3$ ). This was subsequently heated on a hotplate until all acid had evaporated, leaving only a white precipitate. All samples were then diluted by a factor of 4,500 in 2%  $\text{HNO}_3$  that contained 1 ppb indium for machine tuning. Concentrations were obtained by a Finnegan Element II inductively coupled plasma-mass spectrometer (ICP-MS) at the Scripps Institute of Oceanography Unified Laboratory Facility under the supervision of Liyan Tian and myself.

Sample processing for strontium isotope analysis took place in the Isotope and Geochronology Clean Laboratory at Scripps Institute of Oceanography, University of California, San Diego under the direction of professor Paterno Castillo, Christopher MacIsaac, and myself. Between 4 and 6 mg of powdered enamel were placed in pre-cleaned Teflon vials and dissolved in 4 M nitric acid ( $\text{HNO}_3$ ). These vials were then uncapped and the sample solution was dried down under heat until only a white precipitate remained. This precipitate was subsequently dissolved in 100  $\mu\text{L}$  of 0.75 M hydrochloric acid ( $\text{HCl}$ ) at room temperature. Strontium was separated in primary quartz cation-exchange columns (internal diameter = 0.5 cm; height = 25 cm) using 1,000  $\mu\text{L}$  of Bio-Rad AG50W-X8 resin (200-400 mesh). The columns were first conditioned with 1.8N  $\text{HCl}$  and then the dissolved samples were loaded in the solution of 0.75 M  $\text{HCl}$ . Strontium was eluted with 1.8 M  $\text{HCl}$  into Teflon beakers, loaded onto degassed W filaments, and the ratios of  $^{87}\text{Sr}/^{86}\text{Sr}$  were obtained through thermal ionization mass spectrometry (TIMS) on a Micromass Sector 54 multicollector mass spectrometer.

Recent analyses of carbonate standard NBS-987 produced an average  $^{87}\text{Sr}/^{86}\text{Sr}$  value of  $0.710259 \pm 0.000016$  ( $2\sigma$ ), which is well within the range of previously published values (Platzner 1985).

To obtain elemental concentrations of strontium, barium, and calcium, the powdered enamel samples were analyzed at the Scripps Institute of Oceanography Unified Laboratory Facility by inductively coupled plasma-optical emission spectroscopy (ICP-OES), model Optima 3000DV. Between 4 and 6 mg of powdered enamel were dissolved 4 M HCl. An aliquot of sample solution was then placed in a pre-cleaned centrifuge tube, diluted in 1%  $\text{HNO}_3$ , and analyzed on the ICP-OES. Results are presented in parts per million (ppm).

## RESULTS

### *Diagenesis*

Results from the ICP-MS indicate that concentrations of uranium and the rare earth elements are extremely low and are well within the range of biogenic enamel (Kohn, et al. 1999). The average ratio of U/Ca =  $8.4 \times 10^{-8} \pm 1.0 \times 10^{-7}$  (n=15, 1 $\sigma$ ) with an average U concentration of 0.03 ppm. These values indicate no post-mortem uptake of U and thus suggest that the strontium isotope and trace element data represent the ratios and concentrations consumed in vivo. The rare earth element lanthanum, like uranium, readily substitutes for Ca in the apatite lattice of post-mortem bone and its presence in enamel in concentrations less than 1 ppm suggest that the bone or enamel contain biogenic values (Trueman and Tuross 2002). The enamel samples from Pusilhá exhibit an average La/Ca ratio of  $2.9 \times 10^{-7} \pm 5.7 \times 10^{-7}$  (n=15, 1 $\sigma$ ) with an average concentration of 0.11 ppm. Neither the U nor the REE results provide any evidence of post-mortem chemical changes in the apatite lattice and all subsequent data are expected to represent biogenic values.

### *Strontium Isotope Results*

The teeth samples from Pusilhá display a strontium isotope range of  $^{87}\text{Sr}/^{86}\text{Sr} = 0.7061 - 0.7086$  with an average  $^{87}\text{Sr}/^{86}\text{Sr}$  value of  $0.7078 \pm 0.0007$  (n=15, 1 $\sigma$ ) (Figure 3; Table 1). The individual from Bu 5/1 was analyzed and a  $^{87}\text{Sr}/^{86}\text{Sr}$  value was produced ( $^{87}\text{Sr}/^{86}\text{Sr} = 0.7079$ ), but the sample appeared dirty on the filament and will not be included in the following discussion, although the produced ratio falls very close to the mean. Because no small mammals from Pusilhá were analyzed to provide a background

$^{87}\text{Sr}/^{86}\text{Sr}$  signal, the sampled humans provide the local baseline in comparison with the published data from the region (Hodell et al. 2004).

To detect any nonlocal individuals within the sample population, the mean value  $\pm$  two standard deviations was established as the local signature for Pusilhá. The resulting  $^{87}\text{Sr}/^{86}\text{Sr}$  range is 0.7064 - 0.7091. Within these parameters, one individual clearly stands out as nonlocal. The adult female from Burial 4/1 exhibits a  $^{87}\text{Sr}/^{86}\text{Sr}$  value of 0.7061, the lowest ratio of the sample set. Her partially-articulated remains were found on the surface of the Terminal Classic plaza and were associated with a smashed red-ware vessel. The intact cranium was discovered beneath a capstone while scattered arm bones were found several meters away, suggesting that they were disturbed by animal activity. Additionally, as will be discussed below, the trace element data further support her nonlocal status. However, the exact temporal provenience of this individual is unknown and her death may represent a period long after the abandonment of Pusilhá.

Due to the small sample size and obviously nonlocal status of Burial 4/1, we may recalculate the site mean and range with her  $^{87}\text{Sr}/^{86}\text{Sr}$  value excluded in order to establish a tighter local baseline signature. With Burial 4/1 removed, the mean  $^{87}\text{Sr}/^{86}\text{Sr}$  enamel value becomes  $0.7079 \pm 0.0005$  ( $n=14$ ,  $1\sigma$ ) and the two sigma range becomes 0.7068 - 0.7089 (Figure 3). Assigning an average baseline  $^{87}\text{Sr}/^{86}\text{Sr}$  value of approximately 0.7079 for Pusilhá is supported by isotopic results from the enamel of Burial 8/4. This adult male was interred in by far the most elaborate tomb uncovered at Pusilhá and has been tentatively identified as the Terminal Classic *ajaw*, Ruler G (Braswell, et al. 2005:80-81). Although his paternal grandfather was a noble from an unidentified site and his father was not an *ajaw* of Pusilhá, Ruler G was the son of a local female ruler and should

therefore represent the local  $^{87}\text{Sr}/^{86}\text{Sr}$  value (Braswell, et al. 2004). The present study finds that this individual has a  $^{87}\text{Sr}/^{86}\text{Sr}$  value of 0.7078, which is very similar to the group average and well within the regional range produced by Hodell et al. (2004).

The “trimmed” range reveals one to two more individuals who appear nonlocal isotopically, both of whom were recovered from within Structure 3, a 2-m high north-south orientated platform mound in the Gateway Hill Acropolis. This multiple burial consisted of one primary individual, a young adult male, and two unsexed companion individuals who are represented by only their dentition and a few fragments of bone. The remains of the sampled companion were discovered within a flat red-ware dish located near the pelvis of the principal individual while the remains of the second, unsampled, companion were found near the head of the principal figure. Although the companion ( $^{87}\text{Sr}/^{86}\text{Sr} = 0.7067$ ) falls outside of the Pusilhá range, the principal figure ( $^{87}\text{Sr}/^{86}\text{Sr} = 0.7069$ ) falls at the low end but within the range by 0.0001. Nevertheless, this individual will be considered nonlocal for three reasons. First, his association, both isotopically and contextually, with the nonlocal companion suggests that he was affiliated with this foreign individual. Secondly, this individual, along with his companion figure and Bu 4/1, falls, not only far from the Pusilhá mean, but outside of the broad  $^{87}\text{Sr}/^{86}\text{Sr}$  range provided by Hodell et al. (2004) for the Southern Lowlands. Finally, because of the small sample size, the two sigma range for Pusilhá should not be considered a hard line, but rather a suggestive tool for interpreting the isotopic evidence. If the individual from Bu 4/1 and the two individuals from Bu 3/1 are excluded, 92% (11 out of 12) of all other sampled individuals fall tightly within one standard deviation of the mean. Although the principal figure from Bu 3/1 is slightly within two standard deviations, he appears

isotopically different from nearly all other individuals (Figure 6). Taken together, these lines of evidence suggest that both the principal and the sampled companion figure in Bu 3/1 are nonlocal individuals who spent their childhood in a geologically distinct region and migrated to Pusilhá sometime before their death. Possible locations for these individuals will be discussed in more detail below.

Importantly, the  $^{87}\text{Sr}/^{86}\text{Sr}$  data from all three sets of principal-companion burials exhibit no significant differences between the primary and secondary individuals, although the possibility remains that the sampled individuals came from different sites with isotopically similar geology. Nevertheless, the current  $^{87}\text{Sr}/^{86}\text{Sr}$  data provide no evidence that the companion figures were sacrificed enemies from foreign locations.

Even when the three nonlocal individuals are excluded, the range for the rest of the Pusilhá population is somewhat large. This may in part be due to differential consumption of salt or marine foods, which would raise the enamel  $^{87}\text{Sr}/^{86}\text{Sr}$  ratios toward 0.7092 in individuals who consumed more of these products. Also, as discussed above, the local geology of the Toledo District is quite heterogeneous (Meerman and Clabaugh 2009) and if individuals were consuming crops grown in different micro-locations, variations in the  $^{87}\text{Sr}/^{86}\text{Sr}$  signal would be expected.

### *Trace Element Results*

The trace element results produced from analysis by ICP-OES provide a second line a data to the Sr isotope results and allow for a finer-resolution examination of residential mobility at Pusilhá. The Sr and Ba trace element concentrations are normalized with Ca concentrations and, because Sr/Ca and Ba/Ca exhibit logarithmic

rather than normal distributions, values are here expressed in  $\text{Log}_{10}(\text{Sr}/\text{Ca})$  and  $\text{Log}_{10}(\text{Ba}/\text{Ca})$  form to enable quantitative comparative analyses (Burton, et al. 2003). The average  $\text{Log}(\text{Sr}/\text{Ca})$  value for the Pusilhá enamel is  $-3.91 \pm 0.25$  ( $n=16$ ,  $1\sigma$ ) while the mean  $\text{Log}(\text{Ba}/\text{Ca})$  value is  $-4.8 \pm 0.19$  ( $n=16$ ,  $1\sigma$ ; Figures 4 & 5, Table 1).

The raw ppm Sr data from all teeth appear very low at first glance (mean= 57.4 ppm). All individuals exhibit low Sr concentrations with the exception of Burial 4/1 (Sr = 259.8 ppm), the above discussed adult female who had a nonlocal Sr isotope ratio (Figure 4). This individual exhibits a  $\text{Log}(\text{Sr}/\text{Ca})$  value of -3.19, giving her the most positive value of the sample set. Furthermore, this sample has the only  $\text{Log}(\text{Sr}/\text{Ca})$  value that falls more than two standard deviations from the population mean, further supporting her status as a nonlocal individual. The  $\text{Log}(\text{Ba}/\text{Ca})$  value for Bu 4/1 is -4.69, which is not significantly different from the mean. Apparently this individual spent her childhood years in a different region where differences in the local geology or stark differences in diet resulted in a much higher concentration of Sr in her enamel apatite.

The only  $\text{Log}(\text{Ba}/\text{Ca})$  value that falls more than two standard deviations from the mean comes from Bu 5/1. This individual is a subadult, aged 4-5 by dental development (Pitcavage 2008), and is here represented by a deciduous molar. Interestingly, this child had jade inlays set into its deciduous incisors, a unique feature in the Maya world. Although Bu 5/1 exhibits the most positive  $\text{Log}(\text{Ba}/\text{Ca})$  value (-4.36) of the sample set, his or her  $\text{Log}(\text{Sr}/\text{Ca})$  value (-3.82) falls close to the average. Since the deciduous first molar begins forming in utero and is complete shortly after birth, the  $\text{Log}(\text{Ba}/\text{Ca})$  value partially reflects the fetal source of barium, which is partially a factor of the maternal Ba intake and might also be altered by fetal biological processes. Unfortunately, the  $^{87}\text{Sr}/^{86}\text{Sr}$

data produced for this individual are not reliable due to a “dirty” filament (though the produced value is close to the sample mean). At this time, no conclusions may be made regarding geographic origin.

Although the trace-element data are not being used for paleodietary analysis in this paper, it is interesting to note that within the multiple-interment burials, all three principal figures exhibit lower  $\text{Log}(\text{Sr}/\text{Ca})$  values than their respective companions. This suggests that the principal figures may have consumed foods with less calcium than their companions. Yet these differences, although suggestive, are very small and not on an order large enough to suggest differing trophic levels.

## DISCUSSION

### *Companion Burials*

The isotopic and trace element data produced from the Pusilhá enamel provide valuable information on the nature of elite rulership and on the political affiliations of Pusilhá. By comparing the data from the principal and companion figures we may better understand methods by which the elite Maya maintained their right to rule. The data presented here do not support the theory that the companion figures were nonlocal individuals who were captured and sacrificed as a display of the elites' authority. The strontium isotope results demonstrate no significant differences between the principal and companion figures, as would be expected if they were nonlocal sacrificial victims (Figure 6). Additionally, the trace element data of the companions do not significantly differ from the principal figures, further supporting their local origin.

At this point, the second question to ask is whether the companion skeletal remains belonged to revered ancestors/family members or to local sacrificial victims. When the dental health analysis by Pitcavage (2008) is considered alongside the isotopic and chemical data, a complex picture emerges. Pitcavage's results demonstrate that average differences do exist between the general health, and consequently status, of the principal and companion remains from Bu 3/1 and Bu 3/2, with the principals exhibiting higher average percentages of caries and higher average calculus scores than their respective companions.

Nevertheless, if the nonlocal status of the principal figure from Burial 3/1 is accepted, then the data suggest that he was buried at Pusilhá along with at least one other individual from his original location. In this situation, the identity of the companion is

confused by its ambiguous dental health. The companion figure exhibits caries on 25% of his or her teeth, which is a higher percentage than the principal figure from Bu 3/2 and higher than the high-status average for Pusilhá (22%, n=15). Additionally, his or her calculus score is not substantially less than the average score for principal individuals (0.92 vs. 1.16) and no linear enamel hypoplasia was observed, indicating no periods of severe stress during the period of enamel development (Pitcavage 2008). Moreover, the second companion figure had jade inlays set into its incisors, a general marker of status. When singled out and compared to the rest of the population, the sampled companion figure appears more high-status than low-status. Based on the current data, the companion heads interred within Bu 3/1 are tentatively interpreted here as belonging to revered ancestors. The companion skulls may represent either the remains of individuals who migrated to Pusilhá during their life or individuals who perished in their original location and whose remains were brought to Pusilhá by the principal figure at some point during the Late Classic Period.

The dental data from Burial 3/2, on the other hand, does indicate clear differences in diet, health, and consequently status, between the principal and companion figure. The most likely explanation for the companion from Bu 3/2 is that he was a lower status local individual sacrificed by the elite of Pusilhá, a practice documented in the ethnohistorical and archaeological literature (de Landa 1978; Tiesler 2007).

The third multiple burial analyzed in the present study, Burial 8/3, similarly to Bu 3/1 and Bu 3/2 exhibits no appreciable difference in strontium isotope or trace element data between the principal individual and the secondary interment. However, unlike Bu 3/1 and Bu 3/2, the companion figure, an old adult female, was interpreted to have had

greater access to maize than the principal figure based on percentage of caries and dental calculus scores (Pitcavage 2008). This is consistent with the general notion that women tend to consume more carbohydrates than men due to their association with maize-processing activities. Also unlike Bu 3/1 and Bu 3/2, which were single depositional events, Bu 8/3 appears to have been opened and sealed on multiple occasions. This companion figure, flexed and located to the north of the principal individual, has been interpreted to be the wife of the principal figure and the mother of the subadult. Because of her older age, she presumably died later in life than the male (Pitcavage 2008). The isotope and trace element data confirm the fact that both individuals spent their childhood lives at Pusilhá, where they were both later buried.

In sum, the isotopic and elemental data, in combination with Pitcavage's (2008) relative health study, suggest a complicated picture of mortuary practices at Pusilhá. The three multiple burials may represent three very different types of interments. Burial 3/1 appears to contain the remains of at least two foreigners with roughly similar health and social status. In this situation, the relationship of the primary to secondary individuals may represent the curation of the remains of revered ancestors. Burial 3/2 appears to contain a principal elite figure and the remains of a local sacrificial victim who was of lower social status. Finally, Burial 8/3 contains the remains of what may be a family unit. A local adult male interred with a local adult female and the scattered remains of a subadult most likely represents a family vault.

### *Geographic Origins*

Due largely to abuse by archaeologists who, among other faults, equated changes in ceramic styles with migratory events, migration theory largely fell out of fashion in archaeology during the 1960s and 1970s (cf. Cameron 1995; Chapman and Hamerow 1997). More recently, migration as a viable concept of study and as a potential source for social change, has seen a resurgence in the past two decades and new models and methods for investigating human mobility have been the focus of a number of scholars (e.g. Anthony 1990; Montgomery, et al. 2005; Price, et al. 2000; Smith 1984). In reference to the sea-change in migration studies, Beekman and Christensen (2003:134), note that recently

archaeologists have recognized that migrations are excellent occasions for the study of ethnicity, culture contact, restructuring of power relations, crisis decision making, and the adjustments necessary to accommodate new people into an existing social situation, all important theoretical issues.

With the reemergence of mobility studies in anthropological archaeology, scholars have turned away from notions of migration as merely a mechanistic response to push and pull factors and now view residential mobility as a social strategy - one option among several to negotiate complex problems such as climate change or political turmoil (Anthony 1997). Additionally, this theoretical framework allows for an understanding of the movement of people as a part of internal social and political processes and not merely as responses to external inputs to the system. For example, individuals within the Classic Maya world migrated as part of political processes of forming strategic alliances, especially through marriage, which would send local men or women to live in distant communities (e.g. Marcus 1973).

Ascertaining the geographic origins of nonlocal individuals from Pusilhá may provide important information concerning the political and economic history of the site. However, baseline sampling for strontium isotopes and trace elements across Mesoamerica has yet to reach a level of precision necessary to determine which specific settlements nonlocal individuals may have originated from. The discussion below, then, considers *possible* childhood locations for the individuals identified as foreigners at Pusilhá. As discussed above, three individuals exhibit  $^{87}\text{Sr}/^{86}\text{Sr}$  or trace element values that suggest they spent their childhood years in a different geological region. While both strontium isotope and trace-element data are useful in identifying individuals as nonlocal, much more baseline work has been done on  $^{87}\text{Sr}/^{86}\text{Sr}$  ratios than trace-element distribution in Mesoamerica and, consequently, the following discussion will rely primarily on the isotope rather than trace-element data.

Since Pusilhá and Lubaantun, another Late Classic Maya site of southern Belize, share a nearly identical ceramic assemblage (Bill, et al. 2005; Hammond 1975) and similar architectural styles, the settlement, located a short 31 km from Pusilhá, makes an attractive option as the source of nonlocal individuals of the current study. Unfortunately, a recent strontium isotope investigation of faunal enamel samples from Lubaantun produced an average ratio of  $0.7076 \pm 0.0002$  ( $n=4$ ;  $1\sigma$ ) (Thornton 2008:23-24), which is indistinguishable from the human  $^{87}\text{Sr}/^{86}\text{Sr}$  ratios from the Pusilhá sample. If an individual who spent their childhood years at Lubaantun was buried at Pusilhá, strontium isotope analysis would not be able to detect them. The three individuals identified as nonlocal in the Pusilhá collection must have come from elsewhere.

All three nonlocal individuals from the Pusilhá sample, Bu 4/1 and the principal and companion burials from Bu 3/1, exhibit  $^{87}\text{Sr}/^{86}\text{Sr}$  values that fall below the expected range for the Southern Lowlands as defined by Hodell et al. (2004). Burial 4/1, the partially disarticulated adult female discovered on the surface of the Terminal Classic plaza, has a  $^{87}\text{Sr}/^{86}\text{Sr}$  value of 0.7061, the lowest ratio of the sample set, and a  $\text{Log}(\text{Sr}/\text{Ca})$  value of -3.19, the most positive value of the set. The principal figure and sampled companion from Burial 3/1 exhibit  $^{87}\text{Sr}/^{86}\text{Sr}$  values of 0.7069 and 0.7067, respectively (Figure 6). The values of all three individuals fit within the range of the Metamorphic Province, which Hodell et al. (2004) define as 0.7055 – 0.7071 (n=50). This geologically diverse area of ultrabasic and metamorphic rocks along the Motagua River Valley includes the Maya site of Copan, Honduras.

Several papers have discussed the isotopic data from Copan (Buikstra, et al. 2004; Price, et al. 2008:174; Price, et al. 2007) and have established a baseline value from both human and faunal skeletal remains. The human bone  $^{87}\text{Sr}/^{86}\text{Sr}$  average is  $0.7064 \pm 0.0002$  while the fauna have a slightly higher average of  $0.7068 \pm 0.0003$ . Interestingly, human enamel samples from Copan are slightly higher than the bone ratios, with an average value of 0.7069 (Buikstra, et al. 2004). Although the lower end of Copan's values are close to the observed value of Bu 4/1, her Sr isotope ratio still falls below the reported range for humans at Copan (Figure 8). The nearest archaeological zone to exhibit a similar  $^{87}\text{Sr}/^{86}\text{Sr}$  value to Bu 4/1 is El Chayal ( $^{87}\text{Sr}/^{86}\text{Sr} = 0.7061$ ), an obsidian source located in the highlands of Guatemala (Figure 7). Interestingly, much of the obsidian from Pusilhá comes from this location. The individual from Burial 4/1 most likely spent

her childhood years somewhere within the Metamorphic Province, although more baseline work is needed.

Although Bu 4/1 most likely did not come from Copan, the two individuals from Bu 3/1 exhibit  $^{87}\text{Sr}/^{86}\text{Sr}$  values that fall within the published human range for Copan (Figure 8). Interestingly, several lines of evidence seem to link Pusilhá to the larger Honduran center. Copan and Pusilhá share an artistic tradition of carving zoomorphic altars in the round, both sites reference a mysterious “Foliated Ajaw” figure, and Pusilhá and Quiriguá have very similar emblem glyphs (Braswell, et al. 2005:62). Joyce Marcus (2003:95; 2004:371) has proposed that Pusilhá was conquered by Copan and incorporated into the expansionist state, later claiming independence during the fragmentation of the state. However, neither site mentions the other in the entire body of their hieroglyphic inscriptions. Moreover, recent excavations by PUSAP found that the ceramic evidence points to a variety of influences, especially from the southwestern Peten and only very minimally (three sherds) from western Honduras (Braswell and Gibbs 2006; Braswell, et al. 2004). Instead of being ruled by Copan, Braswell et al. (2004; 2005) suggest that Pusilhá remained largely independent throughout the course of its political history and probably shared more culturally with the Peten than with Copan.

Nevertheless, the two individuals from Burial 3/1 exhibit isotopic ratios very similar to the published  $^{87}\text{Sr}/^{86}\text{Sr}$  averages for Copan, where tooth enamel samples average 0.7069 (Buikstra, et al. 2004:210; Price, et al. 2008:170). When all of the published  $^{87}\text{Sr}/^{86}\text{Sr}$  values of individuals described as ‘local’ to Copan are grouped together, they exhibit an average  $^{87}\text{Sr}/^{86}\text{Sr}$  value of  $0.7067 \pm 0.0003$  ( $n=15$ ,  $1\sigma$ ) (Buikstra, et al. 2004:208), which is nearly identical to the observed values of both individuals from

Pusilhá's Burial 3/1 (Figure 8). Moreover, Copan is geographically the closest sampled Maya site with a  $^{87}\text{Sr}/^{86}\text{Sr}$  average less than 0.7070, making it, or a yet unsampled nearby site, possible candidates for the origin of the individuals from Burial 3/1. Although suggestive, the results cannot determine with any degree of certainty that the individuals from Bu 3/1 came from Copan. More lines of data will be needed to further explore this potential connection.

## CONCLUSION

Companion burials in the Maya world have variously been interpreted as belonging to captured enemy warriors, local sacrificial victims, or the remains of revered ancestors (McAnany, et al. 1999; Tiesler 2007; Welsh 1988). Due to the frequent poor preservation of bone in the Maya lowlands, scholars have employed indirect methods, such as relative health, status, burial context, and demographic profiles, to investigate the nature of companion burials. The present project used isotopic and trace-element analyses as additional methods of exploring this question at Pusilhá, a Late and Terminal Classic Maya site in southern Belize.

Results from this study indicate that no significant isotopic or trace elemental differences exist between the sampled principal and companion figures, providing no support for the hypothesis that companions were captured enemies from different settlements. Nevertheless, the two sampled individuals from Burial 3/1, the principal figure and a companion cranium, *both* exhibit a nonlocal strontium isotope signature that most closely resemble the average  $^{87}\text{Sr}/^{86}\text{Sr}$  values from within the Metamorphic Province, which includes the Maya site of Copan. The companion head from this burial may represent either the remains of an individual who migrated to Pusilhá during his or her life or an individual who perished earlier and whose remains were brought to Pusilhá by the principal figure. Although Pitcavage (2008) tentatively suggests that the companion figure was a lower status sacrificial victim, I propose that it may represent the remains of a curated ancestor.

Though not a multiple burial, Bu 4/1 exhibits the clearest evidence for a foreign origin. Her remains were left on the surface of the Terminal Classic plaza and, although

possibly associated with the abandonment of Pusilhá, the temporal provenience is unsecure and her death may have post-dated the Terminal Classic Period. Although her observed  $^{87}\text{Sr}/^{86}\text{Sr}$  ratio most closely resembles the ratio from the El Chayal obsidian source, the lack of temporal control for Bu 4/1 does not allow any conclusions to be made regarding her presence at Pusilhá.

The multiple interments at Pusilhá reflect a diversity of mortuary practices. As discussed by Carr (1995), in addition to social ranking, a wide variety of factors, such as ideology, religion, economic circumstances, and world views, influence the composition of mortuary assemblages. A more nuanced understanding of Maya companion burials provides valuable information on the nature of Maya rulership and legitimation. Human sacrifice and ancestor veneration, though both potential methods of social control, may serve as very different symbols for the same end – one symbolizes the right to rule by evoking tradition and lineage while the other legitimizes authority through a display of power and prowess. Distinguishing between the two and observing the patterns of their occurrence increases our understanding of elite Maya rulership. As demonstrated in this paper, the inclusion of human sacrifices in mortuary contexts was not the norm for the elite Maya, but one possibility out of several. Here, the evidence suggests the presence of three different mortuary practices in three different mortuary contexts and implies, instead of a singular method of elite legitimation through the manipulation of human remains, a general symbolic importance of the dead to the ancient Maya.

Significantly different from our modern Western view of the departed, the ancient Maya conceived an ongoing and active relationship with the deceased. In regards to this view of the afterlife and the connection of the living to it, McAnany et al. (1999:129)

state that the ancient Maya would “often blur the boundary between life and death” and that this boundary was “viewed as a permeable membrane rather than an unbreachable chasm.” Human bones were not merely reminders of those once living, but symbols of their ongoing presence. The manipulation of human remains was a general, powerful symbol for the Maya and for centuries the dead, whether ancestor or enemy, aided the living in practices of social control and political maneuvering.

APPENDIX

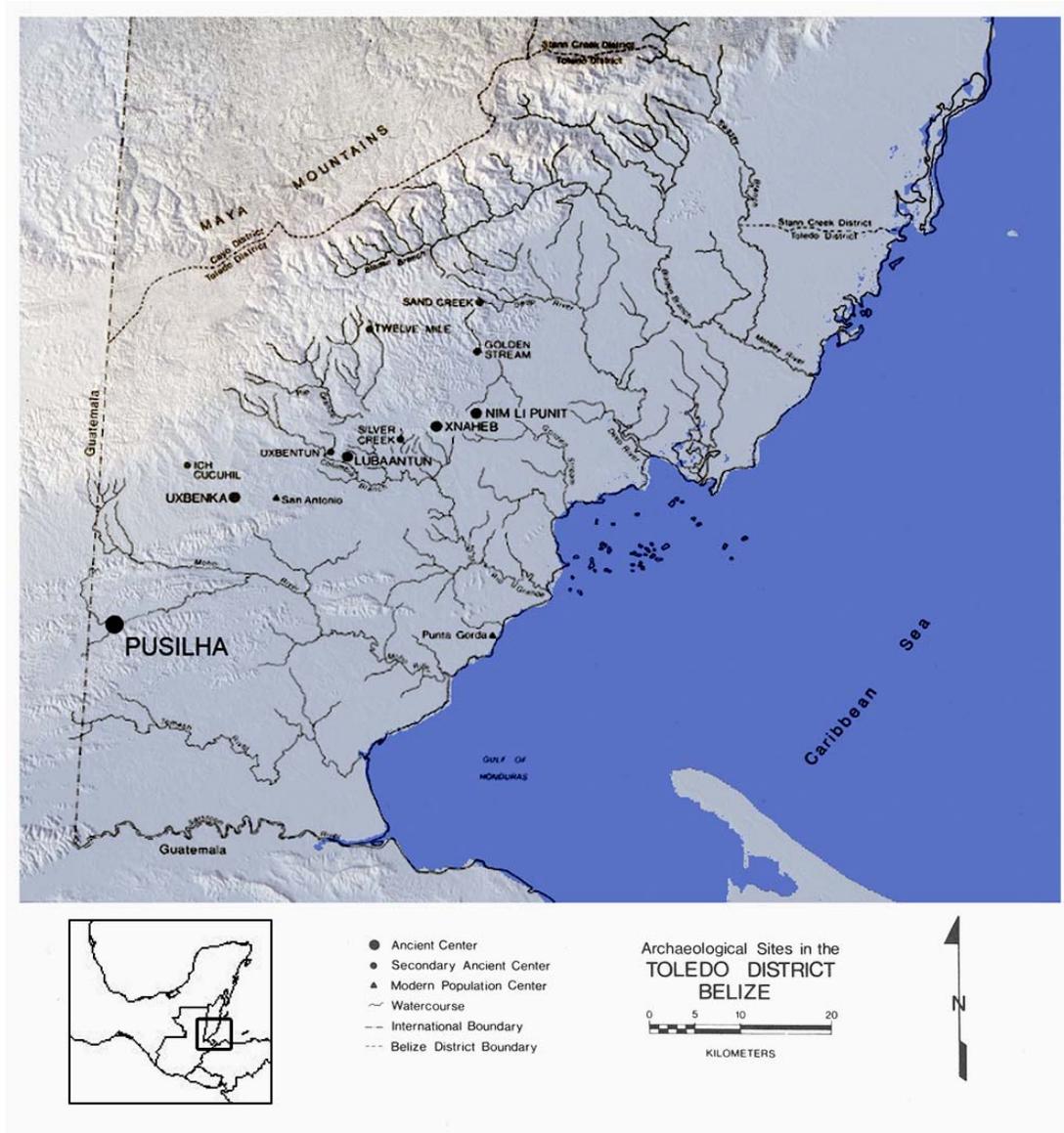


Figure 1. Southern Belize region, showing the location of Pusilhá and other Maya sites

(Volta 2007:Figure1)

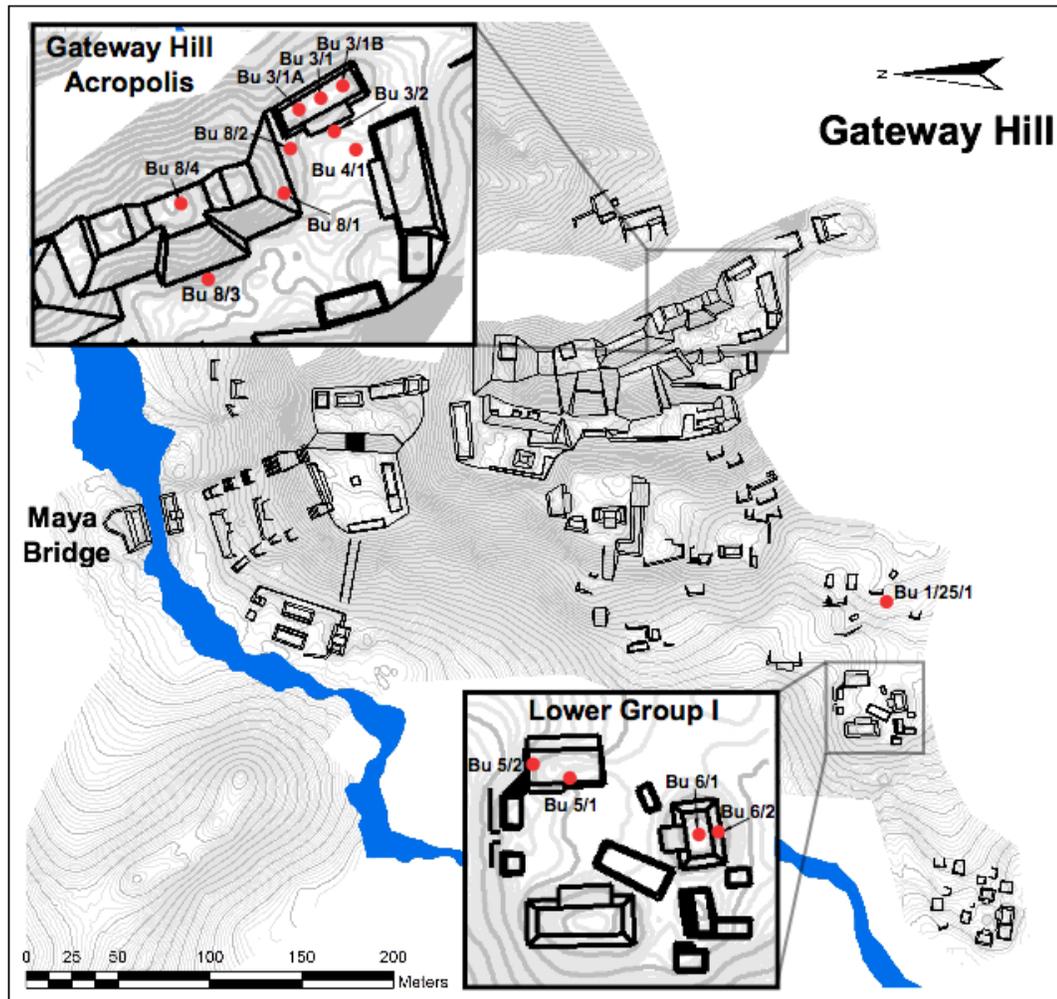


Figure 2. Locations of burials on Gateway Hill (modified from Volta 2007:Figure10 and Pitcavage 2008: Fig 3).

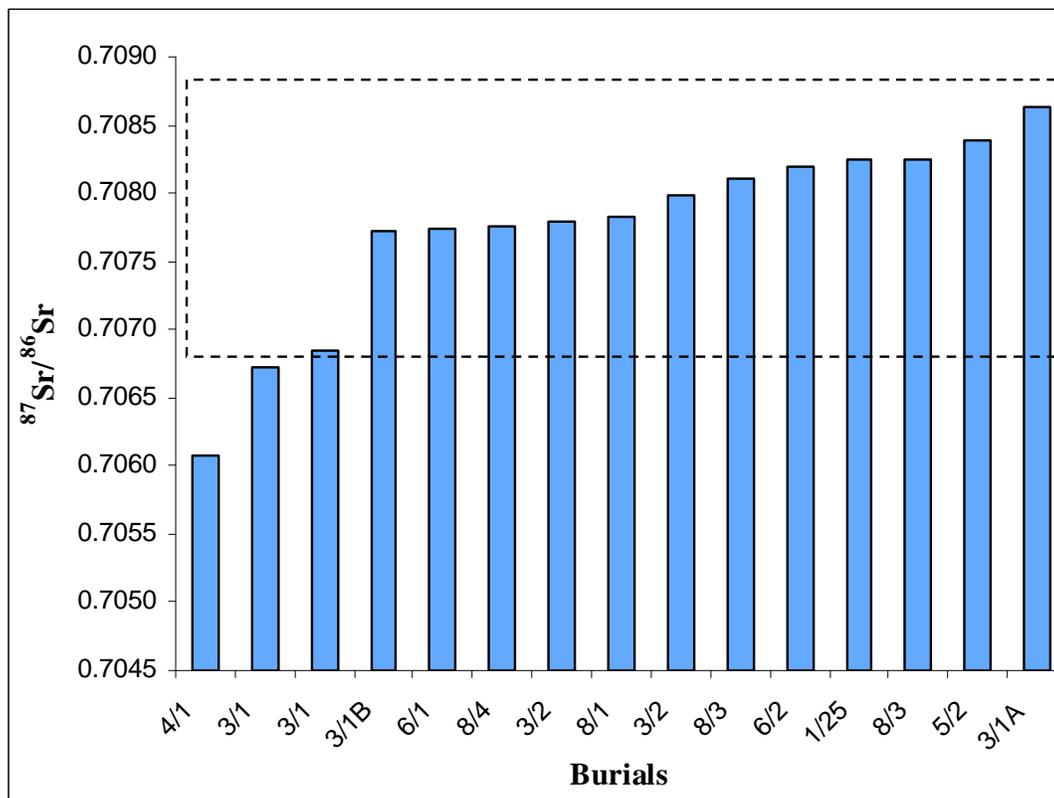


Figure 3. Graph of strontium isotope ratios by burial number. Dashed box represents two sigma baseline range for Pusilhá once the  $^{87}\text{Sr}/^{86}\text{Sr}$  value of Burial is 4/1 excluded.

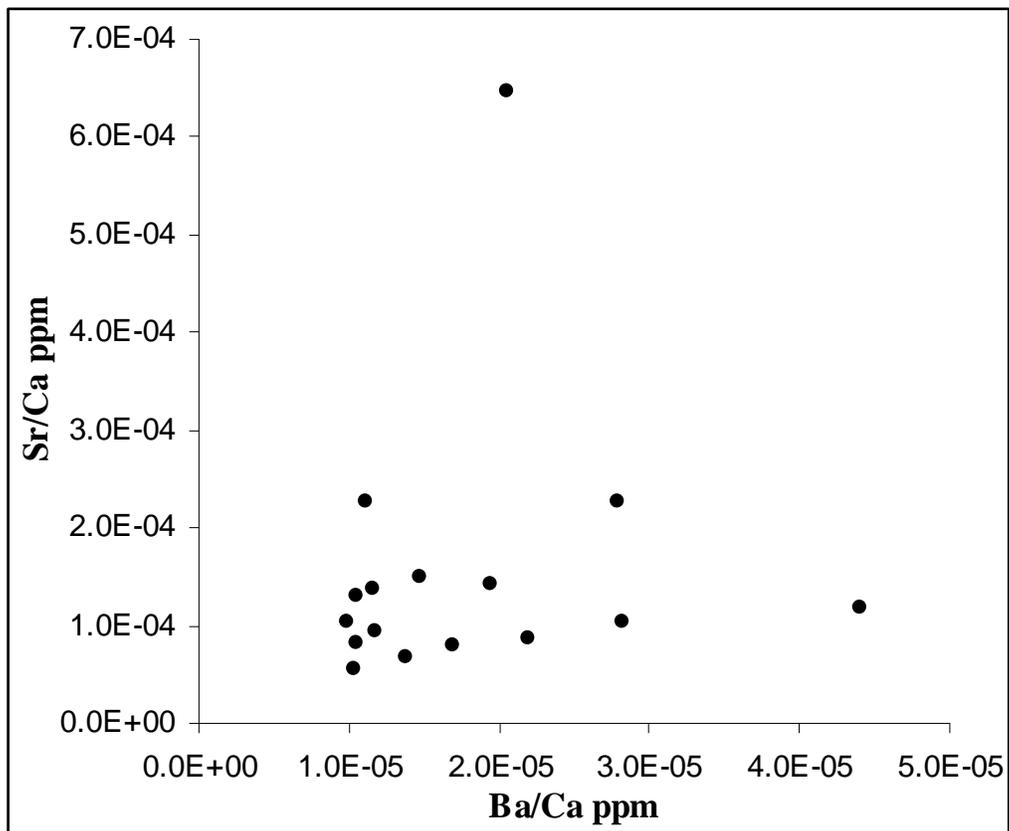


Figure 4. Scatterplot of raw Sr and Ba concentration values normalized over Ca.

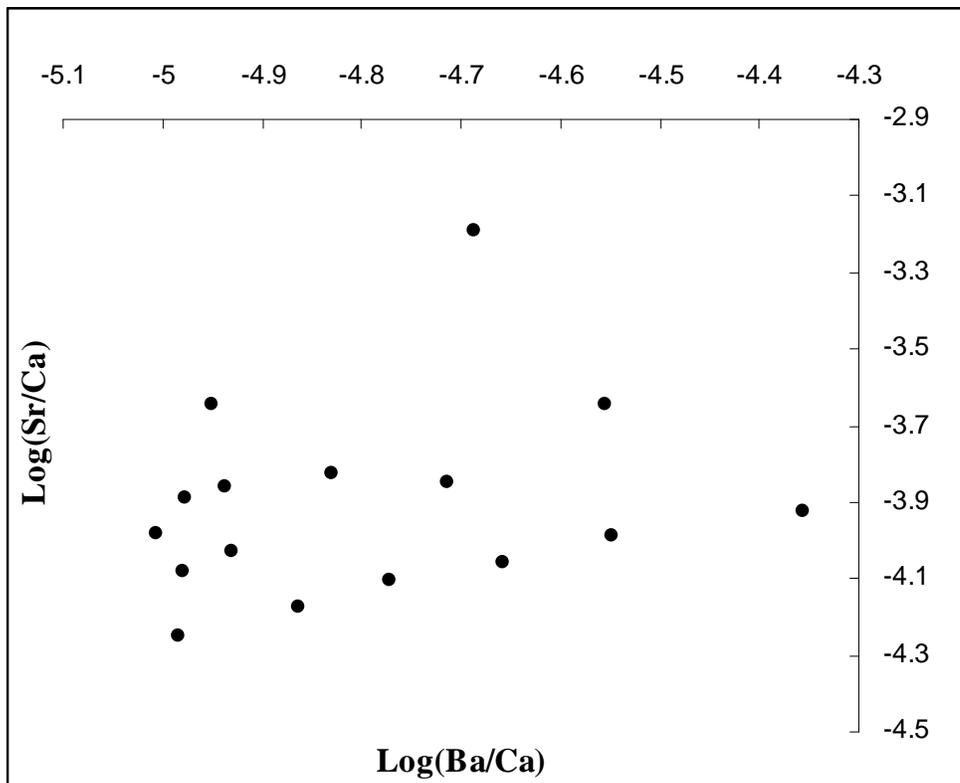


Figure 5. Scatterplot of Log(Sr/Ca) vs. Log(Ba/Ca) values.

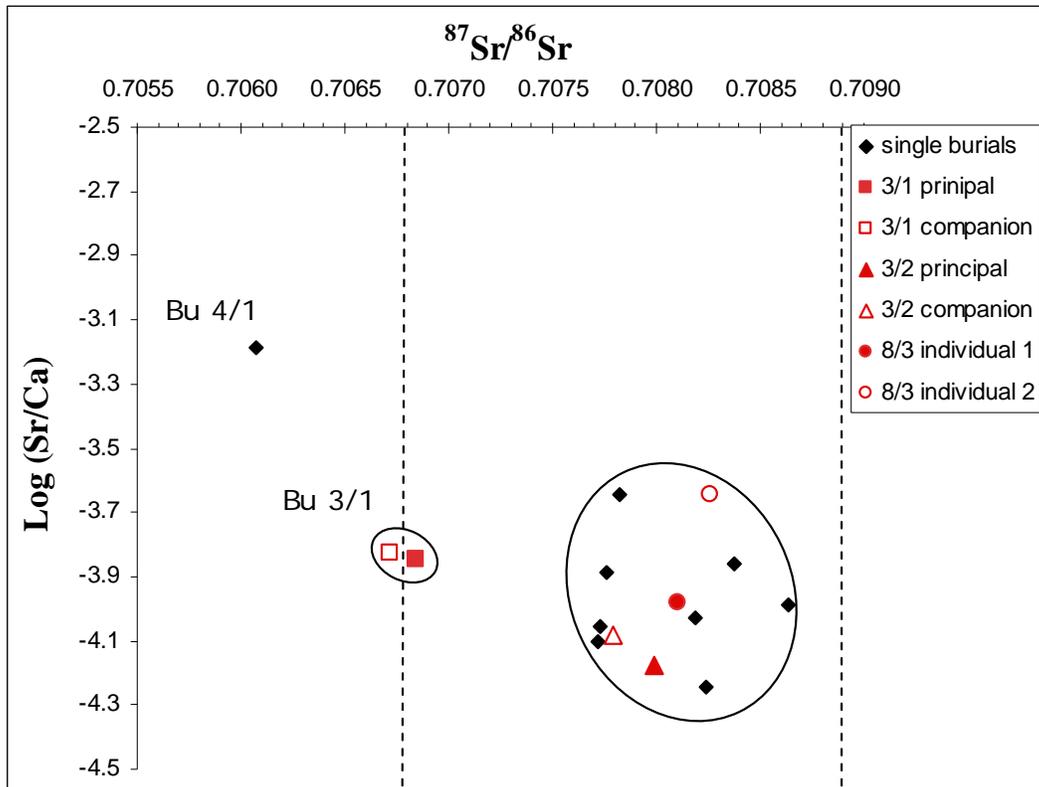


Figure 6. Scatterplot of  $^{87}\text{Sr}/^{86}\text{Sr}$  ratios vs.  $\text{Log}(\text{Sr}/\text{Ca})$  concentration values. Dashed lines represent the two sigma baseline range for Pusilhá once the  $^{87}\text{Sr}/^{86}\text{Sr}$  value of Burial is 4/1 excluded.

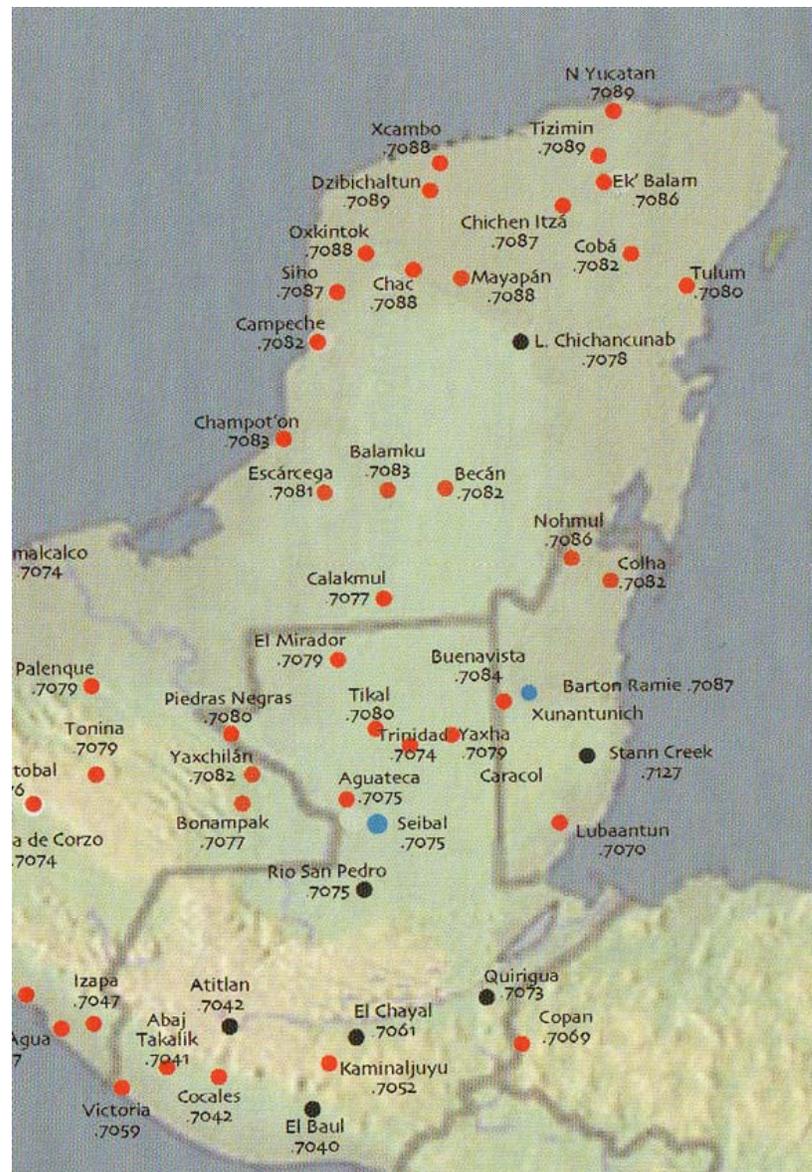


Figure 7. Map of  $^{87}\text{Sr}/^{86}\text{Sr}$  ratios from across the Maya world. Adapted from Price et al. 2008: 170.

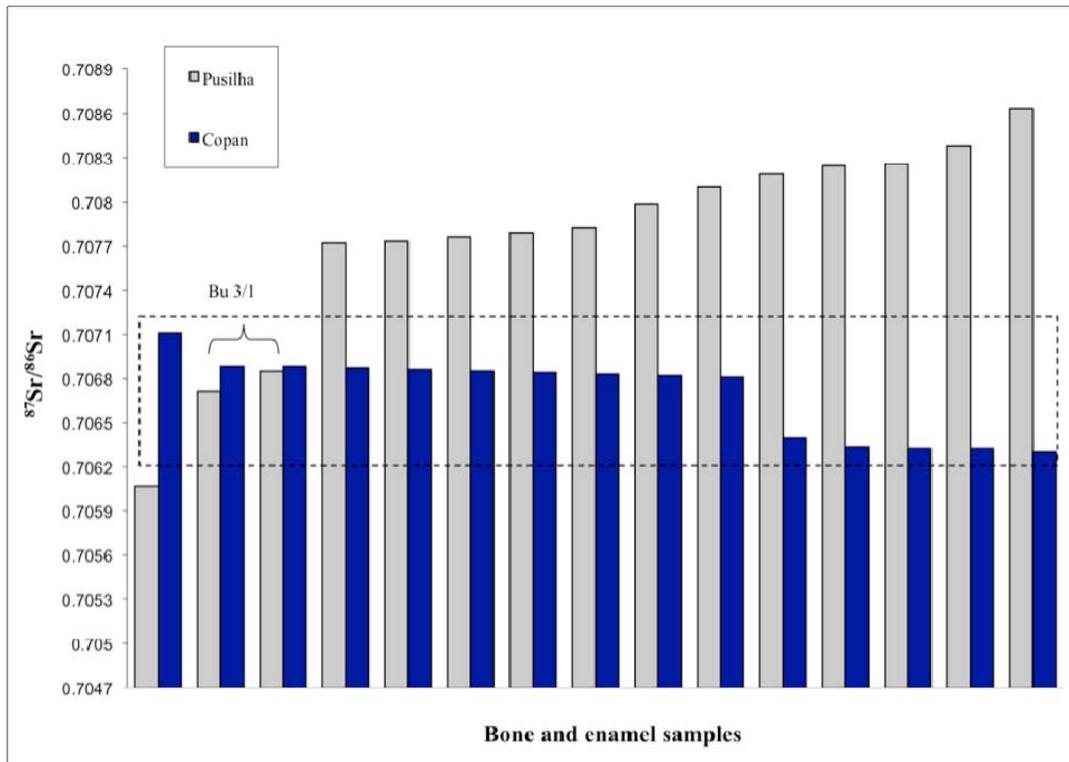


Figure 8. Graph of Pusilhá Sr isotope values compared with Copan Sr isotope values.

Dashed box represents the two sigma baseline range for local Copan values.

Table 1. Strontium isotope and trace-element data.

Burial	Tooth	Period	Sex	Age	Notes	<sup>87</sup> Sr/ <sup>86</sup> Sr	U/Ca	La/Ca	Log(Ba/Ca)	Log(Sr/Ca)
1/25	rm2	TC		7-9		0.7082434	1.16123E-08	2.32245E-07	-4.983063544	-4.247286566
3/1	LM2	LC	M	YA	principal	0.7068487	4.93582E-08	1.19694E-06	-4.712556797	-3.849081129
3/1	LM2	LC		YA	companion	0.7067153	1.28278E-07	1.46937E-06	-4.829821257	-3.825066979
3/1A	LM2	LC		YA		0.7086336	-2.40777E-08	-1.80583E-07	-4.548797453	-3.98670312
3/1B	RM1	LC		OA		0.7077226	1.09714E-07	1.75543E-07	-4.771234521	-4.103605474
3/2	LC-	TC	M	OA	companion	0.7077875	2.41152E-08	2.29095E-07	-4.978702564	-4.081280819
3/2	LM2	TC	M	OA	principal	0.7079868	1.24857E-07	8.61512E-07	-4.862079875	-4.175405034
4/1	LM2	TC	F	A		0.7060699	-4.47593E-08	-2.01417E-07	-4.68732468	-3.18916778
5/1	rm1	LC		4-5		--		0	-4.355609747	-3.923174972
5/2	LM2	LC		SA		0.7083787	3.04364E-07	8.75045E-07	-4.936223826	-3.860972874
6/1	LM1	LC		YA		0.7077337	2.95053E-07	5.25964E-07	-4.658160511	-4.057459815
6/2	LM2	LC		A		0.7081875	1.37081E-07	-2.99086E-07	-4.931263066	-4.029329657
8/1	LM3	TC	M	A		0.7078217	1.33691E-08	8.02144E-08	-4.95121118	-3.644743124
8/3	RM2	TC	M	A	individual #1	0.7081012	4.67569E-08	-3.27298E-07	-5.00629994	-3.983759215
8/3	LM2	TC	F	OA	individual #2	0.7082555	6.34234E-08	-2.28324E-07	-4.555044977	-3.644115238
8/4	RM2	TC	M	OA		0.7077607	2.43588E-08	7.30765E-08	-4.977974715	-3.887604247

M – Male  
 F- Female  
 SA - Subadult  
 YA – Young Adult  
 A - Adult  
 OA – Old Adult

## REFERENCES

- Ambrose, S. H. and J. Krigbaum  
2003 Bone chemistry and bioarchaeology. *Journal of Anthropological Archaeology* 22(3):193-199.
- Anthony, D. W.  
1990 Migration in Archaeology: The Baby and the Bathwater. *American Anthropologist* 92(4):895-914.  
  
1997 Prehistoric Migration as Social Process. In *Migrations and Invasions in Archaeological Explanation*, edited by J. Chapman and H. Hamerow. Archaeopress, BAR S664, Oxford.
- Beekman, C. S. and A. F. Christensen  
2003 Controlling for Doubt and Uncertainty Through Multiple Lines of Evidence: A New Look at the Mesoamerican Nahua Migrations. *Journal of Archaeological Method and Theory* 10(2):111-164.
- Bentley, R. A.  
2006 Strontium Isotopes from the Earth to the Archaeological Skeleton: A Review. *Journal of Archaeological Method and Theory* 13(3):135-187.
- Bill, C. R., G. E. Braswell and C. M. Prager  
2005 Interaccion Economica y Politica en la Periferia Maya: Evidencia Nueva de Pusilha, Belice. In *XVIII Simposio de Investigaciones Arqueologicas en Guatemala, 2004*, edited by J. P. Laporte, B. Arroyo and H. Mejia, pp. 455-463. vol. . Museo Nacional de Arqueologica y Etnologia, Guatemala.
- Botha, J., J. Lee-Thorp and A. Chinsamy  
2005 The paleoecology of the non-mammalian cynodonts *Diademodon* and *Cynognathus* from the Karoo Basin of South Africa, using stable light isotope analysis. *Palaeogeography, Palaeoclimatology, Palaeoecology* 223(3-4):303-316.
- Braswell, G., C. M. Prager and C. R. Bill  
2005 The Kingdom of the Avocado: Recent Investigations at Pusilha, A Classic Maya City of Southern Belize. *Anthropological Notebooks* 11:59-86.
- Braswell, G. E.  
2001 *Pusilha Archaeological Project*. Report submitted to the Foundation for the Advancement of Mesoamerican Studies:(<http://www.famsi.org/reports/00029/>).
- Braswell, G. E. and S. A. Gibbs (editors)

2006 *In the Land of the Avocado: Recent Archaeological Investigations at Pusilha, Toledo District, Belize*. Vol. 3. Institute of Archaeology, National Institute of Culture and History, Belmopan, Belize.

- Braswell, G. E., C. M. Prager, C. R. Bill, S. A. Schwake and J. B. Braswell  
2004 The Rise of Secondary States in the Southeastern Periphery of the Maya World. *Ancient Mesoamerica* 15:219-233.
- Budd, P., J. Montgomery, B. Barreiro and R. G. Thomas  
2000 Differential Diagenesis of Strontium in Archaeological Human Dental Tissues. *Applied Geochemistry* 15:687-694.
- Buikstra, J. E., T. D. Price, L. E. Wright and J. A. Burton  
2004 Tombs from the Copan Acropolis: A Life History Approach. In *Understanding Early Classic Copan*, edited by E. E. Bell, M. A. Canuto and R. Sharer. Museum of Archaeology and Anthropology, University of Pennsylvania, Philadelphia.
- Burton, J. H. and T. D. Price  
1990 The ratio of barium to strontium as a paleodietary indicator of consumption of marine resources. *Journal of Archaeological Science* 17:547-557.  
  
2000 The use and abuse of trace elements for paleodietary research. In *Biogeochemical Approaches to Paleodietary Analysis*, edited by S. H. Ambrose and M. A. Katzenberg, pp. 159-171. Kluwer Academic/Plenum Publishers, New York.
- Burton, J. H., T. D. Price, L. Cahue and L. E. Wright  
2003 The Use of Barium and Strontium Abundances in Human Skeletal Tissues to Determine their Geographic Origins. *International Journal of Osteoarchaeology* 13:88-95.
- Burton, J. H. and L. E. Wright  
1995 Nonlinearity in the relationship between bone Sr/Ca and diet: paleodietary implications. *American Journal of Physical Anthropology* 96:273-282.
- Cameron, C. M.  
1995 Migration and the Movement of Southwestern Peoples. *Journal of Anthropological Archaeology* 14(2):104-124.
- Carr, C.  
1995 Mortuary Practices: Their Social, Philosophical-Religious, Circumstantial, and Physical Determinants. *Journal of Archaeological Method and Theory* 2(2):105-200.
- Chapman, J. and H. Hamerow

1997 *Migrations and Invasions in Archaeological Explanation*. Archaeopress, BAR S664, Oxford.

Christensen, A. F. and M. Winter

1997 Culturally Modified Skeletal Remains from the Site of Huamelulpan, Oaxaca, Mexico. *International Journal of Osteoarchaeology* 7:467-480.

de Landa, D.

1978 *Yucatan Before and After the Conquest*. Translated by W. Gates. Dover Publications, New York.

Elias, R. W., Y. Hirao and C. C. Patterson

1982 The circumvention of the natural biopurification of calcium along nutrient pathways by atmospheric inputs of industrial lead. *Geochim Cosmochim Acta* 46:2561-2580.

Ezzo, J. A., C. S. Larsen and J. H. Burton

1995 Elemental signatures of human diets from the Georgia Bight. *American Journal of Physical Anthropology* 98:471-481.

Faure, G. and J. W. Powell

1972 *Strontium Isotope Geology*. Minerals, Rocks, and Inorganic Materials: Monograph Series of Theoretical and Experimental Studies. Springer-Verlag, New York.

Fowler Jr, W. R.

1984 Late Preclassic Mortuary Patterns and Evidence for Human Sacrifice at Chalchuapa, El Salvador 49(3):603-618.

Gruning, E. L.

1930 Report on the British Museum Expedition to British Honduras. *Journal of the Royal Anthropological Institute* 60:477-483.

Hammond, N.

1975 *Lubaantun: A Classic Maya Realm*. Monographs of the Peabody Museum, No. 2: Peabody Museum of Archaeology and Ethnology, Cambridge, MA.

Hillson, S.

1996 *Dental Anthropology*. Cambridge University Press, New York, NY.

Hodell, D. A., R. L. Quinn, M. Brenner and G. Kamenov

2004 Spatial Variation of Strontium Isotopes ( $^{87}\text{Sr}/^{86}\text{Sr}$ ) in the Maya Region: A Tool for Tracking Ancient Human Migration. *Journal of Archaeological Science* 31:585-601.

- Houston, S. D., J. Robertson and D. Stuart  
2000 The Language of Classic Maya Inscriptions. *Current Anthropology* 41:321-356.
- Joyce, T. A.  
1929 Report on the British Museum Expedition to British Honduras. *Journal of the Royal Anthropological Institute* 59:439-457.
- Joyce, T. A., C. Clark and J. E. Thompson  
1927 Report on the British Museum Expedition to British Honduras. *Journal of the Royal Anthropological Institute* 57:295-323.
- Joyce, T. A., T. Gann, E. L. Gruning and R. C. E. Long  
1928 Report on the British Museum Expedition to British Honduras. *Journal of the Royal Anthropological Institute* 58:323-350.
- Katzenberg, M. A. and R. G. Harrison  
1997 What's in a bone? Recent advances in archaeological bone chemistry. *Journal of Archaeological Research* 5(3):265-293.
- Knudson, K. J. and T. D. Price  
2007 Utility of Multiple Chemical Techniques in Archaeological Residential Mobility Studies: Case Studies From Tiwanaku- and Chiribaya-Affiliated Sites in the Andes. *American Journal of Physical Anthropology* 132:25-39.
- Knudson, K. J., T. D. Price, J. Buikstra and D. E. Blom  
2004 The Use of Strontium Isotope Analysis to Investigate Tiwanaku Migration and Mortuary Ritual in Bolivia and Peru. *Archaeometry* 46(1):5-18.
- Knudson, K. J., S. R. Williams, R. Osborn, K. Forgey and P. R. Williams  
2009 The geographic origins of Nasca trophy heads using strontium, oxygen, and carbon isotope data. *Journal of Anthropological Archaeology* in press.
- Kohn, M. J., M. J. Schoeninger and W. W. Barker  
1999 Altered States: Effects of Diagenesis on Fossil Tooth Chemistry. *Geochimica et Cosmochimica Acta* 63(18):2737-2747.
- Lee-Thorp, J. and M. Sponheimer  
2003 Three Case Studies Used to Reassess the Reliability of Fossil Bone and Enamel Isotope Signals for Paleodietary Studies. *Journal of Anthropological Archaeology* 22:208-216.
- Levanthal, R. M.

1990 Southern Belize: An Ancient Maya Region. In *Vision and Revision in Maya Studies*, edited by F. S. Clancy and P. D. Harrison, pp. 124-141. University of New Mexico, Albuquerque.

Marcus, J.

1973 Territorial Organization of the Lowland Classic Maya. *Science* 180(4089):911-916.

1974 The Iconography of Power among the Classic Maya. *World Archaeology* 6(1, Political Systems):83-94.

1992a Dynamic Cycles of Mesoamerican States: Political Fluctuations in Mesoamerica. *National Geographic Research and Exploration* 8:392-411.

1992b *Mesoamerican Writing Systems: propaganda, myth, and history in four ancient civilizations*. Princeton University Press, Princeton, New Jersey.

2003 Recent Advances in Maya Archaeology. *Journal of Archaeological Research* 11(2):71-144.

2004 Primary and Secondary State Formation in Southern Mesoamerica. In *Understanding Early Classic Copan*, edited by E. E. Bell, M. A. Canuto and R. Sharer, pp. 347-373. Museum of Archaeology and Anthropology, University of Pennsylvania, Philadelphia.

Martin, S. and N. Grube

1995 Maya Superstates. *Archaeology* 48(6):41-46.

McAnany, P. A.

1995 *Living With the Ancestors: Kinship and Kingship in Ancient Maya Society*. University of Texas Press, Austin, TX.

McAnany, P. A., R. Storey and A. Lockard

1999 Mortuary Ritual and Family Politics at Formative and Early Classic K'axob, Belize. *Ancient Mesoamerica* 10:129-146.

Meerman, J. C. and J. Clabaugh

2009 Biodiversity and Environmental Resource Data System. *World Wide Web electronic publication*. <http://www.biodiversity.bz/mapping/samples/>(January 2009).

Montgomery, J., J. A. Evans, D. Powlesland and C. Roberts

2005 Continuity or Colonization in Anglo-Saxon England? Isotope Evidence for Mobility, Subsistence Practice, and Status at West Heslerton. *American Journal of Physical Anthropology* 126:123-128.

- Nelson, B. A., J. A. Darling and D. A. Kice  
1992 Mortuary Practices and the Social Order at La Quemada, Zacatecas. *Latin American Antiquity* 3(4):298-315.
- Nickels, K.  
2008 *Food Function and Status: Analysis of faunal remains from the Maya site of Pusilha, Belize*, University of California, San Diego.
- Pitcavage, M. R.  
2008 *Companion burials in the Kingdom of the Avocado: Indirect Evidence of Human Sacrifice in Late and Terminal Classic Maya Society*, University of California, San Diego.
- Platzner, I.  
1985 Multiple ion collection in thermal ionization isotope ratio mass spectrometry of strontium. *International Journal of Mass Spectrometry and Ion Processes* 67:129-136.
- Price, T. D., J. H. Burton and R. A. Bentley  
2002 The Characterization of Biologically Available Strontium Isotope Ratios for the Study of Prehistoric Migration. *Archaeometry* 44(1):117-135.
- Price, T. D., J. H. Burton, P. D. Fullagar, L. E. Wright, J. E. Buikstra and V. Tiesler  
2008 Strontium isotopes and the study of human mobility in ancient Mesoamerica. *Latin American Antiquity* 19(2):167-180.
- Price, T. D., J. H. Burton, L. E. Wright, C. D. White and F. J. Longstaffe  
2007 Victims of Sacrifice: Isotopic Evidence for Place of Origin. In *New Perspectives on Human Sacrifice and Postsacrificial Body Treatments in Ancient Maya Society*, edited by V. Tiesler and A. Cucina, pp. 263-292. Springer, New York.
- Price, T. D., C. M. Johnson, J. A. Ezzo, J. E. Ericson and J. H. Burton  
1994 Residential Mobility in the Prehistoric Southwest United States: A Preliminary Study Using Strontium Isotope Analysis. *Journal of Archaeological Science* 21:315-330.
- Price, T. D., L. Manzanilla and W. D. Middleton  
2000 Immigration and the Ancient City of Teotihuacan in Mexico: A Study Using Strontium Isotope Ratios in Human Bone and Teeth. *Journal of Archaeological Science* 27:903-913.
- Purdy, E. G., E. Gischler and A. J. Lomando

2003 The Belize margin revisited. 2. Origin of Holocene antecedent topography. *International Journal of Earth and Science* 92:552-572.

Schele, L. and M. Miller

1986 *The Blood of Kings: Dynasty and Ritual in Maya Art*. Kimball Art Museum, New York.

Schoeninger, M. J.

1979 Diet and Status at Chalcatzingo: Some Empirical and Technical Aspects of Strontium Analysis. *American Journal of Physical Anthropology* 51:295-310.

Schoeninger, M. J. and K. Moore

1992 Bone stable isotope studies in archaeology. *Journal of World Prehistory* 6(2):247-296.

Schroeder, H. H., L. H. Tipton and A. P. Nason

1972 Trace metals in man: strontium and barium. *Journal of Chronic Diseases* 25:491-517.

Smith, M. E.

1984 The Aztlan Migrations of the Nahuatl Chronicles: Myth or History? *Ethnohistory* 31(3):153-186.

Thornton, E. K.

2008 Zooarchaeological and Isotopic Perspectives on Ancient Maya Economy and Exchange. *Report submitted to the Foundation for the Advancement of Mesoamerican Studies: (<http://www.famsi.org/reports/06027/>)*.

Tiesler, V.

2007 Funerary or Nonfunerary? New References in Identifying Ancient Maya Sacrificial and Postsacrificial Behaviors from Human Assemblages. In *New Perspectives on Human Sacrifice and Postsacrificial Body Treatments in Ancient Maya Society*, edited by V. Tiesler and A. Cucina, pp. 14-44. Springer, New York.

Tiesler, V. and A. Cucina

2007 *New Perspectives on Human Sacrifice and Postsacrificial Body Treatments in Ancient Maya Society*. Springer, New York.

Toots, H. and M. R. Voorhies

1965 Strontium in fossil bones and the reconstruction of food chains. *Science* 149(3686):854-855.

Trueman, C. N. and N. Tuross

- 2002 Trace elements in recent and fossil bone apatite. In *Phosphates: Geochemical, Geobiological, and Materials Importance*, edited by M. J. Kohn, J. Rakovan and J. M. Hughes. Reviews in Mineralogy and Geochemistry. Mineralogical Society of America, Washington, DC.
- Tung, T. A. and K. J. Knudson  
2008 Social identities and geographical origins of Wari trophy heads from Chonchopata, Peru. *Current Anthropology* 49(5):915-925.
- Tunich-Nah, C. a. E.  
2007 *An Environmental Impact Assessment for a Proposed Oil Exploration Project*.
- Volta, B. P.  
2007 *Archaeological Settlement Patterns in the Kingdom of the Avocado*. MA Thesis, University of California.
- Walters, G. and L. O. Weller  
1992 *Pusilha Project: 1992 Field Report*.
- Welsh, W. B. M.  
1988 *An Analysis of Classic Lowland Maya Burials*. BAR International Series 409, Oxford, England.
- Wessen, G., F. H. Ruddy, C. E. Gustafson and H. Irwin  
1977 Characterization of archaeological bone by neutron activation analysis. *Archaeometry* 19:200-205.
- White, C. D.  
1999 *Reconstructing Ancient Maya Diet*. University of Utah Press, Salt Lake City.
- Wright, L. E.  
2005 Identifying Immigrants to Tikal, Guatemala: Defining Local Variability in Strontium Isotope Ratios of Human Tooth Enamel. *Journal of Archaeological Science* 32:555-566.