# POROTIC HYPEROSTOSIS AND LINEAR ENAMEL HYPOPLASIA AS INDICATORS OF HEALTH FOR THE ANCIENT MAYA OF K'AXOB, BELIZE

A Thesis
Presented to
The Faculty of the Department
of Anthropology
University of Houston

In Partial Fulfillment

Of the Requirements for the Degree of

Master of Arts

By

Shannon M. Vance

May, 2014

POROTIC HYPEROSTOSIS AND LINEAR ENAMEL HYPOPLASIA AS INDICATORS OF HEALTH FOR THE ANCIENT MAYA OF K'AXOB, BELIZE

Shannon M. Vance

**APPROVED:**

Rebecca Storey, Ph.D.
Committee Chair

Randolph Widmer, Ph.D.

Dirk Van Tuerenhout, Ph.D.
Houston Museum of Natural Science

John W. Roberts, Ph.D.
Dean, College of Liberal Arts and Social Sciences
Department of English

# POROTIC HYPEROSTOSIS AND LINEAR ENAMEL HYPOPLASIA AS INDICATORS OF HEALTH FOR THE ANCIENT MAYA OF K'AXOB, BELIZE

---

An Abstract of a Thesis
Presented to
The Faculty of the Department
of Anthropology
University of Houston

---

In Partial Fulfillment

Of the Requirements for the Degree of

Master of Arts

---

By

Shannon M. Vance

May, 2014

**ABSTRACT**

Human remains recovered during archaeological investigation often are used to inform on the health and living conditions of past populations. Excavations at the ancient Maya community of K'axob, Belize, have yielded a skeletal population of 154 individuals dating from the Middle Preclassic to the Late Classic periods. By examining these remains for evidence of porotic hyperostosis and enamel hypoplasia, this study aims to analyze the health of the people of K’axob over time in relation to other sites in the Maya area. Porotic hyperostosis was found in 24 (54.5%) of 44 evaluable individuals, and linear enamel hypoplasia in 71 (78.9%) of 90 evaluable individuals. These rates are higher than what would be expected in a location with such abundant dietary resources, suggesting that the rates of these pathologies are influenced not by diet, but by other environmental factors, such as a high parasitic load.

**ACKNOWLEDGEMENTS**

Firstly, I would like to thank my committee members, Dr. Rebecca Storey, Dr. Randolph Widmer, and Dr. Dirk Van Tuerenhout, for their excellent advice and support throughout the process of researching and writing this thesis. In particular, I would like to thank Dr. Storey, who served as my advisor and my committee during my time at University of Houston. Not only did she allow me to study the skeletal sample from K'axob, she also answered innumerable questions as I was conducting my research, and I greatly appreciate her support throughout this endeavor.

My dearest and closest friend, Hannah Plumer, was by my side through most of my time at UH and I may not have made it through without her there. Not only was she there for me to talk through my ideas and issues regarding my schoolwork and this thesis, she has also been a great friend and confidante as long as I have known her, and I will always fondly remember the years we lived together in Houston. I would also like to thank my friend and fellow graduate student, Karen Belvin. Though I have only known her a short while, she became an invaluable source of advice and support during the many, many hours we spent together in the osteology lab, and she was always very kind and encouraging, which I appreciate very much.

To my family, I would like to say how much I appreciated their support and encouragement during my long absence from home as I pursued this degree.

Even from more than 1100 miles away, they never let me forget that I was loved and missed back home in Ohio, all the while encouraging me to pursue my educational goals. I would especially like to thank my parents and grandparents in particular, who were always there for me to talk to when I needed them. I am very lucky to have such a wonderful support system.

# TABLE OF CONTENTS

## LIST OF FIGURES

## LIST OF TABLES

Dedicated with love to my parents,

Jeff Vance and Lori Angel York

# Chapter One
## Introduction

Porotic hyperostosis and linear enamel hypoplasia are two of the most commonly-recorded pathologies in bioarchaeological studies, often used to make inferences about health and nutrition in past populations (Danforth 1999; Goodman, et al. 1984; Keita and Boyce 2001; Storey, et al. 2002; Walker, et al. 2009; Wright 1997b; Wright and White 1996). Porotic hyperostosis, a condition causing porosities in the thin cortical bone of the cranial vault, as well as *cribra orbitalia*, the same condition occurring in the top of the eye orbits, are commonly believed to be the result of iron deficiency anemia (Stuart-Macadam 1987a; Walker, et al. 2009; White and Folkens 2005). Linear enamel hypoplasias are linear discolorations or pits on the enamel of the tooth caused by a disruption in the formation of the enamel during a prolonged period of stress in the individual's life (Buikstra and Ubelaker 1994; Goodman and Armelagos 1985; Hillson 1996; White and Folkens 2005; Wright 1997b; Wright and White 1996). Both of these conditions are the result of episodes of biological stress during childhood(Goodman and Armelagos 1989; Stuart-Macadam 1985; Wright and White 1996).

The Maya are one of the most well-known populations of the ancient world and have been well-studied archaeologically in the past century and a half. They lived in an area made up of the modern-day countries of Guatemala, Belize, southern Mexico, and parts of Honduras and El Salvador (Coe 2005; Demarest 2004). The Maya were organized into hundreds of political, religious, and administrative centers which varied in size and political power. The largest of these polities included sites such as Tikal, Palenque, and Copan, but there were many smaller centers, as well. The chronology varies for each site, but the Maya experienced three general periods of development: the Preclassic or Formative period, from about 2000 B.C. to A.D. 250, the Classic period, from A.D. 250-1000, and the Postclassic, from A.D. 1000 to the time of the Spanish conquest in the early 1500s (Coe 2005). The Classic period has often been regarded as the height of Maya civilization, the time at which the Maya experienced the greatest degree of political control and organization, although more recently it has been recognized that the Pre- and Postclassic eras were important periods in Maya history, as well.

The site of K'axob in northern Belize was a relatively small center with a long history, lasting nearly two thousand years (McAnany 2004a; McAnany and Lopez Varela 1999). Excavations at the site have revealed that initial construction began at approximately 800 B.C., and the site was continuously occupied throughout the Classic period and very likely into the Postclassic, as well. Located between the New River and Pulltrouser Swamp, the site was a highly desirable location for raised field agriculture and had access to a diverse array of animal protein resources (Henderson 2003; McAnany 2004a; McAnany and Lopez Varela 1999). Much of the excavation of K'axob focused on the Middle and

Late Formative periods (approximately 800 B.C.-A.D. 250) initially, and then attention turned to the Classic period in later field seasons. A skeletal population totaling 155 individuals was recovered at the site over six seasons of excavation in the 1990s from burials dating from the Middle Preclassic to the Late Classic periods (McAnany 1997; McAnany 2004a).

It has been suggested that population growth, increasing social complexity, and the rise of elite power during the Formative and into the Classic would have necessitated the intensification of agriculture, resulting in increased reliance on the primary staple crop of the region, maize, as well as a decrease in the availability of meat as animal resources were overexploited (Coe 2005). Because of this, the Maya likely would have experienced increased nutritional and health stresses (Coe 2005; Larsen 1995; Webster, et al. 2000; Wright and White 1996). However, these stresses would have affected different regions to different degrees based on differing ecological conditions. Porotic hyperostosis, which records nutritional stress in the form of iron deficiency anemia, and enamel hypoplasias, which are nonspecific nutritional and disease stress indicators, are two conditions commonly studied to indicate the level of health in a population. Examination of the skeletal population recovered from K'axob, Belize, has revealed that this small Maya center experienced a higher degree of health and nutritional stress than would have been expected given its diverse and abundant resource base, suggesting that these pathological conditions were the result not of diet alone but of other environmental factors, such as a high pathogen load.

### PROBLEM AND HYPOTHESES

The residents of K’axob had access to a diverse array of food sources, a wide variety of animal protein resources, including fish and other aquatic fauna, and were less dependent on intensive cultivation of maize (Harrigan 2004; Henderson 2003; Masson 2004). Further, the agricultural lands of the people of K’axob were mostly located in raised fields in Pulltrouser Swamp (McAnany 2004a). Because of this, their crops would have been less susceptible to drought and soil degradation, as the swamp ecology would have ensured continuous fertilization of the soils and provided a supply of fresh water not dependent on rainfall. These factors most likely meant a decreased amount of nutritional stress for the population of K’axob. However, risk of infection by various pathogens, many of which would cause intestinal problems that would results in malabsorption of nutrients, would likely still be a concern.

The main purpose of this study is to examine whether the resource advantages would have meant that the population of K'axob was healthier than other lowland Maya populations of the Formative and Classic periods, and if not, what other environmental factors might have had an impact. To address this problem, an assessment of the prevalence of porotic hyperostosis and linear enamel hypoplasias were conducted on the K'axob skeletal sample. The expectation is that the residents of K'axob were healthier in terms of their nutritional status than people in other parts of the lowlands. This should be reflected in the prevalence of porotic hyperostosis and linear enamel hypoplasias in the K'axob sample, which are expected to be lower than sites in the southern Maya lowlands (represented in this study by Copán and the Pasión region), and similar to sites in within the same ecological context (northern Belize, particularly Cuello). The hypotheses are as follows:

1. The prevalence of porotic hyperostosis within a population is lower in ecological settings with a greater diversity of resources available compared to sites with less ecological diversity.
2. The prevalence of linear enamel hypoplasias within a population is lower in ecological settings with a greater diversity of resources available compared to sites with less ecological diversity.

The null hypothesis in both cases is that there are no observable differences between populations based on ecological setting and resource availability. These hypotheses will be tested by comparing the prevalence of both pathological conditions in the sample at K'axob to those reported for Copán, the Pasión region, and Cuello.

This study also intends to evaluate whether there were differences in diet and health within the population of K'axob based on social factors, including between males and females and between lineages, as well as differences over time, comparing the Formative period to the Classic period. While it is possible that there were social differences in diet, the expectation is that, given the abundance and variety of resources, everyone would have had been similar in terms of nutritional status. In addition,  Hope Henderson's (2003) isotopic analysis of 25 samples representing the Formative and Classic periods indicates that there was very little difference in diet over time at K'axob. Therefore, the prevalence of porotic hyperostosis and linear enamel hypoplasias is not expected to differ between social groups and over time.

### RELEVANCE

Porotic hyperostosis and enamel hypoplasias are health indicators that have been found in archaeological remains throughout the Maya area and around the world. They are two of the most commonly-recorded skeletal pathologies and each can provide valuable information about the health status of the population under study. Study of porotic hyperostosis and enamel hypoplasia at K'axob can help to illuminate patterns of health and nutrition in the ancient Maya and identify differences between sites based on ecological variation. Previous studies of paleopathology in the Maya area have often focused on major political centers, which may not be representative of the conditions at smaller centers such as K'axob. Additionally, unlike many Maya skeletal samples, the K'axob sample contains individuals from both the Preclassic and Classic periods, allowing for a comparison on health and nutrition between these two time periods.

A better understanding of ancient Maya health and nutrition has implications for the study of health in the modern world, as well. Linear enamel hypoplasias still occur in stressed individuals in various parts of the developing world (Goodman and Rose 1990). Iron deficiency is one of the most prevalent deficiency disorders in the world; not only does it affect populations in developing regions, but it is also one of the few nutritional deficiencies still prevalent in the developed world (Hallberg 2001). Within the Maya world, nutrition is possibly even more of an issue in modern populations than it was in the past (Storey, et al. 2002). Modern Maya population receive as much as 70% of their protein and overall calories from maize (Gerry and Krueger 1997), much more than what was consumed by ancient populations. As a result of poor nutrition and parasitic infection, both porotic hyperostosis and enamel hypoplasias are still seen in Maya populations today (Goodman and Rose 1990; Wright and Chew 1998).

# Chapter Two
## THE ANCIENT MAYA

Maya culture developed more than three thousand years ago in a region that consists of the modern-day countries of Guatemala and Belize, southeastern Mexico, and western portions of Honduras and El Salvador (Figure 2.1). The Maya region is part of the larger culture area known as Mesoamerica. The term 'Mesoamerica' (Kirchhoff 1943) is distinct from the term Central America (or Middle America) in that it refers to a cultural region, rather than a geographic one (Demarest 2004; Evans 2008). One of the primary cultural traits that defines this area is the cultivation of maize; other traits include a complex calendrical system, knowledge of astronomy, hieroglyphic writing, the "ballgame" - a team sport played in a specialized court with a solid rubber ball, and similar polytheistic belief systems (Coe 2005). Other major cultures that existed in Mesoamerica at various points in its history include the Olmecs of the Gulf Coast region of Tabasco and Veracruz and the Teotihuacanos, the Toltecs, and, most recently, the Aztecs, all based in the highlands of Central Mexico, west of the Maya area across the Isthmus of Tehuantepec.

Archaeologists typically refer to two broad regions of the Maya area: the highlands, which include all areas lying above one thousand feet of elevation, and the lowlands, which consist of all areas below that elevation (Coe 2005; Demarest 2004). The highlands make up the southern portion of the overall


**Figure 2.1: Map of the Maya Area (adapted from Webster, et al. 2000)**

Maya area (Figure 2.2), including western Guatemala and the southern portion of the state of Chiapas, Mexico, and are characterized by a more temperate climate due to their high elevation. The landscape consists of steep peaks and valleys, as well as several active volcanoes. The lowlands, on the other hand, are relatively flat in most places, except for the Maya Mountains of southern Belize and the slightly hilly Puuc region of the Yucatan Peninsula. The lowlands can further be divided into the northern lowlands of the northern Yucatan Peninsula in Mexico, which are flatter and drier, covered in a dense, low scrub forest, and the southern lowlands, made up mainly of southern Campeche, Mexico, Belize, and Petén, Guatemala, characterized by tropical forest. The southern lowlands are

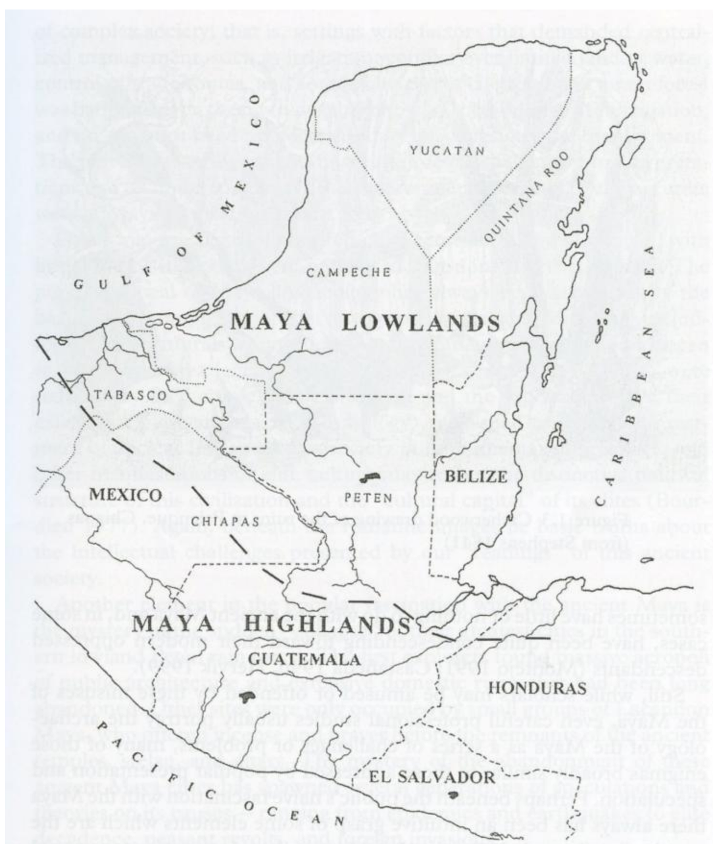


**Figure 2.2: Map of Highlands and Lowlands (Demarest 2004, p. 3)**

considered to have been the heartland of Classic Maya culture (Coe 2005; Demarest 2004). However, these distinctions barely scratch the surface of regional variability in the Maya area, as will be discussed later in this chapter.

Much of the literature focuses on what is known as the Classic period of Maya civilization, which existed from approximately A.D. 250-1000. This period was characterized by use of the Long Count calendar and hieroglyphic writing, grand architectural projects, and unique artistic styles (Coe 2005). However, the first Maya people began to settle in the region at least two millennia prior to that time period, and their modern descendents still inhabit the same area today. The three major time periods (see Table 2.1) of Maya civilization, as defined by archaeologists, include the Preclassic, the Classic, and the Postclassic; this study primarily focuses on the Preclassic and Classic, as these are the time periods during which K'axob was occupied, and from which its skeletal sample comes.

| Time Period | Interval |
|---|---|
| **Archaic** | 8000 - 2000 B.C. |
| **Formative/Preclassic** | 2000 B.C. - A.D. 250 |
| **Classic** | A.D. 250 - 1000 |
| ***Early*** | *A.D. 250 - 600* |
| ***Late*** | *A.D. 600 - 800* |
| ***Terminal*** | *A.D. 800 - 1000* |
| **Postclassic** | A.D. 1000 - 1542 |
| **Colonial** | A.D. 1542 - 1821 |
| **Modern** | A.D. 1821 - *present* |

**Table 2.1: Maya Time Periods**
**(adapted from Coe 2000, p. 10, and Demarest 2004, p. 13 )**

## POPULATION HISTORY

The six thousand year time span prior to the Formative period in Mesoamerica is known to archaeologists as the Archaic period. This pre-Maya time period is defined by a very gradual shift away from hunting and gathering to a more sedentary lifestyle, as the first small villages developed in the place of seasonal camps. It was a time of population growth and expansion, as well as the beginnings of plant domestication in Mesoamerica, including the domestication of maize, which would become the primary staple crop of the region (Coe and Koontz 2008). Because they would now be several thousand years old, sites from this period are difficult to locate, especially given that they predate the use of ceramics and structures were built of perishable materials. Because preservation tends to be very poor in the humid Maya lowlands, much of the information about the Archaic period in Mesoamerica comes from the much drier central Mexican highlands. However, in the past few decades, there have been a few research projects undertaken to attempt to uncover more information about what was going on in the Maya region at this time (Lohse 2010; MacNeish and Nelken-Terner 1983; Marcus 2003; Zeitlin 1984).

In the early 1980s, the Belize Archaic Archaeological Reconnaissance project, under the direction of Richard S. MacNeish, conducted four seasons of investigation into the Archaic period in the coastal lowlands of Belize (MacNeish and Nelken-Terner 1983; Zeitlin 1984). The project identified six stone tool complexes in the coastal and inland coastal plains areas of Belize, which span from the end of the Paleoindian period up to the beginning of the Preclassic, a period of about 7,000 years. During this time, they determined, occupants of the region were seasonally nomadic, making use of a variety of habitats, including coastal areas. The shift to a focus on agriculture as the main subsistence strategy may have occurred around 3,000 B.C. in the millennium prior to the Preclassic period, as people began to settle in the riverine and estuarine environments, which had rich alluvial soils particularly well-suited to agriculture.

Maya farming villages began to be established in the Maya lowlands sometime between 2000 and 1000 B.C. (Marcus 2003). This was the beginning of the Formative period, or the Preclassic as it is known in the Maya area. The Preclassic period lasted from the end of the Archaic to the beginning of the Classic, roughly between 2000 B.C. and A.D. 250. However, the first major centers did not begin to appear until the Middle Preclassic, which began at about 1000 B.C. (Demarest 2004). By the end of the Preclassic period, hieroglyphic writing and a complex calendrical system were in use and stone monuments and monumental architecture began to appear. Kaminaljuyu was a major center in the Guatemalan highlands, and the central lowland area of northern Guatemala and the southern part of the state of Campeche in Mexico had a high density of Late Preclassic sites, some of them very large, both in scale and in architecture (Marcus 2003, p. 82). In the Mirador Basin of Guatemala, the enormous Preclassic sites of El Mirador and Nakbe emerged, containing some of the largest pyramids ever found in the Maya area, not just of the Preclassic, but of all time periods. In fact, the La Danta pyramid is one of the largest in the world in terms of its total volume in cubic meters (Coe 2005; McAnany 2004c).

The area of northern Belize situated around the New River Valley also saw population increase and the rise of political complexity at this time. McAnany (2004c) states that much of the Formative settlement of the Maya area initially occurred near rivers and wetlands, as these areas provided fertile soils for cultivation and aquatic food resources. By the Late Preclassic in this region of the lowlands, raised fields were being built in the swamps and *bajos* (Marcus 2003). It should also be noted that, although the Maya lowlands are generally regarded as being "tropical," water sources and water management were of great concern to the Maya, especially as agriculture intensified; thus, the wetlands of northern Belize were highly valuable. In the 1970s and 1980s, excavations in northern Belize at such sites as Cuello, Cerros, and Lamanai showed Preclassic occupation and the beginnings of monumental construction during this time (Hammond 1991; Pendergast 1981).

The Classic period, between approximately 250 and 900 A.D., was the period of greatest political complexity for much of the Maya area, particularly the southern lowlands (Coe 2005; Demarest 2004). This period is defined by the use of the Long Count calendar in the inscriptions on stone monuments. It is commonly regarded as the height of Mayan civilization, a period once seen by archaeologists as the "cultural florescence" of the Maya; but, as Demarest (2004) points out, many of the cultural achievements that were believed to have come from this period actually came about much earlier, and some sites continued to flourish much later. While some cities, such as El Mirador and Nakbe, did not survive past the Preclassic period, other major political centers, such as Tikal, Copán, and Calakmul, continued to grow and reached their height during the Classic period.

The Postclassic (A.D. 1000-1542) began with the collapse of Classic Maya civilization and ended with the arrival of the Spanish *conquistadores* (Coe 2005; Demarest 2004). Around the end of the eighth and into the ninth and tenth centuries A.D., the Terminal Classic, many of the major Maya centers fell into decline and were eventually abandoned. This is commonly known as the "collapse" of the ancient Maya. A variety of factors are thought to have influenced the Classic Maya collapse, the two predominant models calling for either an ecological or a political cause (Marcus 2003; Wright 1997a; Wright 2006). Archaeologists recognize now that different areas experienced the collapse in different ways: for instance, ecological issues seem to be a dominant factor at Copán (Storey, et al. 2002; Webster, et al. 2000), while in the Petexbatun region of Guatemala, warfare and political problems are believed to be the main cause (Demarest 2004; Marcus 2003). However, some sites did not experience a collapse at all at this time, continuing to flourish well into the Postclassic, including Lamanai in Belize and major centers in the highlands of Guatemala (Coe 2005; Marcus 2003; Pendergast 1981). In the northern Yucatán, the population grew during Postclassic, with new centers continuing to be built during this time, including the large center of Mayapan (Coe 2005). By the sixteenth century arrival of the Spaniards, many of the major political centers had been abandoned, but there was still a large population of Maya living in the same area, a population which persists in modern times.

### Social and Political Structure

It is important to note that the Maya world was not a single, politically unified entity at any point in its history. Rather, it was composed of hundreds of communities of varying sizes and degrees of influence (Coe 2005). Some of the largest and most well-known political centers during the Classic period included Tikal, Calakmul, Palenque, and Copán, but there were many others, and power tended to shift between them at various points in their histories. These large administrative centers would have had control over the smaller villages and rural areas that surrounded them. Additionally, conflict between the larger polities was quite common, as they competed for territory and resources (Demarest 2004).

The establishment of ranked society most likely occurred during the Middle to Late Preclassic in the Maya area, as larger villages began to take control over smaller ones, creating multivillage chiefdoms (Marcus 2003). Major chiefdoms of the Late Classic period included Kaminaljuyu in the Guatemala highlands (now buried beneath Guatemala City) and El Mirador and Nakbe in the lowlands. Cities like Tikal and Calakmul, which would later become major Classic period centers, were also influential chiefdoms at this time. According to

Joyce Marcus (2003), the increase in political complexity from chiefdoms to state-level society may have occurred during the Late Preclassic period, but as yet there is not enough evidence to be sure of when exactly this occurred. Certainly by the Classic period, however, Maya political centers had increased in power to the level of city-states, and this level of political complexity persisted up until the Collapse in the central lowlands, and into the Postclassic period in some areas like the highlands and the northern lowlands.

Because of the Classic-period use of hieroglyphic inscriptions on stone monuments, political histories of many of the largest Maya centers are well-known, including information about rulers and their dynasties, as well as political conquests and alliances with other polities (Martin and Grube 2008). For instance, sixteen successive generations of kings are depicted, along with their name glyphs, on the famous Altar Q from Copán, and a dynasty of at least 33 rulers has been identified from monuments at Tikal (Coe 2005; Martin and Grube 2008). Major dates were recorded using the Long Count calendar system, which has been correlated with the Gregorian system, meaning that the exact dates of many major events are known. From these hieroglyphic histories, it has been established that rulership was hereditary, the right to power passed between related males in a patrilineal system (such as father to son or brother to brother), with queens ruling only in rare cases when their sons were not yet old enough to inherit their titles.

Maya political centers were not like true cities, in the sense that they did not host a large urban population (Coe 2005). For instance, the city of Teotihuacan, a civilization in the highlands of central Mexico that was contemporaneous to the Early Classic Maya, had a dense urban population that reached 125,000-200,000 residents (Coe and Koontz 2008). These residents lived in large apartment compounds within the estimated 8 square miles of the city. By contrast, Maya population tended to be more dispersed, with commoners living in the more rural agricultural areas (Demarest 2004). The larger cities would have vast public architecture that served ritual and administrative functions, including large pyramid temples and royal palaces. Surrounding the administrative centers were smaller elite complexes and shrines, the residences of nobles, who may have gained their elite status due to their relationship to the king. In the more rural regions outside the main centers, lesser local elites had political influence within their communities, replicating the main political-ritual centers on a smaller scale with smaller administrative structures and shrines (Demarest 2004).

Central administrative centers would have collected tribute in the form of surplus food, material items, and labor from the surrounding smaller communities and rural areas (Coe 2005). Commoners were primarily engaged with agricultural production, as well as producing necessary household items such as lithic materials and ceramics. They would also be called upon to provide labor in elite architectural projects. Nobles may have been engaged with administrative tasks, long-distance trade, craft specialization in the production of elite items, or work as scribes (Coe 2005; Demarest 2004).

The basic social unit in Maya society was the household group (Demarest 2004). Maya houses ranged from simple wattle and daub houses to larger masonry structures to vast royal palaces, with the elaborateness of the structure reflecting social status. However, fundamentally they were all arranged in the same way. Closely-related families would arrange their homes in groups around a shared courtyard or patio. This central space was used by families for domestic tasks such as food preparation and for socialization. Social identity was determined by one's lineage, and ancestor veneration was very important (McAnany 1995). Family members who were important within their lineages were buried beneath patios and the floors of houses at all levels of Maya society. Placing revered ancestors within the home was a way of expressing the lineage's claim to the land and its place within the community.

### ANCIENT MAYA DIET

Analysis of paleodiet draws from several lines of archaeological evidence. These include studies of botanical remains, including pollen and phytoliths, faunal analyses, and bioarchaeological studies. Additionally, archaeological excavations can reveal evidence of agricultural practices, including signs of agricultural intensification, such as terracing and ditched fields. Bioarchaeological analysis provides information about past diets both directly, through the analysis isotope ratios of chemical elements in both the collagen and mineral components of bones and teeth, and indirectly, through inferences made based on pathological conditions observed in the skeleton. Many such studies have been conducted by archaeologists in the Maya area, and although there is still much that is not fully understood, after several decades of research, a picture has emerged of a complex landscape with a great deal of regional and cultural variation in resources and subsistence (Coyston, et al. 1999; Gerry and Krueger 1997; Lentz 1991; Lentz 1999; Mansell, et al. 2006; Scherer, et al. 2007; Storey, et al. 2002; White, et al. 2001; Wright and White 1996).

*Plant Resources*

The first concrete signs of agriculture in the Maya area come from as far back as 3,000 years ago at the site of Cuello, Belize, and soon after that at other Formative period sites, including Pulltrouser Swamp and Cerros, also in Belize, and the Copán Valley in Honduras (Lentz 1999: 4). Studies of early Maya wetland agriculture at Pulltrouser Swamp and Albion Island in northern Belize show that maize and other cultigens were grown starting at least as early as the Middle Preclassic period, from about 1,000 B.C. onward (Miksicek 1990; Pohl, et al. 1990; Turner and Harrison 1983). At Preclassic Cuello, Charles Miksicek (1991), found evidence for use of squash, nance, and especially maize from the earliest stratigraphic levels at the site, and maize was found in a high percentage of the flotation samples from every time period, from the early Middle Preclassic to the abandonment of the site.

David Lentz (1999) states that remains of maize have been found at every Maya site at which archaeobotanical research has been conducted. Maize (*Zea mays*) was the primary staple crop throughout Mesoamerica, as well as in other parts of the New World (Danforth 1999; Larsen 1995; Storey 1999; Storey, et al. 2002; Whittington and Reed 1997b; Wright and White 1996). Another major component of the Maya diet, the common bean (*Phaseolus vulgaris* L.), first shows up in the Maya area between 945 and 340 B.C., but unfortunately its remains do not preserve well and are not commonly found; beans were probably actually introduced to the Maya area much earlier. Lentz explains that maize and beans would together have provided all of the essential amino acids required in the human diet. Beans also would have provided a source of protein, and the third main cultigen in the Mesoamerican agricultural triad, squash (*Cucurbita moschata*), would provide carbohydrates as well as several other key nutrients, including vitamins A and B, niacin, and potassium . Lentz suggests that these three crops were probably grown together in large fields away from the households, as is the most common practice today, probably most often using swidden agricultural methods, as well as terraces, raised fields, and other methods when the landscape called for them.

Lentz (1999) also discusses several other plant resources that have been identified in the Maya area, drawing on paleobotanical evidence from several different sites. One such site includes the Maya village of Cerén, in El Salvador. Cerén provides important evidence not only of what plant foods were available, but information about how they were used and where they were grown, as well, since the entire village was covered over by a thick layer of volcanic ash by an eruption that occurred around 600 A.D., similar to what happened to Pompeii. This event preserved material remains *in situ* in the houses and small garden plots nearby, just where they had been left by Cerén's ancient inhabitants as they fled the eruption. The advantage to this is that the layer of ash preserved plant materials that ordinarily do not preserve well archaeologically. From Cerén and other sites, Lentz identifies several plant resources that would have been used by the Maya in addition to maize, beans, and squash. These include chili peppers, used for flavoring and an important vitamin source, cotton for its fiber and its seeds possibly used as a cooking oil, agave for twine and textiles, and potentially the root crop manioc. Manioc and possibly other root crops may have been used in the Maya area, but evidence for them is extremely limited given that all parts of these starchy plants are highly perishable even in the best of conditions. Lentz states that there has been some limited evidence for the use of manioc at Cuello, and casts of the plant were found at Cerén, but this is not enough to consider it to have been a key agricultural product in any other part of the Maya area. Several tree fruits were also utilized by the Maya, including avocado, cacao, cashew, papaya, nance, guava, and others. A few varieties of palms, such as *coyol*, were probably also utilized for their oils, and as such would have been an important source of fats, which were relatively scarce in the Maya diet.

*Animal Resources*

Analyses of faunal remains found at several sites throughout the Maya area have shown which animal species were most commonly used as food sources. One of the most common species, the white-tailed deer, has been found in archaeological deposits throughout the lowlands from the Preclassic through the Colonial periods (Emery 1999; Emery 2003; Götz 2008; Shaw 1999; Tykot, et al. 1996; Webster, et al. 2000; Wing and Scudder 1991; Wright 2006). Other terrestrial vertebrate fauna were also utilized to varying degrees, including tapir, peccary, brocket deer, and other forest species (Shaw 1999; Webster, et al. 2000; Wright 2006). The remains of small, maize-fed domesticated dogs have been found at sites such as Copán, Cuello, and others (Clutton-Brock and Hammond 1994; Tykot, et al. 1996; Webster, et al. 2000; Wright 2006), and Robert Tykot and colleagues (1996) state that evidence of butchering on dog bones suggest that they were a food source, rather than being used for hunting.

Marine and freshwater fauna were used in varying amounts, depending on the region, generally where they were most accessible. For instance, Altun Ha, only seven kilometers from Chetumal Bay, shows abundant use of marine resources, whereas sites in Belize further inland shows less (White, et al. 2001), and similar patterns were observed in the northern lowlands (Götz 2008). Freshwater fish and turtles were another food source in many parts of the Maya area (Webster, et al. 2000; Wright 1997a; Wright 1999; Wright 2006), but especially in northern Belize, where residents made use of the wetlands and rivers (Coyston, et al. 1999; Emery 1999; Shaw 1999; Tykot, et al. 1996; White and Schwarcz 1989; Wing and Scudder 1991). Terrestrial and aquatic mollusks may have supplemented the diet as well (Covich 1983; Miksicek 1991; Webster, et al. 2000).

*Dietary Chemistry*

While paleobotanical and faunal analyses provide valuable information about which plant and animal resources were available, the most direct line of evidence for paleodiet comes from the analysis of stable isotope ratios and trace elements in human bones and teeth. Studies of dietary chemistry are particularly useful in that they show what was consumed on an individual basis, revealing patterns of variation in terms of age, sex, social status, and geographic location, and allowing bioarchaeologists to study the relationship between diet and paleopathology (Danforth 1999; Wright and White 1996).

One of the most important and frequently-studied aspects of dietary chemistry in ancient populations is the analysis of stable isotopes of carbon (C) in human bones and teeth (Bartelink and Wright 2011; Coyston, et al. 1999; Scherer, et al. 2007; White, et al. 2001; White and Schwarcz 1989; Wright 1997a; Wright 2006; Wright and White 1996). The ratio of $^{13}C$ to $^{12}C$ isotopes in bone can vary based on the carbon fixation pathway utilized during photosynthesis by the different plant foods that are consumed. (Gerry and Krueger 1997). Most plants use the C3, or Calvin-Benson, method of carbon fixation during photosynthesis, but some, including many grains, use the C4, or Hatch-Slack, method. Some plants use a third method called Crassulacean Acid Metabolism (CAM), but none of the plants that use this method were important food sources for the Maya. The different methods of carbon fixation each leave different ratios of carbon isotopes in the tissues of the animals that consume them, including humans. In the Maya area this is particularly useful because the only plant in the region that is known to have contributed significantly to the diet that uses the C4 method of carbon fixation is maize. Therefore, the amount of the maize consumed by an individual, in relation to other plants, which use the C3 method, can be determined from the $\delta^{13}C$ value. In short, a heavier $\delta^{13}C$ value indicates a greater proportion of maize in the diet. Isotope studies at several different sites throughout the southern Maya lowlands have demonstrated that maize was an important component of Maya diet throughout time, though to differing degrees in different ecological zones, as will be discussed later in this chapter.

Similarly, isotope ratios of nitrogen (N) in bone collagen can provide valuable information about the diet, as well. The $^{15}N$ to $^{14}N$ ratio in human bone can provide evidence of meat consumption, as $\delta^{15}N$ values are enriched by 3-4‰ over each trophic level (Gerry and Krueger 1997; Wright 2006). In other words, the average $\delta^{15}N$ ratio for a carnivore is 3-4‰ higher than that of an herbivore, and therefore the higher an individual's $\delta^{15}N$ ratio, the more meat they likely consumed. Additionally, marine foods have even higher values, so particularly high $\delta^{15}N$ values often indicate a diet high in marine resources. For a more thorough discussion of the theory and methods behind both carbon and nitrogen isotopic analyses, see in particular White and Schwarcz (1989: 455-457), Wright and White (1996: 169-172), Gerry and Krueger (1997: 197-200). Studies of nitrogen isotopic ratios in the Maya areas have shown that meat consumption tended to vary both by status (Danforth 1999; Whittington and Reed 1997b) and by what was available regionally (Coyston, et al. 1999; Gerry and Krueger 1997; White, et al. 2001), as will be discussed in more detail in the last section of this chapter.

Another aspect of dietary chemistry that has been studied in the Maya area are ratios of alkaline earth elemental ratios in bone (White and Schwarcz 1989; Wright 1999; Wright 2006). Calcium (Ca) is an important component of bone which is absorbed from sources in the diet. However, strontium (Sr) and barium (Ba), which have no metabolic function in the human body, are sometimes absorbed instead. Because Ca is absorbed preferentially over Ba and Sr, the ratios of Ba/Ca and Sr/Ca in bone are a good indicator of trophic level; in other words, these ratios can provide evidence of meat consumption, because animal foods have lower concentrations of Ba and Sr compared to plant foods. Additionally, Ba levels are low in marine waters, so the Ba/Ca ratio can provide information about marine contributions in the diet. Sr levels tend to be high in freshwater foods, as well, as Sr leaches into freshwater bodies from ground water; therefore, the Sr/Ca ratio can be useful in providing information about freshwater plant and faunal contributions to the diet, as well. See White and Schwarcz (1989: 455-457), and Wright (1999: 197-206; 2006: 82-84, 87-88) for more on the theory and methods behind alkaline earth elemental analysis.

*Diet and Paleopathology*

Although the majority of nutritional deficiencies do not leave a mark of their presence on the human skeleton, there are a few that have specific signatures that have been recognized by osteologists, and their presence (or absence) in skeletal samples is often used to make inferences about the nutritional state of past populations. Of few of the most common examples of these include porotic hyperostosis and cribra orbitalia as evidence of anemia, scurvy, caused by vitamin C deficiency, and rickets, caused by vitamin D deficiency (Danforth 1999; Wright and White 1996). There are also several nonspecific stress indicators frequently used to make inferences about diet and health, including conditions such as enamel defects in the dentition and trends in stature within a population over time. A few of these conditions have frequently been observed in the Maya area, as will be discussed in Chapter Four, in particular porotic hyperostosis and linear enamel hypoplasias.

REGIONAL VARIATION IN RESOURCES AND SUBSISTENCE

Regional variability in Maya diet has been recognized for some time (Coyston, et al. 1999; Gerry and Krueger 1997; Lentz 1999). As Shannon Coyston and colleagues state, "Subsistence practices and dietary choices are influenced by a complex set of factors that include resource availability, cultural traditions, and economic, social and political considerations" (1999: 221). While many social factors, such as social status, influenced diet, much of dietary variation was based on the ecological setting in which a settlement was located. Gerry and

Krueger (1997) argue that, while diet does tend to vary over time and social status, the most significant source of variation is geographic location, with the most dramatic differences being between the heartland area, such as the Petén and Copán, and eastern area in Belize. Tykot and colleagues agree, stating that "It would appear that geography and local ecology played the greatest role in determining the diet of the ancient Maya, with relatively minor local differences in terms of gender or status," (1996: 363). The following discussion provides a more in-depth examination of resources and diet for three distinct regions of the Maya lowlands: Copán, the Pasión region, and northern Belize.

*Copán*

Copán sits at the southeastern corner of the Maya world in far western Honduras, only about twelve kilometers from the border of Guatemala (Webster, et al. 2000; see Figure 2.1). At the height of its power in the Late Classic period, Copán was an influential Maya center, with a peak population of 20,000-25,000 people in the eighth century A.D., with 9,000-12,000 people concentrated around the urban core of the site, and the rest living in the surrounding rural areas (Webster, et al. 2000). The urban center, with its monumental architecture and surrounding elite residences, was located in a large pocket of the Copán Valley alongside the Copán River.

Several geographical features make Copán different from Maya centers in the central lowlands. First, Copán is located in a valley at 600 meters above sea level (asl) in elevation at its lowest point, and the peaks surrounding the valley at nearly 1,400 m asl (Abrams and Rue 1988; Webster, et al. 2000). Although it is sometimes referred to as a lowland site, Copán is really in the transition zone between the southern lowlands and the highlands of Guatemala. This higher elevation means that Copán had different ecological features compared to other lowland centers.

Copán is situated in a river valley that is characterized by a series of alluvial pockets, or *bolsas*, of varying sizes (Webster, et al. 2000). There are five such pockets, the largest of which is the Copán pocket, about 12.5 km long and 4 km wide at the widest point, in which the urban core of the site is located. There are three zones in the valley: the bottomlands, the piedmont area, and the upland forests (Abrams and Rue 1988). The best agricultural lands were in the bottomlands, as the alluvial soils along the river were rich and fertile, constantly replenished with nutrients. Before being cleared for agriculture, these lands would have been covered in tropical deciduous forest. The piedmont, or foothill zone, was also farmed in the Late Classic period out of necessity as the population grew dramatically. However, the more temperate upland forestlands, dominated by pine, were not used for agriculture, as the slopes were too steep and the soils too acidic; however, they were heavily exploited for wood, and probably for hunting.

Its location in the highland-lowland transition zone meant that Copán was also somewhat isolated geographically. The easiest way northward out of the valley was along the Sesesmil River, which would eventually lead to the Petén and beyond (Webster, et al. 2000). Copán's closest neighbor during the Classic period, the small Maya kingdom of Quiriguá, was about 50 km away, also located northward near the Sesesmil. Because of the rugged landscape surrounding the valley and the limited agricultural lands within it, the ability of the people of Copán to expand beyond its boundaries was limited.

Archaeobotanical evidence at Copán suggests a diet primarily based on the typical Mesoamerican cultigens, with maize as the staple grain, supplemented with beans and squash (Lentz 1991). Tree fruits were also used, including avocado and nance, as well as some wild foods, such as wild grapes and hackberry. Palm species were also utilized, especially *coyol*. Lentz (1991) states that there were significant differences found between elite and commoner households in terms of the foods eaten between these status groups in the Late Classic period, with the elite having access to a greater variety of plant foods at Copán. Abrams and Rue (1988) also found the pine trees of the upland forests were exploited for fuel for heating and cooking, house building materials, and the production of ceramics and lime plaster. They note that as population increased in the Late Classic, deforestation was a significant problem, causing the erosion of the acidic upland soils into the agricultural lands, decreasing their productivity and likely contributing to the ninth century collapse of Copán.

Stable isotope analysis has revealed that the entire population of Copán relied heavily on maize as the main component of the diet, based on carbon and nitrogen isotope analyses on 25 commoners and 57 elite individuals recovered from both rural and urban contexts (Whittington and Reed 1997b). Both elites and commoners had high-maize diets, though the elites seem to have had access to a wider variety of plant foods based on carbon isotopic ratios. However, based on the nitrogen isotopic ratios, there was no difference in meat consumption between status groups, meaning that the elites do not appear to have consumed more meat than did commoners. Whittington and Reed also state that diet became slightly more varied during the latter part of the Late Classic than it was during the Middle Classic or the early half of the Late Classic. Considering that the late Coner phase was a time of decline as Copán neared its political collapse, the authors suggest that, as the production of maize began to fail due to environmental degradation in the Copán Valley, the residents of Copán had to turn to other plant food sources. They also found a difference in mean carbon isotope values between the sexes that suggested that maize made up a higher percentage of the male diet than in the female diet among commoners.

Pathologies on the remains of the people of Copán also suggest a high reliance on maize at Copán. Stephen Whittington's (1999) analyzed the remains of 148 individuals excavated from commoner contexts at the site for dental caries and antemortem tooth loss. Dental caries often indicate a diet high in carbohydrates, and tooth loss sometimes results from caries if they become severe enough to expose the pulp chamber. Whittington proposes that a high rate of caries within the Copán population would be indicative of a diet with a high proportion of maize, as maize was the main carbohydrate consumed by the

Maya. He found that 68.2% of individuals of the individuals with permanent teeth preserved (N=85), as well as 43.5% of subadults with preserved deciduous teeth, had at least one carious tooth. Further, he found evidence of antemortem tooth loss in 37.2% of scorable individuals (N=86). These figures suggest a high carbohydrate diet at Copán, probably mostly maize; however, he does state that caries rates were lower than at other locations in the New World that are known to have been maize-dependent. Additionally, he states that females showed higher caries rates than males, and overall the peak in frequency seems to have occurred after A.D. 800, when Copán was on the verge of collapse. Other pathological conditions that inform on nutritional status include porotic hyperostosis and enamel defects, and the prevalence of these conditions at Copán will be discussed in Chapter 4.

*The Pasión Region*

The Pasión region (Figure 2.3) consists of a number of Maya centers located in an area between the Pasión and Chixoy rivers in southwestern modern-day Petén, Guatemala. This was part of the broader region of the southern lowlands, what would have been the heart of Maya civilization during the Classic period. In contrast to Copán, centers in this region were very close together and politically very active, with shifting alliances and frequent conflicts (Demarest 2004). For this reason, the causes of the collapse in this region are believed to be social and political, rather than ecological, in nature (Demarest 2004; Wright 1997a; Wright 2006; Wright and White 1996).

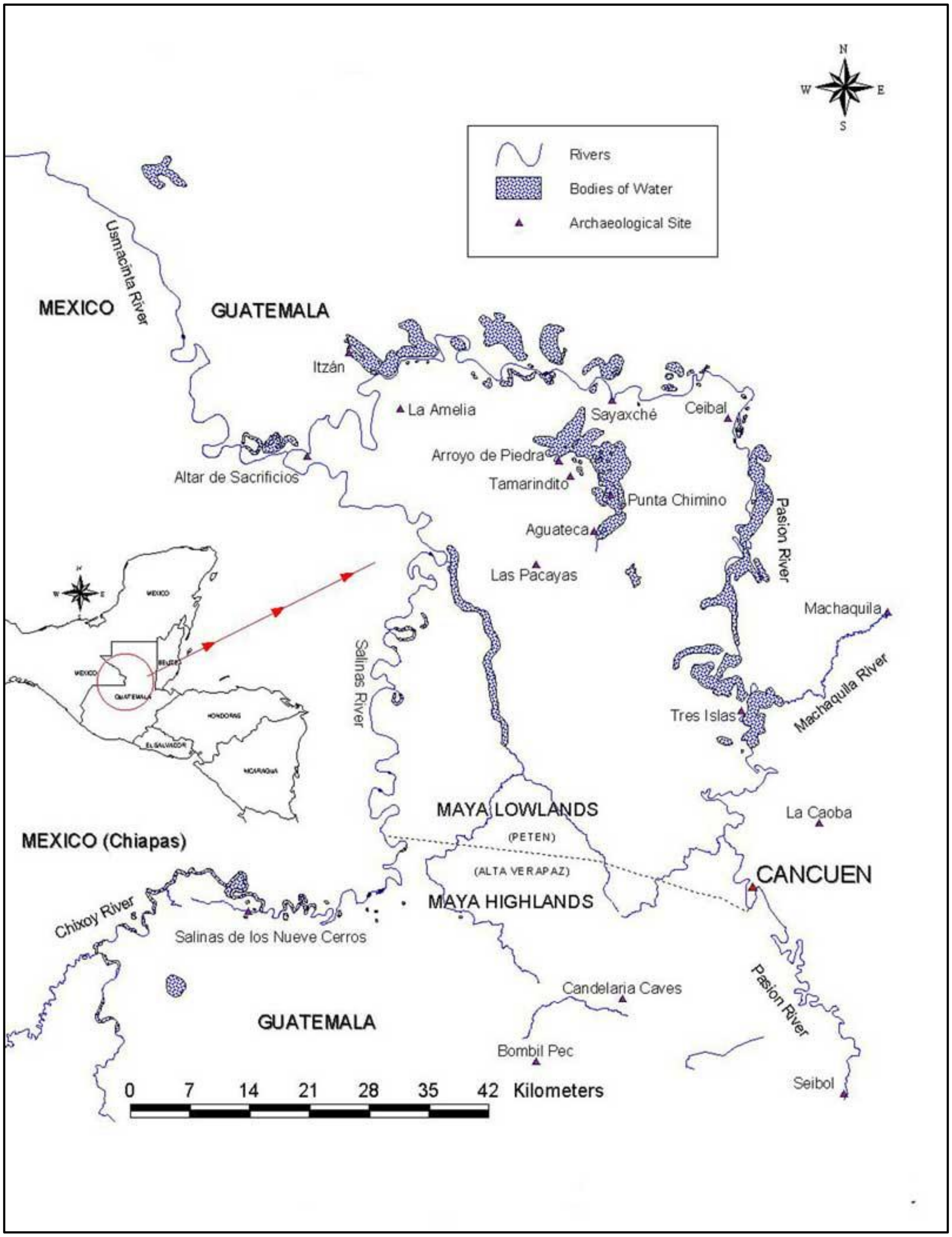


**Figure 2.3: Map of the Pasión Region (http://www.vanderbilt.edu/exploration/resources/map1_800.jpg)**

The Department of Petén, Guatemala and adjacent portions of southern Mexico were the heartland of lowland Maya civilization during the Preclassic and Classic periods. The karst limestone landscape in this portion of the Maya region is generally less than 100 meters above sea level in elevation and relatively flat (Demarest 2004). Like much of Mesoamerica, the Maya lowlands experience a rainy season and a dry season, and in the Petén total rainfall during the rainy season can measure from two to three meters (Demarest 2004). However, because of the lengthy dry season, which lasts about four months in the Petén, the forests that cover the landscape here are not considered a true tropical rainforest, but rather a "humid subtropical forest" (Demarest 2004, p. 122). The trees are deciduous, dropping their leaves annually during the dry season (Coe 2005).

Although the forests in the Petén are humid and experience heavy rainfall during the wet season, water may sometimes be scarce during the dry months (Coe 2005). However, Lori Wright (2006) states that the Pasión region receives an average of 2,000 mm of precipitation per year, and with several major rivers in the area (the Salinas, the Petexbatun, and the Pasión), water procurement is generally not a problem, and nearby water sources provide a source of freshwater fish. The Petén does have fairly good soils for agriculture, as long as the land is left fallow for long enough periods to regain its fertility (Coe 2005). The soils here are thin and quickly depleted by sun exposure and erosion if used too long. In this part of the lowlands the Maya were probably using a shifting, slash-and-burn agricultural system in which fields were used for a couple of seasons, then left to regrow for several years while the farmers cleared and used a new piece of land (Coe 2005; Demarest 2004). The typical maize-beans-squash triad were the main plants cultivated in this system, supplemented by tree fruits and wild edibles, as at Copán.

Extensive dietary chemistry analysis has been performed by Lori Wright on the human remains recovered from sites in the Pasión region (Wright 1997a; Wright 1999; Wright 2006). These include stable isotope analysis of carbon and nitrogen as well as analyses of the alkaline earth elements barium and strontium in relation to calcium in the bones. Carbon and nitrogen isotopic ratios from 104 adults from Pasión sites have indicated that maize was a significant portion of the diet as it was at Copán (Wright 1997a; Wright 2006). Analysis of the white-tailed deer specimens from archaeological contexts also show a diet heavy in maize, indicating that the deer were probably feeding on the fringes of the agricultural fields, which likely were very extensive. The meat from these deer and also domesticated dogs, which had a high maize diet, as well, would have had heavier carbon isotopic ratios, which would also influence the carbon ratios of the humans who consumed it, meaning that the proportion of C4 plant food sources would appear greater.

Wright (2006) also discusses patterns of maize consumption across time for each site in order to evaluate whether failure of the agricultural system might have impacted the Classic period collapse in the Pasión region. At Altar de

Sacrificios, she found the maize consumption increased up to the Late Classic, but decreased in the Terminal Classic. There was a similar, but not statistically significant, decrease in maize consumption at Dos Pilas. At Seibal, maize consumption was relatively unchanged from the Preclassic through the Terminal Classic. As the ecological model for the collapse calls for a more dramatic increase as populations reached high numbers in the Late Classic, Wright concludes that an overburden on the agricultural system did not contribute to the collapse in this part of the Maya area.

Nitrogen values for the Pasión sites indicate a relatively high-meat diet for the whole region. Wright states that "meat consumption was also important and contributed a substantial amount of dietary protein toward collagen synthesis" (1997, p. 188). This is contrary to the situation at Copán, where meat consumption was found to be quite low for the entire population. At Altar de Sacrificios and Dos Pilas, N ratios do not change significantly over time, and at Seibal they decrease only in a minor way during the Terminal Classic, probably due to a decrease in fish consumption compared to the Late Classic. From these data, Wright suggests that the populations of the Pasión region had not overexploited their meat resources. Nitrogen values further indicated that freshwater fish contributed significantly to the diet in addition to terrestrial animals. This is apparent based on the fact that freshwater fish were determined to have a heavier nitrogen isotopic signature in relation to other meat resources available (Wright 2006). The Pasión region is far from the coast in either direction, and very little evidence for marine fauna has been found at the site, so it is highly unlikely that any marine foods were part of the diet at these sites.

Wright (1999) examined Ba/Ca and Sr/Ca ratios for three of the sites in the region, Altar de Sacrificios, Seibal, and Dos Pilas, looking for temporal and social differences in diet. Because Ba and Sr levels in the environment can vary even within the Pasión region, each site was examined separately, as the ratios themselves could not be compared. She found status differences in the diet at both Altar de Sacrificios and Dos Pilas. At Seibal, it appears that there was greater consumption of freshwater fish during the Late Classic period. Alkaline earth elements in the diet can be difficult to interpret, however, so many of the patterns in Ba/Ca and Sr/Ca ratios remain unclear. However, Wright does conclude that food appears to have been obtained locally, not traded, and there were some social differences apparent in the diet (1999: 215).

*Northern Belize*

Northern Belize is a unique segment of the southern Maya lowlands given its ready access to the Caribbean coast and its relative abundance of permanent rivers . Unlike at Copán, the Maya living in this region would have had ready access to other sites via riverways, which facilitated interaction and trade (Guderjan 2007; McAnany 1989; McAnany 2004b). The proximity of rivers, the Caribbean to the east, the Chetumal Bay to the north, and wetland areas resulted in easy access to abundant aquatic resources in this region. Wetland agriculture also meant that more fertile agricultural soils were available (Pohl 1990; Turner and Harrison 1983).

The modern-day country of Belize (Figure 2.3) lies south of the Yucatan Peninsula and east of the Department of Petén, Guatemala (Zeitlin 1984). The karst limestone platform that makes up the Yucatan Peninsula extends down through the northern half of Belize, resulting in a flat topography less than 100 m in elevation. The interior portion of the southern part of the country is dominated by the Maya Mountains, some of which reach 1,000 m or more. Offshore there are barrier reefs and sandy cayes, and along the mainland shore are areas of marsh grasses, mangrove swamps, and palmetto. In the northern interior are several rivers, including the New River, the Belize River, and the Río Hondo. Areas of subtropical pine and broadleaf forests, savannas, and wetlands characterize the northern interior, though today much of this area has been replaced by fields of sugarcane.

Evidence for maize cultivation goes as far back as 1,000-1,500 B.C. in northern Belize, probably using raised field agriculture in the fertile wetland soils, in which the nutrients would be constantly replenished (Lentz 1999; Miksicek 1990; Pohl, et al. 1990; White and Schwarcz 1989). While maize was the dominant species, other plant remains found in the area at the earliest time periods included nance, squash, hackberry, mamey, and others (Miksicek 1991). Faunal remains found include terrestrial mammals such as white-tailed and brocket deer, tapir, and domesticated dogs, freshwater fish and turtles, and

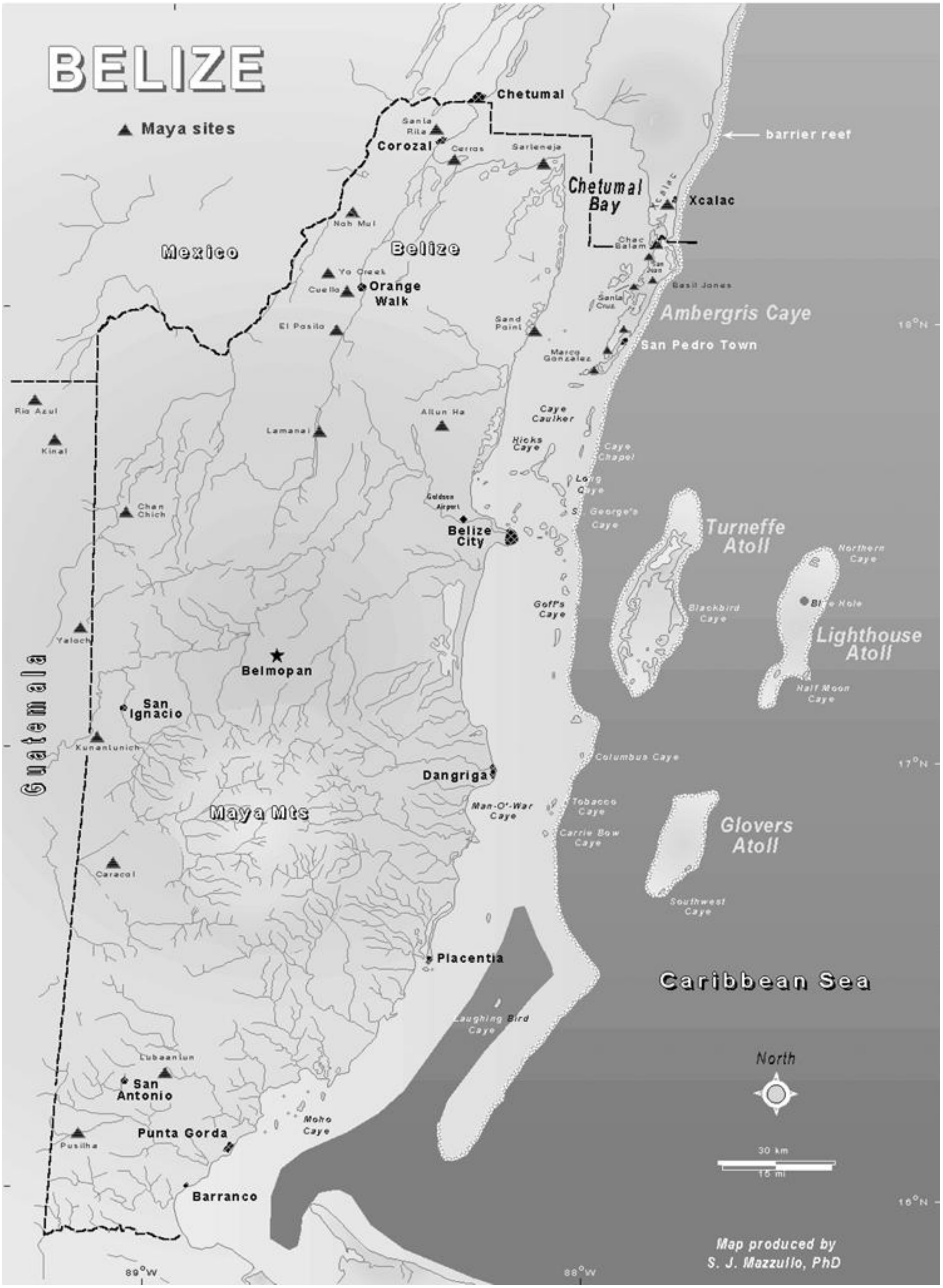


**Figure 2.4: Map of Belize with Major Maya Sites**
**(http://ambergriscaye.com/pages/town/mapbelizesal.html)**

marine fish (Coyston, et al. 1999; Shaw 1999; Tykot, et al. 1996; Van der Merwe, et al. 2002; Wing and Scudder 1991).

Isotopic analyses have been carried out at several different sites in Belize, including Lamanai (Coyston, et al. 1999; White and Schwarcz 1989), Altun Ha (White, et al. 2001), Cuello (Tykot, et al. 1996), Pacbitun (Coyston, et al. 1999), Baking Pot (Gerry and Krueger 1997), and Barton Ramie (Gerry and Krueger 1997). The samples from each site come from various time periods: Cuello was occupied only in the Preclassic and abandoned sometime at the beginning of the Classic period, Lamanai has an extensive collection for human remains from throughout its exceptionally long history (Middle Preclassic-Historic), Pacbitun and Altun Ha have samples from the Middle Preclassic through the end of the Classic, and only samples from the Classic period from Baking Pot and Barton Ramie were analyzed.

In general, the carbon isotope ratios indicate a greater variety of plant resources and less reliance on maize compared to other parts of the Maya area, except for Pacbitun, which was located in a more resource-limited environment to the south in the foothills of the Maya Mountains. According to Gerry and Krueger (1997), for the Classic period residents of the Belize River Valley sites, Baking Pot and Barton Ramie, maize made up about 59% of the diet on average. Tykot and colleagues (1996) report a similar figure of 30-58% maize (varying by the type of bone tissue sampled, apatite or collagen, with apatite producing the lower figure) for Preclassic Cuello. Specific percentages are not reported for

Lamanai, but the overall indication was that in general reliance on maize was low, actually decreasing from the Preclassic to the Classic period, before rising again in the Postclassic and Historic periods (Coyston, et al. 1999; White and Schwarcz 1989).

Nitrogen isotope ratios reflect the wide variety of faunal resources available in northern Belize area, with its wide variety of both terrestrial and freshwater fauna, and access to marine fauna for many sites through trade (Shaw 1999; Wing and Scudder 1991). Tykot and colleagues (1996) found that deer, dogs, and freshwater turtles were the most abundant protein resources at Cuello, and the small, domesticated dogs had a maize-based diet similar to humans, probably from intentional feeding of scraps or scavenging. The deer, however, fed on mostly C3 plants, meaning they were not domesticated and were not feeding on the fringes of agricultural fields. Altun Ha, located only seven km from the Caribbean coast, showed the highest nitrogen isotopic signatures, reflecting a diet high in marine resources (White, et al. 2001).

*Summary of Regional Variation*

Overall, the dietary pattern in the southern Maya lowlands suggests a great deal of ecological variation and corresponding resource availability in the relatively small geographic region. The Classic period population of Copán, located in the densely-populated and ecologically-limited valley in the lowland-highland transition zone, was heavily reliant on maize and had a diet low in meat. The Pasión region in southwestern Petén, Guatemala, which included the sites of Altar de Sacrificios, Seibal (also spelled "Ceibal"), Dos Pilas, Aguateca, and Itzan, also had a diet high in maize, but showed a much higher intake of meat. Finally, the resource-rich region of northern Belize, including sites such as Lamanai, Cuello, Barton Ramie, and Baking Pot, had a comparatively low-maize diet, though maize was still a main agricultural staple, and meat was abundant in the diet. Table 2.2 shows the average carbon and nitrogen values found in bone collagen for several sites, including many of those discussed here. Figure 2.3 also shows the regional differences in isotope values in relation to the values for various plant and animal food sources found in the Maya lowlands.

| | $\delta^{13}C$ | | | $\delta^{15}N$ | | | |
|---|---|---|---|---|---|---|---|
| Site | Mean | SD | *N* | Mean | SD | *N* | Reference |
| Lamanai | −10.84 | 2.37 | 50 | 9.81 | 0.89 | 47 | White and Schwarcz, 1989 |
| Pacbitun | −9.86 | 1.39 | 17 | 9.32 | 0.67 | 17 | White *et al., 1993* |
| Barton Ramie | −11.24 | 1.42 | 38 | 8.8 | 0.44 | 38 | Gerry, 1993 |
| Baking Pot | −11.03 | 1.11 | 9 | 9.2 | 1.34 | 9 | Gerry, 1933 |
| Holmul | −9.38 | 1.27 | 14 | 9.3 | 0.84 | 15 | Gerry, 1993 |
| Uaxactun | −10.65 | 1.09 | 6 | 9.4 | 0.97 | 5 | Wright, 1994 |
| Altar de Sacrificios | −9.4 | 1.37 | 38 | 8.6 | 1.02 | 38 | Wright, 1994 |
| Siebal | −9.4 | 1.16 | 34 | 9.39 | 0.97 | 34 | Wright, 1994 |
| Dos Pilas | −9.05 | 0.98 | 19 | 9.57 | 1.05 | 19 | Wright, 1994 |
| Aguateca | −9.56 | 0.69 | 8 | 9.35 | 1.16 | 7 | Wright, 1994 |
| Itzan | −9.17 | 0.30 | 5 | 7.96 | 0.98 | 5 | Wright, 1994 |
| Copan | −9.26 | 0.72 | 46 | 7.56 | 0.48 | 46 | Reed, 1994 |
| Mojo Cay | −8.46 | 0.38 | 8 | 10.13 | 0.92 | 8 | Norr, 1991 |
| Iximche | −7.78 | 0.40 | 13 | 7.92 | 0.40 | 13 | Whittington and Reed 1992 |

**Table 2.2: Mean Isotopic Compositions of Human Bone Collagen at Maya Sites (Wright and White 1996: 175)**

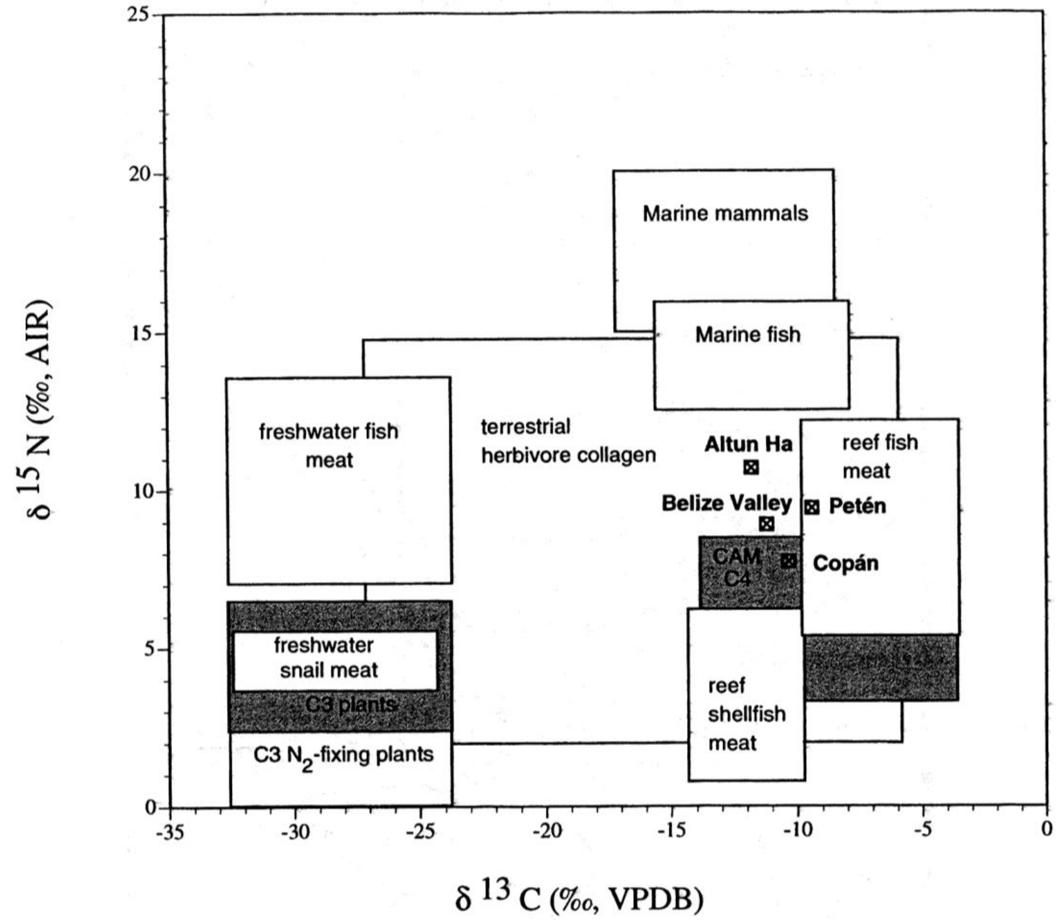


**Figure 2.5: Stable Carbon and Nitrogen Isotopic Ranges for Maya Food Sources (White, et al. 2001: 374)**

# Chapter Three
## K'axob

The site of K'axob is located in the New River Valley of northern Belize, between the New River and Pulltrouser Swamp (Figure 3.1). This small Maya center was occupied for approximately two millennia, from the Middle Formative period, throughout the Classic period, and probably into the Postclassic (McAnany 2004a; McAnany and Lopez Varela 1999). The site's ideal location for agricultural production and the accessibility of a variety of protein resources and wild plants from the wetland environment in which the site is situated likely drew the early residents of K'axob to settle there (McAnany 2004b). By the Late Classic period, the site had grown to include two pyramid plazas and close to one hundred surrounding residences (Figure 3.2). The name of the site is the plural form of the Yucatec Mayan word for "milpa fallow," so named by Peter D. Harrison when the site was first documented in 1981 (McAnany 2004b).

### Politics, History, and Chronology

The people of K'axob had ties to larger political centers in the surrounding area of the New River Valley, particularly through trade networks (McAnany 2004c).The slow-moving, easily-navigable New River facilitated regional exchange between the communities of northern Belize (McAnany 2004b). By the end of the Formative period, McAnany proposes that a settlement hierarchy


**Figure 3.1: Map Depicting K'axob's Location in Northern Belize (McAnany and Lopez Varela 1999)**

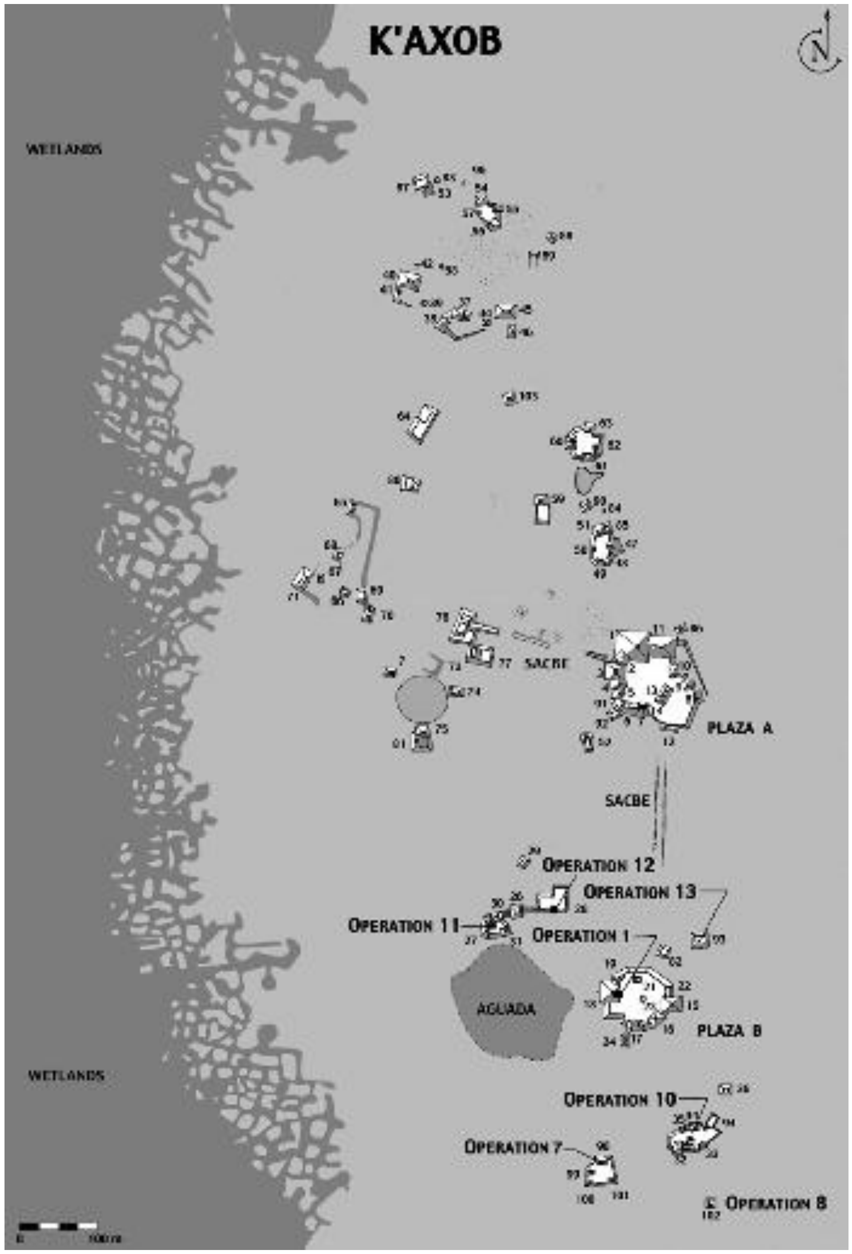


**Figure 3.2: Map of K'axob (McAnany 2004a: 14)**

emerged in this area of northern Belize, with Lamanai, located on the New River Lagoon at the source of the New River and the largest site in the region, being the dominant center. The largest Formative period architecture in the region, including a 33-meter-high pyramid, is found at Lamanai (Pendergast 1981), and probably would have required labor from smaller nearby communities like

K'axob to build (McAnany 2004c). Cerros, located at the end of the New River where it flows into the Chetumal Bay, and Nohmul, between the New River and the Río Hondo, both also had monumental architecture by the latter part of the Late Formative, and probably also occupied a higher political tier (McAnany 2004b). Cuello and San Estevan may have been part of a third tier, followed by the many smaller villages in the valley, including K'axob (McAnany 2004b). Hope Henderson (2003) proposes that regional elites from Nohmul or San Estevan, the two larger centers closest to K'axob, may have had the most direct influence over the village.

Within the community of K'axob, agricultural land rights were established by lineage, with older, more established lineages possessing better agricultural lands and having more control in the K’axob community (McAnany 1995; McAnany 2004a; McAnany and Lopez Varela 1999; McAnany, et al. 1999). However, McAnany and Lopez Varela (1999) suggest that the elite-commoner dichotomy proposed for other, larger centers may not have existed to any significant degree at K’axob. The lineages at K’axob established their claims to the land through mortuary practices (McAnany 1995; McAnany and Lopez Varela 1999; McAnany, et al. 1999). Individuals who were regarded as ancestors of the lineage were frequently buried within residential structures and beneath patios. This practice, which began in the Formative period and continued in the Classic period, served to legitimize each lineage’s claims to the land and to reinforce familial identities (McAnany 1995).

The village of K'axob was founded during the Middle Formative period, sometime around 800 B.C. (Lopez Varela 2004; McAnany and Lopez Varela 1999). The earliest residential structures at K'axob are concentrated around the southern portion of the site, in the vicinity of Plaza B (McAnany and Lopez Varela 1999). The first residents of K'axob built a small farming village in this location, probably drawn to the fertile agricultural land and abundant resources of the wetlands (McAnany 2004b). Throughout the Late Formative, the village continued to expand and grow more elaborate, and during the Classic period, construction expanded further northward (McAnany and Lopez Varela 1999). Also during the Classic period, residential compounds grew in size and small pyramid complexes were constructed, including the tallest structure at the site, Structure 1, a 13-meter-tall pyramid (McAnany 1997).

A relative chronology of the site has been established based on the stratigraphic sequence of ceramic types recovered during excavations (McAnany 2004a; McAnany and Lopez Varela 1999). The “k’ax” at the end of the name of each complex refers to K’axob, as this nomenclature was developed specifically for this site by McAnany and Lopez Varela. The Chaakk'ax and K'atabche'k'ax complexes represent the Middle and Late Formative periods, respectively, while Nohalk'ax and Witsk'ax together represent the Classic. The final complex, Kimilk'ax, dates to the Postclassic. The intervals for each complex were verified from 25 radiocarbon accelerated mass spectrometer (AMS) assays.

| Ceramic Complex | Interval |
|---|---|
| **Chaakk'ax** | 800 - 400 B.C. |
| *Early facet* | 800 - 600 B.C. |
| *Late facet* | 600 - 400 B.C. |
| **K'atabche'k'ax** | 400 B.C. - A.D. 250 |
| *Early facet* | 400 - 200 B.C. |
| *Late facet* | 200 B.C. - A.D. 100 |
| *Terminal facet* | A.D. 100 - 250 |
| **Nohalk'ax** | A.D. 250 - 550 |
| **Witsk'ax** | A.D. 550 - 850 |
| **Kimilk'ax** | A.D. 850 - 1300 |

**Table 3.1: Chronology of K'axob (adapted from McAnany 2004b: 16)**

## LANDSCAPE AND RESOURCES

K'axob's location near Pulltrouser Swamp meant that its residents had access to fertile, drought-resistant soils that could be intensively cultivated as raised fields (Henderson 2003; McAnany and Lopez Varela 1999; Turner and Harrison 1983). Raised fields are preferable to swidden fields because they are continuously irrigated and would not have required fallow periods as other Maya agricultural land would. K'axob was one of ten communities that surrounded the valuable swamp, and archaeological excavations have uncovered evidence of 220 raised fields radiating out from the swamp's shoreline (Henderson 2003).

Although maize was one of the main staple crops cultivated at K'axob, $\delta^{13}C$ ratios in bone apatite collected from 25 individuals randomly selected from 21 different household occupations representing all time periods of the site's occupation have indicated that the grain made up only an average of about 34 percent of the total carbohydrates consumed (Henderson 2003). This percentage is much lower than figures quoted at other parts of the Maya lowlands, such as Copán and sites in the Petén (see Chapter 2), but is consistent with findings at the nearby site of Cuello, where maize was found to contribute about 30% of the diet based on carbon ratios in bone apatite (Tykot, et al. 1996). This suggests a greater variety of plant foods consumed at K'axob, such as, potentially, root crops, beans, squash, and tropical fruits (Henderson 2003).

Henderson (2003) also reports that nitrogen isotopic ratios at K'axob were well within the range of an omnivorous diet, mostly based on terrestrial resources based on difference in carbon isotopic signatures between bone collagen and apatite. She suggests that terrestrial resources were the most important, with some contribution from freshwater fauna, but nitrogen values were too low to have likely included much marine fauna. Marilyn Masson (2004) analyzed over 4500 faunal remains from Formative and Early Classic contexts at K'axob and found that freshwater fish remains were the most abundant, but no marine fish were present. Freshwater turtles were the most abundant among reptile and amphibian remains. Terrestrial mammals included small (armadillos, dogs, and foxes) and large (white-tailed deer, brocket deer, and peccary, mainly) animals. Masson adds that the array of species exploited from both wetlands and forests indicate a "diversified, flexible, and opportunistic set of procurement strategies that adjusted to the fluctuating availability of local game" (2004: 396).

These faunal remains are consistent with those reported for nearby Cuello, as well (Tykot, et al. 1996; Wing and Scudder 1991)

Various species of mollusks were also available as a food source in the Pulltrouser Swamp area (Covich 1983). Ryan Harrigan (2004) studied nearly 4000 specimens of mollusca found at K'axob, mostly freshwater, but including a few imported marine specimens. He reports that *Pomacea flagellata* was the most abundant and was likely a valuable food source, especially during the early periods at the site. He states that this particular species was high source of protein and was sometimes found in burial contexts during the Formative period, as well, suggesting some sort of symbolic significance.

While the wetland environment was ideal in terms of agricultural and wildlife resources, it was also mineralogically poor (McAnany 2004b). While the soft marl found beneath the wetland soils was useful for construction of building platforms and floors, the cut stones necessary for more elaborate architecture, such as stone walls, were unavailable. Materials for ground and chipped stone tools also could not be found in the vicinity of K'axob. Fortunately, the riverine trade networks of northern Belize meant that these items could be obtained through trade. For instance, it has been demonstrated that residents of the Pulltrouser Swamp area likely obtained both chert resources and finished tools from Colha (McAnany 1989).

## EXCAVATIONS AT K'AXOB

Initial investigation at K'axob began in 1981, when the site was first documented as part of the Pulltrouser Swamp project (McAnany 2004b). Part of the goal of this project was to identify settlements surrounding the swamp. During this season, the site was mapped and some test excavations were conducted by Patricia McAnany, a process which helped identify Formative period materials. However, full-scale archaeological excavations of the site did not occur until the 1990s.

Early excavations at K'axob, during the 1990, 1992, and 1993 field seasons, focused specifically on the Formative period (McAnany 2004a). Large excavation units referred to as "operations" were set up in and near Plaza B in the southern portion of the site (Figure 3.3). Operation I, an 8x6-meter, 3.5m-deep excavation trench located to the side of the Structure 18 pyramid, yielded the oldest material found at the site and is regarded as the residential area of the founding lineage (McAnany and Lopez Varela 1999). Operations VII, VIII, X, XI, XII, and XIII were satellite residential platforms located surrounding Plaza B.

Later excavations in 1995, 1997, and 1998 were dedicated to studying the Classic period occupation of the site, as well as use of the nearby wetlands (McAnany 2004b). Operations XIV, XV, XVI, XX, and XXI focused on residential structures in the northern part of the site, while other operations concentrated on monumental architecture in Plaza A (McAnany 1997). Additionally raised fields were mapped in the wetland area.

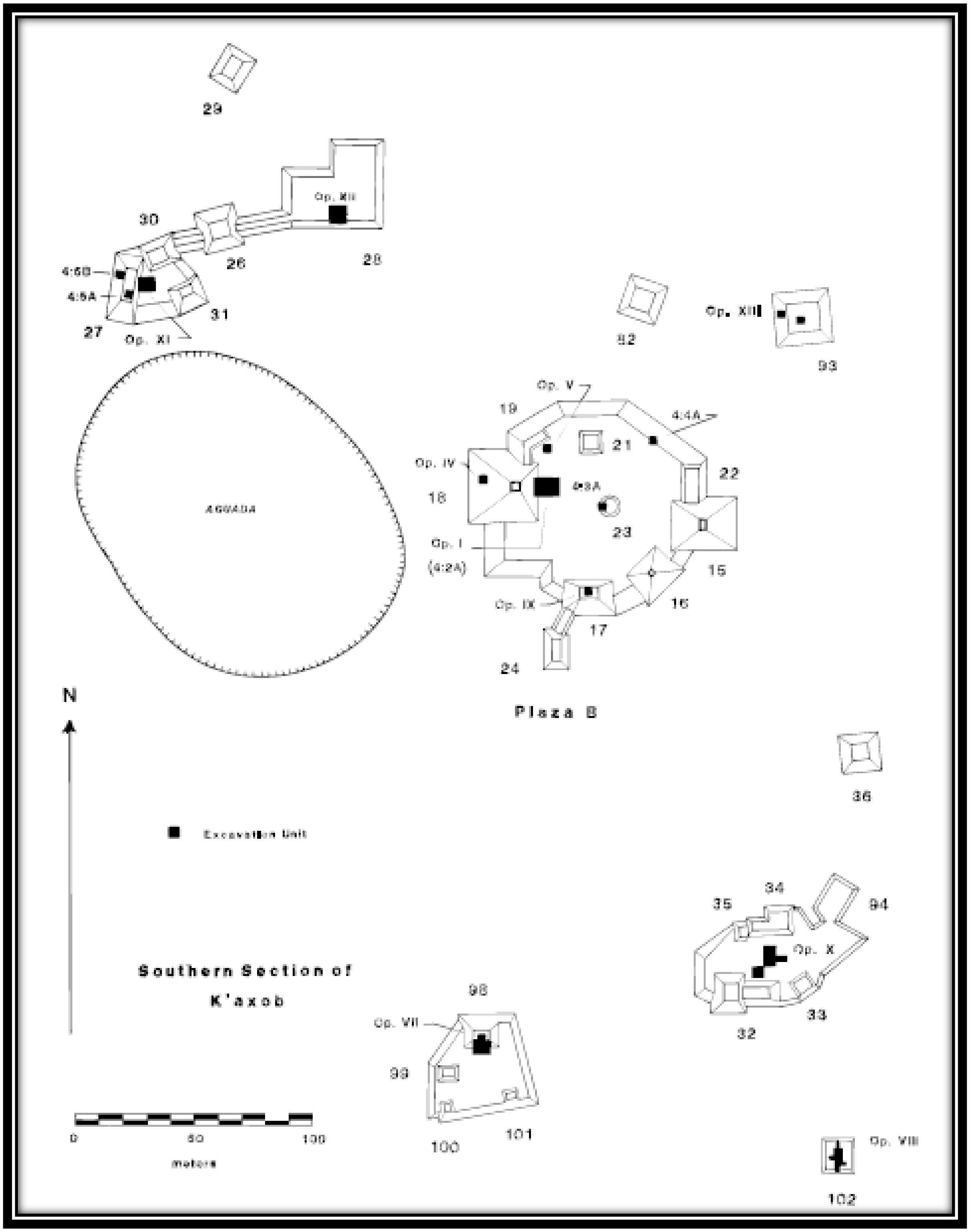


**Figure 3.3: Map of the Southern Section of K'axob, Showing Plaza B and Surrounding Satellite Structures (McAnany and Lopez Varela 1999)**

## MORTUARY PRACTICE AND RECOVERY OF BURIALS

Burials within and around household structures were often encountered during excavation of the residential areas of K’axob (McAnany 1997; McAnany 2004a; McAnany and Lopez Varela 1999; McAnany, et al. 1999). The practice of burying important individuals around domestic structures has been observed throughout the Maya region, including the nearby Formative period site of Cuello (Robin 1989; Robin and Hammond 1991). These individuals could include both males and females, and adults as well as children (McAnany, et al. 1999; Storey 2004). Through careful excavation, the remains of a total of 154 individuals were recovered from K'axob from both the Formative and the Classic periods (McAnany 1995; McAnany 1997).

The greatest number of burials - 63 individuals in total - comes from Operation I. The other operations had as few as two burials (Operation VII) to as many as 27 (Operation XVI). Operation I also contained the earliest burials found at the site, burials 01-43 and 01-46, a male and a female located beneath the earliest Operation I structure (Storey 2004). These may have been the founders of the oldest lineage at K'axob. The latest burials found, two individuals from Operation XVI, date to the late Witsk'ax phase, or the Late-Terminal Classic.

Offerings such as shell, ceramics, and other items were frequently buried with individuals as mortuary offerings (McAnany, et al. 1999; Storey 2004). For instance, the male lineage founder from Operation I, burial 01-43, was buried with two ceramic vessels, bracelets and armbands made of shell beads, and a piece of jadeite (Storey 2004). Seven ceramic vessels with the "quadripartite motif," a symbol of power in Mesoamerican ideology found in both Maya and Olmec artwork, were found buried with five Late Formative individuals at Operation I (Headrick 2004; Storey 2004). Annabeth Headrick (2004) proposes that the use of this motif in this context was a way of asserting this lineage's claim to authority as one of the oldest and most powerful lineages at K'axob.

Temporal trends show increased complexity of burials over time throughout the Formative period, followed by a relative decrease in the elaborateness of mortuary ritual in the subsequent Classic period (McAnany, et al. 1999). This included an increase in secondary and multiple interments in the late-terminal K’atabche’k’ax, suggesting that care was taken to curate the remains of certain individuals so that they could later be reburied with particular people, potentially family members. Similar trends have been found at nearby sites such as Cuello(Robin 1989; Robin and Hammond 1991), indicating a regional pattern.

# Chapter Four
## PALEOPATHOLOGY
### *POROTIC HYPEROSTOSIS AND LINEAR ENAMEL HYPOPLASIA*

Osteological studies of human remains found in archaeological contexts provide valuable information about demographic characteristics of the population under study, as well as information about their diet and various pathologies that may have affected them (Mays 2010; Ortner 2003; White and Folkens 2000; White and Folkens 2005). Bioarchaeologists attempt to identify the age, sex, and other biological characteristics of each burial found during excavation, as well as any paleopathologies and other skeletal anomalies that may be present. More recently, analysis of stable isotopes of various elements, such as carbon and nitrogen, is frequently undertaken on samples of bones to provide information about diet (Wright and White 1996). Various skeletal indicators of disease might be present, as well, most of which are nonspecific, meaning that their precise cause is unknown; however, some diseases, such as tuberculosis, have specific signatures, in which case a differential diagnosis may be possible. Two pathologies commonly observed in human skeletal remains the world over include porotic hyperostosis and linear enamel hypoplasia.

#### POROTIC HYPEROSTOSIS

Porotic hyperostosis is identifiable as porosities in the cranial vault bones, most commonly in the parietals and the frontal, and occasionally seen in the occipital, as well (Buikstra and Ubelaker 1994; Mays 2010; Stuart-Macadam 1987a; Stuart-Macadam 1987b; White and Folkens 2000; White and Folkens 2005). A similar condition in the tops of the eye orbits, cribra orbitalia, is believed to be of the same origin. The consensus by osteologists is that porotic hyperostosis is caused by anemia, although the specific type of anemia that causes it in most archaeological samples is sometimes debated. Technically, nearly any type of anemia, including hereditary anemias, may cause the cranial vault lesions that define porotic hyperostosis (Stuart-Macadam 1987a; Stuart-Macadam 1987b; Walker, et al. 2009). However, in the archaeological context, it is most commonly thought to be the result of iron deficiency anemia.

Porotic hyperostosis is characterized by pitting in the cranial vault, and may also be seen in the upper eye orbits, in which case it is referred to as *cribra orbitalia* (Buikstra and Ubelaker 1994; Larsen 1997; Mays 2010; Ortner 2003; Waldron 2009; Walker, et al. 2009; White and Folkens 2005; Whittington and Reed 1997a; Wright and White 1996). These lesions were first identified in the Maya area by Earnest Hooton (1940) in his analysis of the human remains recovered from the cenote at Chichén Itzá. The pits or porosities are caused by the expansion of the diploë, or the spongy bone, in the cranial bones. The spongy bone contains the bone marrow, in which red blood cells are formed. This hypertrophy of the diploë is the body's response to anemia. In an anemic state, most likely due to a lack of iron, the body attempts to compensate for the low oxygen-carrying capability of the blood by greatly increasing its red blood cell production. Porotic hyperostosis occurs when the marrow expansion causes thinning and eventually destruction of the already-thin cortical bone of the cranial vault bones, often the parietal and frontal bones. This causes "a sieve-like or 'coral-like' appearance of the ectocranial surface" (White and Folkens 2005). These porosities may heal over time, becoming smoother and less distinct, and may even be obliterated in some cases, especially in the eye orbits with cribra orbitalia.

Lesions found in adult remains are always, or very nearly always, healed. This is due to the fact that these lesions are the result of childhood bouts of iron-deficiency anemia (Goodman and Armelagos 1989; Palkovich 1987; Stuart-Macadam 1985; Walker 1986; Walker, et al. 2009). Stuart-Macadam (1985) explains that bone marrow physiology changes throughout life. During infancy, the entire skeleton contains red blood cell-producing marrow. As the child grows older, however, this begins to change, as some of this blood-producing marrow is converted to yellow marrow, which stores fat. By adulthood, most of the red marrow is contained in the axial skeleton, concentrated in the ribs, vertebrae, clavicles, and sternum, and is still present in the skull, though less so. When anemia occurs during infancy and early childhood, stimulating the increase in red blood cell production, the marrow must expand to increase this production, since all of the available space is already devoted to red blood cell production. Adults, on the other hand, can increase red marrow capacity by converting the fatty yellow marrow to red marrow for blood cell production, which is not an option in the child’s skeleton. Additionally, children's bones have not mineralized as much as those of adults, resulting in greater plasticity, meaning they are less likely to resist the expansion caused by marrow hypertrophy.

Iron deficiency is the most common nutritional deficiency that exists in the world today, affecting as many as 500-600 million people (Walker, et al. 2009; Wright and Chew 1998). This condition affects mostly developing countries, but is one of the few deficiencies to still significantly affect the developed world, as well (Hallberg 2001). Hallberg (2001) states that the two groups most susceptible to iron deficiency are children and adolescents during growth and pregnant women, as growth and pregnancy cause the body’s iron requirements to be quite high. Iron is needed for hemoglobin, which allows for the transport of oxygen throughout the body via red blood cells. Although the body recycles about 90% of the iron from old red blood cells (Holland and O'Brien 1997; Stuart-Macadam 1992), deficiencies develop when iron losses are not met by nutritional intake.

There are two types of iron found in the diet: heme and non-heme (Hallberg 2001; Larsen 1997). Heme iron is found primarily in meat, and is readily absorbed in the intestines. Non-heme iron, found mainly in plant foods, is more difficult for the body to absorb. This means that meat provides a much better source of nutritional iron than do most plant foods. Additionally, some compounds, such as calcium (Hallberg 2001; Wright and Chew 1998), phytic acid (Danforth 1999; Holland and O'Brien 1997; Larsen 1995), and tannins (Larsen 1995), have been found to inhibit the absorption of iron by binding with it and thereby reducing its bioavailability to the consumer. This is significant especially in the case of populations in the Americas, who often heavily relied on maize agriculture and who also sometimes soaked maize in lime solutions, known as the *nixtamal* process. Maize contains a great deal of phytic acid, and the lime processing of maize adds calcium carbonate. However, lime soaking also has nutritional benefits, including removing the pericarp of the maize kernel, which contains much of the phytate found in maize (Wright 1999), so the effect of phytic acid in maize absorption may have been reduced when this process was utilized. In other parts of the world, the same effect may be seen with millet and sorghum, which contain tannins that hinder the absorption of iron (Holland and O'Brien 1997; Larsen 1995).

There has been some debate about the cause of iron deficiency anemia in archaeological populations, regarding whether the primary cause of the deficiency is dietary (Larsen 1995), or whether it is caused by nutritional losses from parasitic infections (Stuart-Macadam 1992). Many argue that iron deficiency results from dietary insufficiencies caused by intensive agriculture and reliance on a single staple crop, such as maize in the New World (Danforth 1999; Holland and O'Brien 1997; Larsen 1995; Walker, et al. 2009). They state that with increasing political organization and intensification of agriculture, staple crops began to make up greater proportions of the diet. Often, these populations would also have less access to meat sources, perhaps because of high population density. Not only would these plant foods be a poor source of iron, providing the less absorbable non-heme iron as opposed to the heme iron found in meat, they would also contain compounds that would hinder the absorption of iron, such as phytic acid found in maize. Many of these studies refer to the work of El-Najjar and colleagues in the American southwest during the 1970s, which produced what came to be known as the maize dependency theory.

The dietary model for iron deficiency was contested by researchers in the late eighties and early nineties (Stuart-Macadam 1992). Stuart-Macadam pointed out that the dietary model did not fit with every situation. For instance, she states that some populations with diets that ought to have been high in iron sometimes had high rates of porotic hyperostosis, whereas some populations that were heavily maize-dependent experienced little porotic hyperostosis. Thus, she states that diet plays little role in iron deficiency within a population, but instead is part of the body's adaptive response to parasitic infection. She states that the body has control over the intestinal absorption of iron, and when infected with parasites or bacteria, which require iron to reproduce, will withhold iron as a defense against this infection. This produces what she refers to as a mild state of iron deficiency, called hypoferremia. Stuart-Macadam regards this as an adaptive response in areas where the risk of parasitic infection is high, such as in a tropical environment. This iron-withholding response, coupled with blood loss and malabsorption of nutrients as a direct result of these types of infections, creates a state of iron deficiency severe enough to result in porotic hyperostosis.

However, others were against this "parasite model" (Holland and O'Brien 1997) for iron deficiency in archaeological populations (Goodman 1994; Holland and O'Brien 1997). They contend that both the diet consumed by the population as well as parasitic infections that affect it play a role in the prevalence of porotic hyperostosis. For instance, Stuart-Macadam (1992) refers to a southern California island population that had a high consumption of animal protein in the form of fish and other marine resources, but which still had a high prevalence of porotic hyperostosis and *cribra orbitalia* (Walker 1986). However, as Holland and O'Brien point out, Walker does discuss dietary reasons for the incidence of porotic hyperostosis, in addition to parasitic infection. Walker states that the high prevalence in the population probably resulted from low iron intake during early childhood as a result of a couple of factors: 1) the iron content of human breast milk is low, so nursing infants would not receive the amount of iron needed during growth, and 2) high parasitic infection would result in nutritional losses due to diarrheal diseases and blood loss to intestinal parasites, especially difficult during the weaning period. While parasites do have much to do with the cause of porotic lesions in this population, Stuart Macadam is incorrect in stating that diet plays very little role, and the iron deficiency in this case certainly does not seem to be an adaptive response (Holland and O'Brien 1997). Goodman (1994), too, takes issue with Stuart-Macadam's characterization of iron deficiency as an "adaptation." Rather than iron deficiency being either dietary or parasitic in nature, most bioarchaeologists would agree that the condition results from a combination of these factors (Danforth 1999; Goodman and Armelagos 1989; Holland and O'Brien 1997; Larsen 1995; Walker 1986). Several other osteological studies in various parts of the world seem to support this theory (Keita and Boyce 2001; Klaus and Tam 2009; Palkovich 1987; Wright and Chew 1998).

Although iron deficiency anemia has been regarded for decades as the most likely cause of porotic hyperostosis, Walker et al. (2009) have recently suggested that megaloblastic anemias, rather than iron deficiency anemia, are the cause of porotic hyperostosis and cribra orbitalia. They state that "[c]hronic dietary deficiencies and malabsorption of vitamin $B_{12}$ and/or folic acid are the most common causes of megaloblastic anemia" (Walker, et al. 2009). They contend that iron deficiency would not result in porotic hyperostosis because iron is necessary for the production of red blood cells; increased production of red blood cells, therefore, would not be possible in the case of iron deficiency. Therefore, they argue that megaloblastic anemias, probably most often due to vitamin $B_{12}$ deficiency, are the more likely cause. Vitamin $B_{12}$ comes almost solely from animal food sources, and its absorption would be hindered by parasites in the intestinal tract, much like in the case of iron. However, others disagree that iron deficiency anemia should be ruled out (Oxenham and Cavill 2010). Oxenham and Cavill suggest that while megaloblastic anemias should be considered as deficiencies leading to porotic hyperostosis, iron deficiency anemia is still a leading cause and should not be factored out. They disagree with the conclusion by Walker et al. (2009) that iron deficiency would prevent marrow hypertrophy, and argue instead that marrow hypertrophy would still occur, but would result in the production of inefficient red blood cells with a reduced oxygen-carrying capability.

Thus, iron deficiency anemia is most likely the primary cause of porotic hyperostosis in most archaeological skeletal populations, although other deficiency anemias may be a factor, as well. This nutritional deficiency is the result of several factors. Low-iron diets, coupled with the consumption of elements that inhibit the absorption of iron, such as phytic acid and calcium, will result in low iron stores in the body, often low enough to produce a deficient state, especially in children and pregnant women, both of whom require much greater amounts of iron. Additionally, parasitic infection may reduce the bioavailability of iron, causing nutritional losses due to diarrhea and intestinal bleeding. Parasitic infections might also reduce iron in the body as the body reacts to infection by withholding iron. Therefore, porotic hyperostosis is the combined result of numerous environmental factors impacting the health of populations.

### Linear Enamel Hypoplasia

Linear enamel hypoplasia is regarded as a "nonspecific" indicator of stress during ontogeny (Goodman and Armelagos 1989; Mays 2010; White and Folkens 2005; Wright 1997b; Wright and White 1996). Enamel hypoplasias occur in the dentition, particularly the incisors and canines, whereas the premolars and molars seem to be more buffered against hypoplasia formation (Goodman and

Armelagos 1985; Wright 1997b). They are the result of the failure of the dental enamel to mineralize fully during enamel formation, known as amelogenesis, resulting in discolored lines, pits, or grooves in the crown of the tooth (Hillson 1996; White and Folkens 2005). Because tooth formation occurs during the last two trimesters of pregnancy and the first year of life for deciduous dentition, and during the first six years of life for permanent dentition, enamel hypoplasias will always be a sign of stress during early childhood (Goodman and Armelagos 1989), similar to porotic hyperostosis.

Linear enamel hypoplasias are nonspecific stress indicators, meaning that they might be the result of a number of different stress factors. Goodman and Armelagos state that these defects "can result from systemic disruption, hereditary conditions, or localized trauma" (1989: 229). If only one tooth is affected, the defect likely results from trauma, whereas if several teeth show defects, the cause is probably systemic, caused by infectious disease or nutritional stress of long duration. Additionally, the age at which the defect formed can be estimated based on its location on the tooth crown (Buikstra and Ubelaker 1994; Goodman and Armelagos 1989; Goodman and Rose 1990; Larsen 1997; Waldron 2009). This is because dental development occurs at very predictable ages and does not vary much between individuals or between populations. For instance, at the Dickson Mounds site in Illinois, Goodman and Armelagos found that enamel defects were most likely to occur between the ages of two and four years, an age commonly associated with weaning stress. They conclude that the nutritional stresses associated with weaning and the exposure to bacteria as a result of consuming contaminated water and food for the first time would have increased the stress on the health of individuals at this early stage of life.

The causes of dental enamel hypoplasias are very similar to those of porotic hyperostosis. Like porotic hyperostosis, enamel hypoplasias likely result from nutritional deficiencies and systemic infection by a variety of pathogens. Danforth states that "malnutrition rarely involves only a single deficiency, and usually it operates synergistically with many disease processes" (1999: 2). With the intensification of agriculture, reliance of a single staple crop may have meant that the diets of many past populations were deficient in many of the essential nutrients; even if the diet is sufficient to ensure that the individual does not go hungry, malnutrition often still occurs because the body does not receive the nutrients it needs to function. Further exacerbating the problem is infectious disease. Diseases, especially those that cause diarrhea, can interfere with the absorption of nutrients. Unfortunately, nutritional deficiencies may also make the body more susceptible to infection, resulting in a positive feedback relationship between these two health factors (Danforth 1999).

### POROTIC HYPEROSTOSIS AND ENAMEL HYPOPLASIA IN THE MAYA REGION

Rates of porotic hyperostosis and linear enamel hypoplasias have been analyzed in several skeletal populations in the Maya area, including sites in all three of the lowland regions - Copán, the Pasión region, and northern Belize -

that are the focus of this study (Saul and Saul 1997; Storey 1997; Storey 1999; Storey, et al. 2002; Wright 2006). Both of these conditions have been recorded for all populations that have been examined for paleopathology, though at differing rates. Table 4.1 presents the rates of porotic hyperostosis for several sites in the Maya area, as well as comparative figures for several other populations throughout the world, demonstrating that even though rates of porotic hyperostosis were fairly high in some Maya populations, they were not anomalously so (Wright and White 1996). Rates of hypoplasias also have not been found to be unusually high, though figures between studies are difficult to

| | Subadults | | Adults | | Reference |
|---|---|---|---|---|---|
| Skeletal series | % | *N* | % | *N* | |
| Maya series | | | | | |
| Cuello Preclassic | 12.5 | 8 | 3.6 | 28 | Saul & Saul, 1991 |
| Copán Classic | 58.8 | 17 | 60.0 | 30 | Whittington, 1989 |
| Pasión (combined) | 55.5 | 18 | 65.4 | 81 | Wright, 1994 |
| Chichen Itzá cenote | 77.8 | 18 | 52.9 | 17 | Hooton, 1940 |
| Playa del Carmen[a] | * | | 48.0 | 28? | Marquez Morfin, 1982 |
| Lamanai Postclassic | * | | 9.0 | 53 | White, 1986 |
| Lamanai Historic | * | | 17.0 | 100 | White, 1986 |
| Tipu Historic | 35.8 | 106 | 19.4 | 185 | Cohen *et al.*, 1994 |
| Iximché | * | | 3.0 | 36 | Whittington & Reed, 1994 |
| Comparative series | | | | | |
| Dickson Mounds | 34.6 | 101 | — | — | Lallo *et al.*, 1977 |
| Libben | 44.4 | 241 | — | — | Mensforth *et al.*, 1978 |
| Arroyo Hondo | 25.9 | 54 | — | — | Palkovitch, 1987 |
| California Coastal | 51.3 | 37 | 33.3 | 393 | Walker, 1986 |
| Chiribaya Alta, Peru | 53.3 | 91 | 14.9 | 67 | Burgess, 1996 |
| Canyon de Chelly Pueblo | 88.0 | 17 | 45.9 | 61 | El Najjar *et al.*, 1976 |
| Chaco Canyon | 83.8 | 12 | 65.0 | 20 | El Najjar *et al.*, 1976 |
| Nubia[b] | 23.2 | 129 | 19.9 | 156 | Carleson *et al.*, 1974 |
| Medieval York, UK | 43.2 | 183 | 67.8 | 277 | Grauer, 1993 |

[a]Subadult data are included with adult statistics for these samples.
[b]Data refer to cribra orbitalia instead of porotic hyperostosis of the cranial vault.

**Table 4.1: Frequency of Porotic Hyperostosis in the Maya Area and Comparative Data from Other Parts of the World (Wright and White 1996: 159)**

compare due to differences in methods of scoring and reporting the defects (Wright and White 1996). Details of the occurrence of porotic hyperostosis and linear enamel hypoplasias in each of the study areas are presented below.

*Copán*

The Copán burial sample is one of the largest from any Maya site, estimated to include at least 600 individuals (Webster, et al. 2000). These include the elite burial sample from the urban 9N-8 compound and the commoner sample from smaller residences from both urban and rural contexts. The 9N-8 also called the "House of the Bacabs," was a collection of twelve adjoining patio groups which housed a noble lineage and its servants, as many as 200 people at a time (Storey 1999). 264 individuals were recovered from the 9N-8 compound, 122 of which were children; nearly all date to the Late Classic Coner phase. The commoner sample includes over 150 individuals analyzed by Stephen Whittington (Whittington and Reed 1997b), most of which are also from the Late Classic.

Rebecca Storey (1997; 1999; Storey, et al. 2002) analyzed the elite urban population excavated at the 9N-8 compound located in a residential area near the main center of Copán. Porotic hyperostosis was present in about 25% of individuals (Storey, et al. 2002). A group of 128 adults from both 9N-8 and rural contexts were also examined by Storey (1999). The prevalence of porotic lesions was lowest in the high status group 1 individuals for both males and females, and was significantly higher in the lowest status, rural group 3 individuals

(Storey 1999). In the same study, among those with scorable teeth, there was only one individual, an elite female, who did not have at least one hypoplasia. Finally, in an analysis of dental defects in 32 children from the 9N-8 compound, all individuals were found to have at least one defect (Storey 1997), so linear enamel hypoplasias were virtually ubiquitous at 9N-8 in Copán.

Stephen Whittington (Whittington and Reed 1997b) also looked at the prevalence of porotic hyperostosis at Copán. From a total sample of 157 individuals, both adults and subadults, 44 (28%) of which had porotic lesions present. He states that this is a conservative estimate of the rate of anemia in this population, as many of these individuals did not have enough scorable cranial material present. When narrowed to include only those individuals with 50% of the surface present and scorable, the prevalence was found to be 14/22, or 64%.

*The Pasión Region*

A total population of 261 individuals from nine sites in the Pasión region - Altar de Sacrificios, Seibal, Itzan, Dos Pilas, Aguateca, Tamarindito, Arroyo de Piedra, Punta de Chimino, and La Placiencia - were analyzed by Lori Wright (2006) for paleopathological indicators, including porotic hyperostosis and linear enamel hypoplasia. As at Copán, the majority of the burials excavated at the Pasión sites date to the Late and Terminal Classic periods (Wright 2006). Only about thirty or so date to the Preclassic, and even fewer date to the Early Classic, the majority of the skeletons from these two time periods coming from Altar de Sacrificios.

Wright (2006) was able to analyze 124 crania for porotic hyperostosis and *cribra orbitalia*. She reports that the lesions were quite common in the Pasión population, with healed lesions present in 63% of adult crania. Additionally, active *cribra orbitalia* was found in the eye orbits of 87.5% of children under 12 years of age. She found no statistically significant differences in the rate of porotic hyperostosis over time.

For enamel defects, Wright (2006) found that linear enamel hypoplasias were common in the Pasión population but in general not severe. Most hypoplasias occurred on the upper and lower canines but were also commonly found on the upper central and lateral incisor. She reports a prevalence of just over 60% for the entire region, and rates were generally steady over time. Based on the location of the defects as measured from the cemento-enamel junction (CEJ), the stress episodes causing the hypoplasias tended to occur between 2.5-6.5 years of age.

*Northern Belize*

Julie Mather Saul and Frank P. Saul (1997) examined a skeletal population of 166 total individuals, including both adults and subadults, excavated at the Preclassic site of Cuello for signs of pathologies and trauma. They state that porotic hyperostosis from "virtually absent" (1997: 35) from the population at Cuello: out of 49 individuals with enough cranial material to meet their evaluation criteria, only two were found to have porotic lesions, both young individuals, one male and one of indeterminate sex. Linear enamel hypoplasia was more common: of 96 individuals with evaluable dentition, 57, or 59%, had at least one defect. Additionally, they report that females consistently had a higher prevalence of defects over all time periods.

### SUMMARY

Together, porotic hyperostosis and enamel hypoplasias can shed light on the health and nutritional status of past populations by providing information about nutritional diseases and infections that affect individuals during growth and development. Many bioarchaeological studies include an analysis of one, and very often both, of these traits (Goodman and Armelagos 1989; Keita and Boyce 2001; Klaus and Tam 2009; Larsen 1995; Wright and White 1996). In the Maya area, these and other stress indicators are often examined in order to understand and explain the effects of increasing social complexity and agricultural intensification (Méndez Collí, et al. 2009; Storey, et al. 2002; Whittington and Reed 1997a; Wright 1997b; Wright and Chew 1998; Wright and White 1996).

Although the prevalence of enamel hypoplasia is difficult to compare between sites due to inconsistent methodologies between researchers, the prevalence of porotic hyperostosis does show regional diversity (Saul and Saul 1997; Storey, et al. 2002; Wright 2006). Figure 4.1 compares the prevalence of porotic hyperostosis between several different sites. Copán and the Petén sites, which include the Pasión region sites and Piedras Negras, all show lesions in well over half of the populations. On the other hand, the Belizean sites of Tipu, Lamanai, and Cuello all show a significantly lower prevalence of porotic hyperostosis.

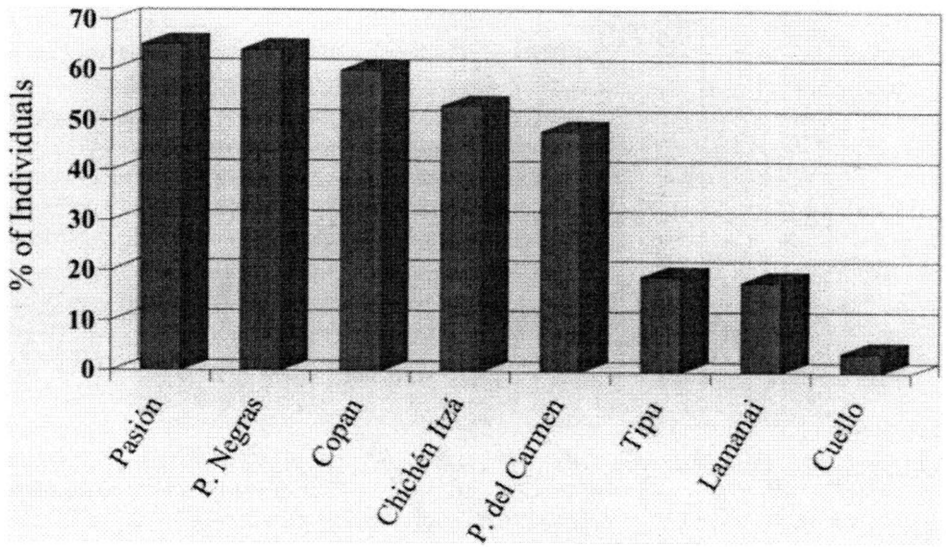


**Figure 4.1: Prevalence of Porotic Hyperostosis in Lowland Maya Sites (Scherer, et al. 2007: 95)**

# Chapter Five
## MATERIALS AND METHODS

### K'AXOB BURIAL SAMPLE

The burial sample analyzed here consists of a total of 154 individuals excavated at the site K'axob, Belize over six field seasons in the 1990s under the direction of Patricia McAnany, at the time out of Boston University (McAnany 1997; McAnany 2004a). The entire collection of human remains is currently housed in the osteology laboratory at the University of Houston in Houston, Texas.

Burials were recovered from 11 different excavation units, or operations. The total number of individuals for each operation is shown in Figure 5.1 below.

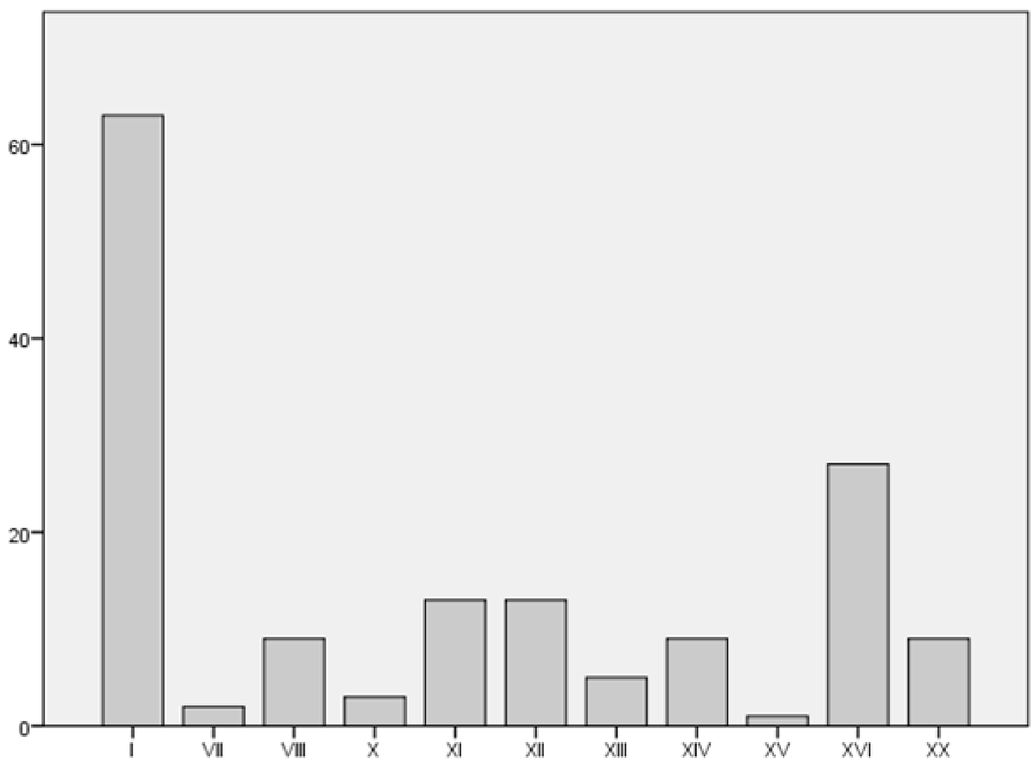


**Figure 5.1: Number of Burials per Operation**

The operation with the greatest number of burials recovered is Operation I, with a total of 63 individuals, while the number of individuals from the rest of the operations range from only a single burial in Operation XV to 27 individuals in Operation XVI.

The approximate age-at-death and sex for the total sample are given in tables 5.1 and 5.2 below. The sample contains a total of 43 (27.9% of the sample) children aged ten years and younger and 111 (72.1%) adults ranging from adolescence (over ten years of age up to young adulthood) to old age. Of the adults, 54 (or 35.1% of the total sample) are considered to be of "prime age," meaning that they were within their main reproductive years, including Adolescents to Middle Adults, while 30 (19.5% of sample) are considered older adults, which includes Middle-Older and Old Adults, or individuals beyond their prime reproductive years. Twenty-seven adults (17.5% of sample) could not be assigned to a more specific age category. An estimation of sex could be made for 72 adults (46.8% of the total sample), including 27 females (17.5%) and 45 males (29.2%).

The total K'axob skeletal sample consists of 110 (71.4%) individuals from the Formative period and 44 (28.6%) from the Classic period (Table 5.3). The distribution of individuals by time period is based on the ceramic phase assigned to each burial, with all individuals from the terminal facet of the K'atabche'k'ax phase and earlier considered Formative burials and all individuals from the early facet of the Nohalk'ax and later considered Classic. The distribution of

**Age**

| | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|
| Infant | 9 | 5.8 | 5.8 | 5.8 |
| Juvenile, 1-5 yrs | 20 | 13.0 | 13.0 | 18.8 |
| Juvenile, 5-10 yrs | 10 | 6.5 | 6.5 | 25.3 |
| Juvenile, Indeterminate Age | 4 | 2.6 | 2.6 | 27.9 |
| Adolescent | 4 | 2.6 | 2.6 | 30.5 |
| Young Adult | 22 | 14.3 | 14.3 | 44.8 |
| Young-Middle Adult | 9 | 5.8 | 5.8 | 50.6 |
| Middle Adult | 19 | 12.3 | 12.3 | 63.0 |
| Middle-Older Adult | 16 | 10.4 | 10.4 | 73.4 |
| Old Adult | 14 | 9.1 | 9.1 | 82.5 |
| Adult, Indeterminate Age | 27 | 17.5 | 17.5 | 100.0 |
| Total | 154 | 100.0 | 100.0 | |

**Table 5.1: Distribution of Approximate Age-at-Death for K'axob Sample**

**Sex**

| | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|
| Female | 27 | 17.5 | 17.5 | 17.5 |
| Male | 45 | 29.2 | 29.2 | 46.8 |
| Indeterminate | 39 | 25.3 | 25.3 | 72.1 |
| Subadult | 43 | 27.9 | 27.9 | 100.0 |
| Total | 154 | 100.0 | 100.0 | |

**Table 5.2: Distribution of Estimated Sex for K'axob Sample**

individuals from each ceramic phase is given in Table 5.4. The greatest number of burials (N=50), almost one third of the total sample, dated to the late facet of the K'atabche'k'ax phase. Most of the Formative period sample comes from the K'atabche'k'ax phase (N=97), or the Late Formative, with comparatively few individuals dating to the earlier, Middle Formative Chaakk'ax phase (N=13). For the Classic period sample, the majority of individuals date to the early facet of the Late Classic Witsk'ax phase (N=31).

**Period**

| | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|
| Formative | 110 | 71.4 | 71.4 | 71.4 |
| Classic | 44 | 28.6 | 28.6 | 100.0 |
| Total | 154 | 100.0 | 100.0 | |

**Table 5.3: Formative and Classic Period Samples at K'axob**

**Ceramic Phase**

| | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|
| Chaakk'ax, early facet | 9 | 5.8 | 5.8 | 5.8 |
| Chaakk'ax, late facet | 4 | 2.6 | 2.6 | 8.4 |
| K'atabche'k'ax, early facet | 22 | 14.3 | 14.3 | 22.7 |
| K'atabche'k'ax, late facet | 50 | 32.5 | 32.5 | 55.2 |
| K'atabche'k'ax, terminal facet | 25 | 16.2 | 16.2 | 71.4 |
| Nohalk'ax, early facet | 10 | 6.5 | 6.5 | 77.9 |
| Nohalk'ax, late facet | 1 | .6 | .6 | 78.6 |
| Witsk'ax, early facet | 30 | 19.5 | 19.5 | 98.1 |
| Witsk'ax, late facet | 3 | 1.9 | 1.9 | 100.0 |
| Total | 154 | 100.0 | 100.0 | |

**Table 5.4: Distribution of Individuals by Ceramic Phase at K'axob**

Unfortunately, conditions were such that preservation of the excavated at K'axob was generally fairly poor, particularly for the Classic period (McAnany 1997). This is due to a variety of factors, including soil conditions such as moisture levels and pH (Gordon and Buikstra 1981), mortuary practices, such as the relocation or reburial of individuals whose remains are already skeletonized, known as secondary burials (Robin 1989; Robin and Hammond 1991), disturbance of burials by later construction or other mortuary activities (i.e., reopening a burial to place another individual within it, often disturbing previously-placed individuals), and modern-day excavation activities, which, even when carried out with the utmost care, can result in the damage or loss of skeletal material. As a result, the majority of the individuals in this sample are fragmentary and only partially complete, and no individual was 100% complete. There were a few individuals, often subadults, for whom only a few teeth or miscellaneous bone fragments were recovered.

### VARIABLES AND MEASUREMENTS

The operation number for each individual refers to the excavation unit that each burial was recovered from. Within each operation, each burial was assigned a number, and the operation number plus the burial number provided the burial identification for each individual. For instance, the first individual excavated from Operation XVI was labeled Burial 16-01, and so forth. In many cases, more than one individual was interred within a single grave; in these instances, letters were added to distinguish between individuals - for example, Burial 01-06 had four individuals: 01-06a, a middle adult female, and 01-06b, 01-06c, and 01-06d, three children of various ages that were buried with her. The ceramic phase for each burial was determined by the original excavators of the K'axob collection and was also used in this analysis.

Estimations of age and sex for the skeletal population of K'axob were made by Dr. Rebecca Storey of the University of Houston. Unfortunately, due to the degradation of the remains, age and sex could not be determined for some individuals. An approximate age at death for each individual was determined primarily by dental eruption for subadults and by tooth wear and cranial suture closure for adults. Because the development and eruption of both the deciduous and permanent dentition occur on a tightly controlled, predictable schedule, it is possible to get a fairly accurate estimation of age for juveniles, especially in early childhood (Buikstra and Ubelaker 1994; White and Folkens 2005). For juveniles, an approximate age range of months or years is given, rather than an exact age; the younger the individual, the smaller the range tends to be. Because skeletal and dental wear is far more variable, approximate age for adult individuals cannot be estimated as reliably, so adults are divided into more broad age categories. In this study, these categories include Adolescent, Young Adult, Middle Adult, and Old Adult. Because some individuals were on the divide between two different age groups, the categories Young-Middle Adult and Middle-Older Adult were also included.

Because of the poor preservation of most burials at K'axob, very few individuals had any pelvic fragments recovered. While sex determination based on the pelvis is usually preferable in osteological analysis, this was not possible at K'axob. Instead, cranial morphology and teeth measurements were used. Cranial features such as the mandible, nuchal crest, eye orbits, brow ridges, and mastoid processes, and overall robusticity were used to estimate sex whenever possible (Buikstra and Ubelaker 1994; White and Folkens 2005). Sexual dimorphism of the dentition within a population is another method of estimating sex and is sometimes used when other methods are not available (Hillson 1996). For the K'axob sample, discriminate function analysis based on individuals of known sex was used to provide sex estimates for individuals whose sex could not be determined using other methods. In total, 72 of the adults from the K'axob sample were able to be sexed, while 39 did not have enough features present for an estimate to be made.

Porotic hyperostosis was recorded according to the procedures outlined by the Standards for Data Collection from Human Skeletal Remains (Buikstra and Ubelaker 1994). All available cranial vault bones were assessed visually under strong light for the presence of porotic lesions. When present, the degree of severity was scored as: 1) barely discernible, 2) true porosity, 3) coalescing pores, or 4) coalescing pores with expansive changes. The activity level was also scored: active lesions (activity score = 1) had sharper edges and no signs of remodeling, while healed lesions (activity score = 2) had smooth edges as the pores closed and the bone remodeled. An activity score of 3 indicates that there were both active and healed lesions present. Finally, the location of score was also given: 1) only within the orbits (*cribra orbitalia*), 2) localized near sutures, 3) away from sutures, 4) within orbits and along suture of frontal, or 5) both parietal bosses and/or squamosal portion of the occipital. See Appendix for a complete list of the database codes used in this analysis.

The amount of cranial material present was another important variable in this study. During analysis, the amount and size of cranial vault bones that were recovered for each individual was recorded. This was then translated into a rough estimated of the percentage of the vault present. The roofs of the eye orbits, where *cribra orbitalia* can be found, are very fragile, and due to poor preservation were not preserved for most individuals in this samples. In the rare cases in which they were preserved, they were never complete. Therefore, *cribra orbitalia* could not be assessed for the K'axob sample. However, portions of the frontal, left and right parietals, and the occipital were often recovered. Because the absence of porotic hyperostosis cannot be confirmed for individuals with little or no cranial material present, the prevalence of porotic hyperostosis was only evaluated for individuals with approximately 25-35% or more of the vault present (i.e., category 3 or higher; see Figure 5.2). In total, 44 individuals, or 28.6% of the sample, had enough cranial material to be included in the analysis.

Linear enamel hypoplasias were also recorded using the procedures outlined for enamel defects in the Standards for Data Collection from Human

Skeletal Remains (Buikstra and Ubelaker 1994). The type of defect was scored using the codes provided by Buikstra and Ubelaker (see Appendix A); however, as this study focused specifically on linear enamel hypoplasias, hypocalcifications were excluded. Because color applies only to hypocalcifications, this attribute was not recorded, either. All defects in the teeth of the K'axob sample were Type 1, or linear horizontal grooves. The location of each defect was measured on each tooth as

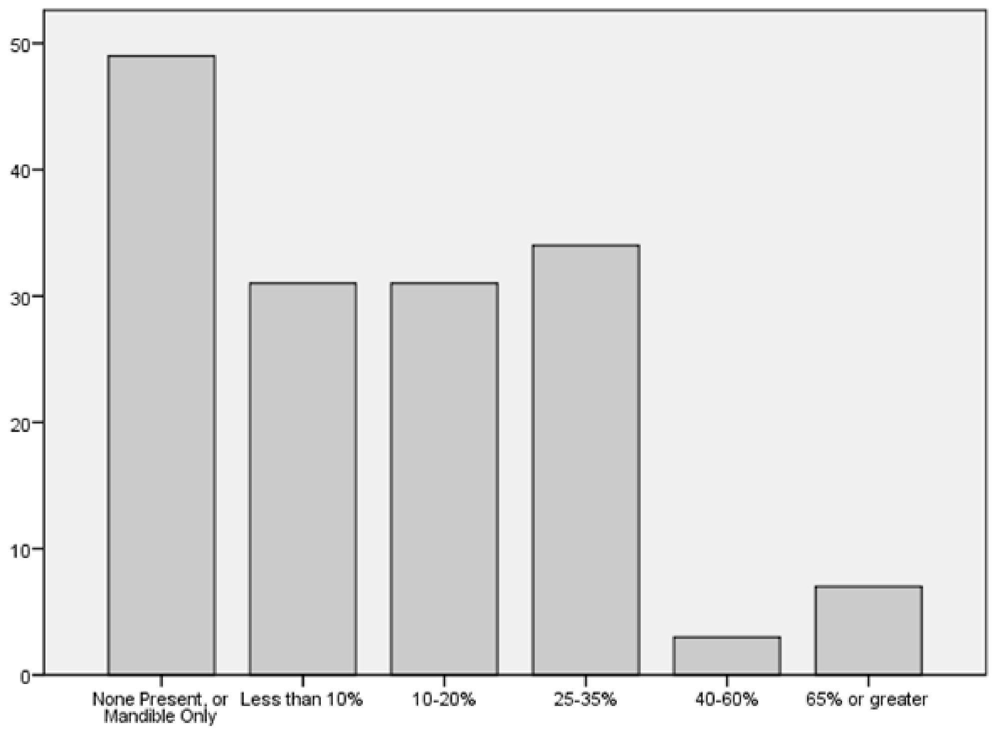


**Figure 5.2: Distribution of K'axob Sample in Terms of the Amount of Cranium Present**

the distance between the midpoint cemento-enamel junction (CEJ) and the most occlusal edge of the defect - in other words, the edge of the defect closest to the chewing surface of the tooth. This measurement was taken to a tenth of a millimeter (mm).

The measurement of the distance between the hypoplasia and the CEJ was also used to determine the age at which the defect occurred. Goodman and Rose (1990) discuss the methods for creating regression equations to convert the defect location in mm into the age of occurrence. This requires knowledge of individual age at the beginning and end of crown formation and the measurement of crown height. However, population-specific equations could not be made for the K'axob sample because the degree of wear was too heavy on most teeth to obtain a measurement of crown height. Therefore, for this study the equations provided by Table 3 by Goodman and Rose (1990: 98; see Appendix C).

The presence or absence of linear enamel hypoplasias cannot be evaluated if no teeth or only a limited number of teeth are present for an individual. Therefore, the total number of teeth for each individual was also recorded (see Figure 5.3). Also, certain teeth are more susceptible to the disruption of amelogenesis than others during periods of ill health, with incisors and canines most frequently affected (Goodman and Armelagos 1985; Goodman and Rose 1990). Therefore, the total number of incisors and/or canines present was recorded as well. For the purposes of this study, analysis of the prevalence of linear enamel hypoplasia was only performed for individuals with at least two permanent incisors and/or canines present. A total of 90 individuals met this criterion.

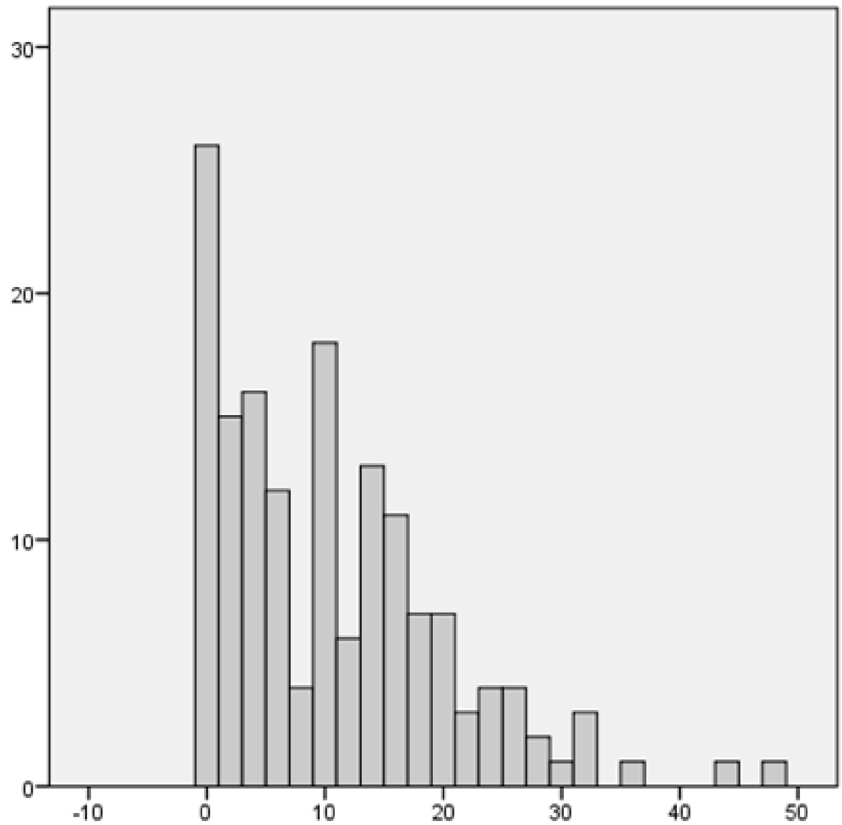


**Figure 5.3: Distribution of Number of Teeth Present per Individual in the K'axob Sample**

DATA ANALYSIS

In order to evaluate the hypotheses stating that the prevalence of porotic hyperostosis and linear enamel hypoplasias at K'axob will be lower compared to other parts of the Maya lowlands and similar to other populations in northern Belize, the frequencies of both pathological conditions in the K'axob sample were compared to those reported for populations at Copán, sites in the Pasión region of the Petén, and Cuello, in northern Belize. Due to the differences in time periods between studies, the K'axob sample was also divided into Formative and Classic period samples in addition to study of the overall prevalence. The Classic period population at K'axob (N=45) was compared to Copán and the Pasión region, as these two populations mostly consisted of Classic period individuals, and the Formative period sample (N=110) was compared to Cuello, since Cuello was abandoned sometime near the start of the Classic and its skeletal sample comes from the Formative, as well.

*Statistical Analyses*

The prevalence of both porotic hyperostosis and linear enamel hypoplasia was analyzed using IBM's SPSS Statistics version 22 statistical analysis software. Crosstabulations and the Odds Ratio were used to examine differences between different groups in the K'axob sample, including differences based on sex and lineage (based on operation number), as well as differences over time. Crosstabulations allow for a comparison of the rates of the two conditions between different groups, while the Odds Ratio, also known as the Risk Ratio, can be used to assess whether one group was more likely to suffer from either of the two pathological conditions than another. For this type of analysis, only two groups can be evaluated at a time, meaning the data has to be broken down into a 2x2 table. For the purposes of the Odds Ratio analysis, therefore, presence or absence of porotic hyperostosis and presence or absence of linear enamel hypoplasias were assessed for males vs. females, Operation I vs. all other operations (as the lineage at Operation I may have been of a higher status with better access to resources and prime agricultural land than other lineages), and for the Formative vs. the Classic period.

Chi-square analysis would also have been a useful tool in this analysis, but unfortunately the small sample sized of evaluable individuals meant that in most cases the assumptions of this statistical test were not met, and therefore it could not be used. Instead, Exact tests were used, which allow for smaller samples which do not meet these assumptions to be tested. Unfortunately, due to differences in scoring and reporting between studies, it was not possible to perform statistical analyses to test the significance of differences between sites.

### SOURCES OF ERROR

A major source of error within the K'axob skeletal sample is the poor state of preservation of human remains in the Maya area as a whole and at the site of K'axob in particular. Poor preservation made evaluation of porotic hyperostosis and linear enamel hypoplasias difficult for the K'axob sample, and many individuals had to be excluded from the analysis of one or both of these conditions due to lack of cranial vault bones or teeth. This is turn decreases the sample size for the study, weakening the conclusions and also making statistical analyses difficult, as small sample size can decrease the significance of the results. Unfortunately, this is a situation that affects skeletal pathology studies in most parts of the Maya area.

Another issue is variability in the evaluation criteria used by different researchers. This seems to be especially true of the reporting of linear enamel hypoplasias, in which the standards for evaluation of the condition tend to vary between researchers, but this is often true for porotic hyperostosis, as well

(Wright and White 1996). In each study, researchers define their own criteria for what makes for an evaluable individual, part of this has to do with differences in preservation for each site. When preservation is very poor, it may be necessary to broaden criteria for evaluation so that more individuals can be included in the analysis. In this study, if 40-60% or more of the cranium were required to be present to evaluate porotic hyperostosis instead of 25-35%, the sample size for this condition would have dropped from 44 individuals to just 10. For the low-status population at Copán, Stephen Whittington (Whittington and Reed 1997b) reported the rate for the total sample, and then the rate for only those individuals with approximately 50% or more of the vault present, which included only 22 of the original 157 individuals. The prevalence of porotic hyperostosis for the total sample was 28%, whereas the prevalence for the 22 individuals with at least 50% of the vault intact was 64%. As this example shows, differences in evaluation criteria can change the results drastically. So, a major issue for osteologists in formulating a research design lies in determining the right methods to use to include a large enough sample to make meaningful statements while at the same time attempting to ensure accuracy and replicability in the results.

Preservation of teeth tends to be better, since dental enamel is the hardest substance in the human body (Hillson 1996). In some cases teeth are the only remains found in a burial when the rest of the skeletal material has disintegrated or otherwise been lost (Wright and White 1996), which was true for a few individuals in the K'axob sample. Still, even though recovery of teeth tends to be somewhat better, methods for the evaluation of dental pathology can vary widely among researchers.

Another issue lies in scoring between researchers. Although attempts have been made to improve comparability of pathological studies, such as the standards produced by Jane Buikstra and Douglas Ubelaker (1994), observers can vary in their interpretations of these scoring standards. Keith P. Jacobi and Marie Elaine Danforth (2002) report a great deal interobserver scoring errors for porotic hyperostosis even between trained osteologists. In addition to this problem, bioarchaeologists seem to have a tendency to adjust the scoring methods to suit their own particular study, reducing comparability between studies, which, again, is especially true for enamel hypoplasias.

# Chapter Six
## RESULTS

### POROTIC HYPEROSTOSIS

Porotic hyperostosis was observed in 36 individuals out of the total sample of 154 individuals at K'axob, or 23.4% of all individuals (Table 6.1). However, this includes individuals with little or no cranial material present, for whom the absence of porotic lesions could not be confirmed. Therefore, the prevalence of porotic hyperostosis for only those individuals with at least approximately 25-35% of the cranial vault present was also evaluated (Table 6.2). This provides a more accurate figure of 24 out of 44 evaluable individuals, or 54.5%.

| | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|
| Absent | 118 | 76.6 | 76.6 | 76.6 |
| Present | 36 | 23.4 | 23.4 | 100.0 |
| Total | 154 | 100.0 | 100.0 | |

**Table 6.1: Frequency of Porotic Hyperostosis for All Individuals at K'axob**

| | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|
| Absent | 20 | 45.5 | 45.5 | 45.5 |
| Present | 24 | 54.5 | 54.5 | 100.0 |
| Total | 44 | 100.0 | 100.0 | |

**Table 6.2: Frequency of Porotic Hyperostosis for Individuals with 25-35% or More of Vault Present at K'axob**

Degree, activity, and location of porotic lesions were also scored for the K'axob sample. Of the 36 total individuals with porotic hyperostosis, 63.9% (N=23) had barely discernible porosity, 27.8% (N=10) had true porosity, and 8.3% (N=3) had coalescing pores (Table 6.3). In terms of activity, only two individuals (5.6%) of the 36 had a mixture of active and healing lesions, both of them juveniles, one a four- to five-year-old juvenile from Operation I and the other a two- to four-year-old from Operation XIV. The rest of the cases (94.4%) were healed. In more than half of the cases (N=19; 52.8%), the porotic lesions were localized near the sutures on the cranial vault (Table 6.4). 36.1% (N=13) were located away from the cranial sutures, while only two cases were located in both the orbits and along the coronal suture of the frontal and two cases localized around the parietal bosses and/or the squamosal portion of the occipital.

| | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|
| Barely Discernible | 23 | 63.9 | 63.9 | 63.9 |
| True Porosity | 10 | 27.8 | 27.8 | 91.7 |
| Coalescing Pores | 3 | 8.3 | 8.3 | 100.0 |
| Total | 36 | 100.0 | 100.0 | |

**Table 6.3: Degree of Porosity at K'axob**

| | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|
| Localized Near Sutures | 19 | 52.8 | 52.8 | 52.8 |
| Away from Sutures | 13 | 36.1 | 36.1 | 88.9 |
| Within Orbits and Along Suture of Frontal | 2 | 5.6 | 5.6 | 94.4 |
| Both Parietal Bosses and/or Squamosal Portion of Occipital | 2 | 5.6 | 5.6 | 100.0 |
| Total | 36 | 100.0 | 100.0 | |

**Table 6.4: Location of Porotic Lesions on the Cranial Vault at K'axob**

Patterns of porotic hyperostosis between groups in the K'axob skeletal sample were evaluated, as well. For this analysis, only those individuals with at least 25-35% of the cranial vault recovered were included, as absence of lesions could not be confirmed for individuals with less than this amount. The prevalence of porotic hyperostosis was compared between sex (Table 6.5), operation number (Table 6.6), and ceramic periods (Table 6.7) for an assessment of differences between social groups and over time. The prevalence of porotic hyperostosis did not differ much between group, and lambda values for these crosstabulations do not indicate that there was any association between the prevalence of porotic lesions based on either sex or lineage (based on operation number), nor was there any association with the prevalence over time based on ceramic periods.

| | | Porotic Hyperostosis | | |
|---|---|---|---|---|
| | | Absent | Present | Total |
| Female | Count | 5 | 10 | 15 |
| | % within Sex | 33.3% | 66.7% | 100.0% |
| | % within Porotic Hyperostosis | 25.0% | 41.7% | 34.1% |
| Male | Count | 9 | 11 | 20 |
| | % within Sex | 45.0% | 55.0% | 100.0% |
| | % within Porotic Hyperostosis | 45.0% | 45.8% | 45.5% |
| Indeterminate | Count | 4 | 2 | 6 |
| | % within Sex | 66.7% | 33.3% | 100.0% |
| | % within Porotic Hyperostosis | 20.0% | 8.3% | 13.6% |
| Subadult | Count | 2 | 1 | 3 |
| | % within Sex | 66.7% | 33.3% | 100.0% |
| | % within Porotic Hyperostosis | 10.0% | 4.2% | 6.8% |
| Total | Count | 20 | 24 | 44 |
| | % within Sex | 45.5% | 54.5% | 100.0% |
| | % within Porotic Hyperostosis | 100.0% | 100.0% | 100.0% |

**Table 6.5: Prevalence of Porotic Hyperostosis by Sex at K'axob**

| | | Porotic Hyperostosis | | |
|---|---|---|---|---|
| | | Absent | Present | Total |
| I | Count | 5 | 12 | 17 |
| | % within Operation | 29.4% | 70.6% | 100.0% |
| | % within Porotic Hyperostosis | 25.0% | 50.0% | 38.6% |
| VIII | Count | 3 | 1 | 4 |
| | % within Operation | 75.0% | 25.0% | 100.0% |
| | % within Porotic Hyperostosis | 15.0% | 4.2% | 9.1% |
| X | Count | 0 | 1 | 1 |
| | % within Operation | 0.0% | 100.0% | 100.0% |
| | % within Porotic Hyperostosis | 0.0% | 4.2% | 2.3% |
| XI | Count | 5 | 3 | 8 |
| | % within Operation | 62.5% | 37.5% | 100.0% |
| | % within Porotic Hyperostosis | 25.0% | 12.5% | 18.2% |
| XII | Count | 1 | 3 | 4 |
| | % within Operation | 25.0% | 75.0% | 100.0% |
| | % within Porotic Hyperostosis | 5.0% | 12.5% | 9.1% |
| XIII | Count | 0 | 1 | 1 |
| | % within Operation | 0.0% | 100.0% | 100.0% |
| | % within Porotic Hyperostosis | 0.0% | 4.2% | 2.3% |
| XIV | Count | 1 | 1 | 2 |
| | % within Operation | 50.0% | 50.0% | 100.0% |
| | % within Porotic Hyperostosis | 5.0% | 4.2% | 4.5% |
| XVI | Count | 3 | 2 | 5 |
| | % within Operation | 60.0% | 40.0% | 100.0% |
| | % within Porotic Hyperostosis | 15.0% | 8.3% | 11.4% |
| XX | Count | 2 | 0 | 2 |
| | % within Operation | 100.0% | 0.0% | 100.0% |
| | % within Porotic Hyperostosis | 10.0% | 0.0% | 4.5% |
| Total | Count | 20 | 24 | 44 |
| | % within Operation | 45.5% | 54.5% | 100.0% |
| | % within Porotic Hyperostosis | 100.0% | 100.0% | 100.0% |

**Table 6.6: Prevalence of Porotic Hyperostosis by Operation at K'axob**

| | | Porotic Hyperostosis | | |
|---|---|---|---|---|
| | | Absent | Present | Total |
| Chaakk'ax, early facet | Count | 0 | 3 | 3 |
| | % within Ceramic Phase | 0.0% | 100.0% | 100.0% |
| | % within Porotic Hyperostosis | 0.0% | 12.5% | 6.8% |
| K'atabche'k'ax, early facet | Count | 4 | 4 | 8 |
| | % within Ceramic Phase | 50.0% | 50.0% | 100.0% |
| | % within Porotic Hyperostosis | 20.0% | 16.7% | 18.2% |
| K'atabche'k'ax, late facet | Count | 9 | 8 | 17 |
| | % within Ceramic Phase | 52.9% | 47.1% | 100.0% |
| | % within Porotic Hyperostosis | 45.0% | 33.3% | 38.6% |
| K'atabche'k'ax, terminal facet | Count | 3 | 6 | 9 |
| | % within Ceramic Phase | 33.3% | 66.7% | 100.0% |
| | % within Porotic Hyperostosis | 15.0% | 25.0% | 20.5% |
| Nohalk'ax, early facet | Count | 1 | 1 | 2 |
| | % within Ceramic Phase | 50.0% | 50.0% | 100.0% |
| | % within Porotic Hyperostosis | 5.0% | 4.2% | 4.5% |
| Witsk'ax, early facet | Count | 2 | 2 | 4 |
| | % within Ceramic Phase | 50.0% | 50.0% | 100.0% |
| | % within Porotic Hyperostosis | 10.0% | 8.3% | 9.1% |
| Witsk'ax, late facet | Count | 1 | 0 | 1 |
| | % within Ceramic Phase | 100.0% | 0.0% | 100.0% |
| | % within Porotic Hyperostosis | 5.0% | 0.0% | 2.3% |
| Total | Count | 20 | 24 | 44 |
| | % within Ceramic Phase | 45.5% | 54.5% | 100.0% |
| | % within Porotic Hyperostosis | 100.0% | 100.0% | 100.0% |

**Table 6.7: Prevalence of Porotic Hyperostosis by Ceramic Phase at K'axob**

An Odds Ratio analysis, or risk analysis, was conducted for the K'axob sample for males vs. females (Table 6.8), Operation I vs. other operations (Table 6.9), and the Formative period vs. the Classic period (Table 6.10). Again, only individuals with 25-35% or more of evaluable cranial material were included in this analysis. In all three cases, the lambda (λ) values calculated for each fell within the 95% confidence interval, indicating that there were no significant differences in the odds of having porotic lesions between males and females, in the lineage at Operation I compared to other lineages, or between the two time periods. These values and the lower and upper limits of each confidence interval are presented in the "Risk Estimate" below each table.

| | | Sex | | Total |
|---|---|---|---|---|
| | | Female | Male | |
| Absent | Count | 5 | 9 | 14 |
| | % within Porotic Hyperostosis | 35.7% | 64.3% | 100.0% |
| | % within Sex | 33.3% | 45.0% | 40.0% |
| Present | Count | 10 | 11 | 21 |
| | % within Porotic Hyperostosis | 47.6% | 52.4% | 100.0% |
| | % within Sex | 66.7% | 55.0% | 60.0% |
| Total | Count | 15 | 20 | 35 |
| | % within Porotic Hyperostosis | 42.9% | 57.1% | 100.0% |
| | % within Sex | 100.0% | 100.0% | 100.0% |

**Risk Estimate**

| | Value | 95% Confidence Interval | |
|---|---|---|---|
| | | Lower | Upper |
| Odds Ratio for Porotic Hyperostosis (Absent / Present) | .611 | .152 | 2.450 |
| For cohort Sex = Female | .750 | .326 | 1.726 |
| For cohort Sex = Male | 1.227 | .698 | 2.158 |
| N of Valid Cases | 35 | | |

**Table 6.8: Porotic Hyperostosis for Males vs. Females**

| | | Status by Operation | | |
|---|---|---|---|---|
| | | Operation I | Other Operations | Total |
| Absent | Count | 5 | 15 | 20 |
| | % within Porotic Hyperostosis | 25.0% | 75.0% | 100.0% |
| | % within Status by Operation | 29.4% | 55.6% | 45.5% |
| Present | Count | 12 | 12 | 24 |
| | % within Porotic Hyperostosis | 50.0% | 50.0% | 100.0% |
| | % within Status by Operation | 70.6% | 44.4% | 54.5% |
| Total | Count | 17 | 27 | 44 |
| | % within Porotic Hyperostosis | 38.6% | 61.4% | 100.0% |
| | % within Status by Operation | 100.0% | 100.0% | 100.0% |

**Risk Estimate**

| | Value | 95% Confidence Interval | |
|---|---|---|---|
| | | Lower | Upper |
| Odds Ratio for Porotic Hyperostosis (Absent / Present) | .333 | .092 | 1.211 |
| For cohort Status by Operation = Operation I | .500 | .212 | 1.179 |
| For cohort Status by Operation = Other Operations | 1.500 | .934 | 2.408 |
| N of Valid Cases | 44 | | |

**Table 6.9: Porotic Hyperostosis for Operation I vs. Other Operations**

| | | Period | | Total |
|---|---|---|---|---|
| | | Formative | Classic | |
| Absent | Count | 16 | 4 | 20 |
| | % within Porotic Hyperostosis | 80.0% | 20.0% | 100.0% |
| | % within Period | 43.2% | 57.1% | 45.5% |
| Present | Count | 21 | 3 | 24 |
| | % within Porotic Hyperostosis | 87.5% | 12.5% | 100.0% |
| | % within Period | 56.8% | 42.9% | 54.5% |
| Total | Count | 37 | 7 | 44 |
| | % within Porotic Hyperostosis | 84.1% | 15.9% | 100.0% |
| | % within Period | 100.0% | 100.0% | 100.0% |

**Risk Estimate**

| | Value | 95% Confidence Interval | |
|---|---|---|---|
| | | Lower | Upper |
| Odds Ratio for Porotic Hyperostosis (Absent / Present) | .571 | .112 | 2.923 |
| For cohort Period = Formative | .914 | .701 | 1.193 |
| For cohort Period = Classic | 1.600 | .405 | 6.324 |
| N of Valid Cases | 44 | | |

**Table 6.10: Porotic Hyperostosis for the Formative vs. the Classic Period**

### LINEAR ENAMEL HYPOPLASIA

Linear enamel hypoplasias were observed in just over half (51.9%) of all individuals at K'axob, a total of 80 out of 154 individuals (Table 6.11). This figure includes individuals who did not have any teeth, as well as individuals who did not have the teeth that are most susceptible to hypoplasia formation. Therefore, when the sample is restricted to only those individuals with two or more incisors and/or canines present to evaluate, LEH occurs at a percentage of prevalence of 78.9% (N=71) of 90 evaluable individuals (Table 6.12).

| | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|
| Absent | 74 | 48.1 | 48.1 | 48.1 |
| Present | 80 | 51.9 | 51.9 | 100.0 |
| Total | 154 | 100.0 | 100.0 | |

**Table 6.11: Frequency of Linear Enamel Hypoplasias for All Individuals at K'axob**

| | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|
| Absent | 19 | 21.1 | 21.1 | 21.1 |
| Present | 71 | 78.9 | 78.9 | 100.0 |
| Total | 90 | 100.0 | 100.0 | |

**Table 6.12: Frequency of Linear Enamel Hypoplasias for Individuals with Two or More Incisors/Canines at K'axob**

The approximate age of occurrence was also calculated for all linear enamel hypoplasias using regression formulas provided by Goodman and Rose (1990). Cases were only included in this analysis if at least two non-adjacent teeth showed the same defect, indicating that the hypoplasias were systemic, rather than being caused by some sort of localized trauma that only affected one tooth. A total of 68 cases met this criterion. The range of the ages of occurrence calculated spanned from 1-1.5 years (one case) to 5-5.5 years (two cases). More than half of the cases fell within the range of 2.5-4.5 years of age. There was only one case, a four- to six-year-old juvenile from Operation XVI (Burial 16-21), in which hypoplasias occurred in the deciduous teeth. These occurred on both deciduous maxillary central incisors in this individual. All other recorded hypoplasias in the sample occurred in the permanent dentition.

As with porotic hyperostosis, the prevalence linear enamel hypoplasia between groups was analyzed. Again, only those individuals who were considered evaluable, who had at least two permanent incisors and/or canines preserved, were included in this analysis. The prevalence of LEH based on sex (Table 6.13), operation number (Table 6.14), and over time by ceramic period (Table 6.15) were examined. Sample size is small within some groups, but prevalence does not differ greatly between groups in any of these three analyses. As with porotic hyperostosis, lambda values do not indicate any association between presence or absence of LEH and sex, operation number, or ceramic phase.

| | | LEH Present | | Total |
|---|---|---|---|---|
| | | Absent | Present | |
| Female | Count | 2 | 17 | 19 |
| | % within Sex | 10.5% | 89.5% | 100.0% |
| | % within LEH Present | 10.5% | 23.9% | 21.1% |
| Male | Count | 2 | 32 | 34 |
| | % within Sex | 5.9% | 94.1% | 100.0% |
| | % within LEH Present | 10.5% | 45.1% | 37.8% |
| Indeterminate | Count | 4 | 12 | 16 |
| | % within Sex | 25.0% | 75.0% | 100.0% |
| | % within LEH Present | 21.1% | 16.9% | 17.8% |
| Subadult | Count | 11 | 10 | 21 |
| | % within Sex | 52.4% | 47.6% | 100.0% |
| | % within LEH Present | 57.9% | 14.1% | 23.3% |
| Total | Count | 19 | 71 | 90 |
| | % within Sex | 21.1% | 78.9% | 100.0% |
| | % within LEH Present | 100.0% | 100.0% | 100.0% |

**Table 6.13: Prevalence of LEH by Sex at K'axob**

| | | LEH Present | | Total |
|---|---|---|---|---|
| | | Absent | Present | |
| I | Count | 8 | 29 | 37 |
| | % within Operation | 21.6% | 78.4% | 100.0% |
| | % within LEH Present | 42.1% | 40.8% | 41.1% |
| VII | Count | 0 | 1 | 1 |
| | % within Operation | 0.0% | 100.0% | 100.0% |
| | % within LEH Present | 0.0% | 1.4% | 1.1% |
| VIII | Count | 1 | 6 | 7 |
| | % within Operation | 14.3% | 85.7% | 100.0% |
| | % within LEH Present | 5.3% | 8.5% | 7.8% |
| X | Count | 0 | 1 | 1 |
| | % within Operation | 0.0% | 100.0% | 100.0% |
| | % within LEH Present | 0.0% | 1.4% | 1.1% |
| XI | Count | 3 | 7 | 10 |
| | % within Operation | 30.0% | 70.0% | 100.0% |
| | % within LEH Present | 15.8% | 9.9% | 11.1% |
| XII | Count | 0 | 10 | 10 |
| | % within Operation | 0.0% | 100.0% | 100.0% |
| | % within LEH Present | 0.0% | 14.1% | 11.1% |
| XIII | Count | 0 | 2 | 2 |
| | % within Operation | 0.0% | 100.0% | 100.0% |
| | % within LEH Present | 0.0% | 2.8% | 2.2% |
| XIV | Count | 1 | 2 | 3 |
| | % within Operation | 33.3% | 66.7% | 100.0% |
| | % within LEH Present | 5.3% | 2.8% | 3.3% |
| XVI | Count | 3 | 9 | 12 |
| | % within Operation | 25.0% | 75.0% | 100.0% |
| | % within LEH Present | 15.8% | 12.7% | 13.3% |
| XX | Count | 3 | 4 | 7 |
| | % within Operation | 42.9% | 57.1% | 100.0% |
| | % within LEH Present | 15.8% | 5.6% | 7.8% |
| Total | Count | 19 | 71 | 90 |
| | % within Operation | 21.1% | 78.9% | 100.0% |
| | % within LEH Present | 100.0% | 100.0% | 100.0% |

**Table 6.14: Prevalence of LEH by Operation at K'axob**

| | | LEH Present | | |
|---|---|---|---|---|
| | | Absent | Present | Total |
| Chaakk'ax, early facet | Count | 1 | 4 | 5 |
| | % within Ceramic Phase | 20.0% | 80.0% | 100.0% |
| | % within LEH Present | 5.3% | 5.6% | 5.6% |
| K'atabche'k'ax, early facet | Count | 2 | 10 | 12 |
| | % within Ceramic Phase | 16.7% | 83.3% | 100.0% |
| | % within LEH Present | 10.5% | 14.1% | 13.3% |
| K'atabche'k'ax, late facet | Count | 9 | 27 | 36 |
| | % within Ceramic Phase | 25.0% | 75.0% | 100.0% |
| | % within LEH Present | 47.4% | 38.0% | 40.0% |
| K'atabche'k'ax, terminal facet | Count | 4 | 14 | 18 |
| | % within Ceramic Phase | 22.2% | 77.8% | 100.0% |
| | % within LEH Present | 21.1% | 19.7% | 20.0% |
| Nohalk'ax, early facet | Count | 0 | 6 | 6 |
| | % within Ceramic Phase | 0.0% | 100.0% | 100.0% |
| | % within LEH Present | 0.0% | 8.5% | 6.7% |
| Nohalk'ax, late facet | Count | 0 | 1 | 1 |
| | % within Ceramic Phase | 0.0% | 100.0% | 100.0% |
| | % within LEH Present | 0.0% | 1.4% | 1.1% |
| Witsk'ax, early facet | Count | 3 | 7 | 10 |
| | % within Ceramic Phase | 30.0% | 70.0% | 100.0% |
| | % within LEH Present | 15.8% | 9.9% | 11.1% |
| Witsk'ax, late facet | Count | 0 | 2 | 2 |
| | % within Ceramic Phase | 0.0% | 100.0% | 100.0% |
| | % within LEH Present | 0.0% | 2.8% | 2.2% |
| Total | Count | 19 | 71 | 90 |
| | % within Ceramic Phase | 21.1% | 78.9% | 100.0% |
| | % within LEH Present | 100.0% | 100.0% | 100.0% |

**Table 6.15: Prevalence of LEH by Ceramic Phase at K'axob**

Odds ratio analysis of linear enamel hypoplasias at K'axob based on males vs. females (Table 6.16), Operation I vs. other operations (Table 6.17), and the Formative vs. the Classic period (Table 6.18) was conducted for individuals with at least two incisors and/or canines. Again, as with porotic hyperostosis, the risk ratio calculated for all three analyses indicated no significant differences between groups, as the calculated risk fell within the 95% confidence interval in all three cases. This means that there were no significant differences in the odds of having hypoplasias between males and females, between Operation I and the other operations, or between time periods.

| | | Sex | | Total |
|---|---|---|---|---|
| | | Female | Male | |
| Absent | Count | 2 | 2 | 4 |
| | % within LEH Present | 50.0% | 50.0% | 100.0% |
| | % within Sex | 10.5% | 5.9% | 7.5% |
| Present | Count | 17 | 32 | 49 |
| | % within LEH Present | 34.7% | 65.3% | 100.0% |
| | % within Sex | 89.5% | 94.1% | 92.5% |
| Total | Count | 19 | 34 | 53 |
| | % within LEH Present | 35.8% | 64.2% | 100.0% |
| | % within Sex | 100.0% | 100.0% | 100.0% |

**Risk Estimate**

| | Value | 95% Confidence Interval | |
|---|---|---|---|
| | | Lower | Upper |
| Odds Ratio for LEH Present (Absent / Present) | 1.882 | .243 | 14.568 |
| For cohort Sex = Female | 1.441 | .503 | 4.129 |
| For cohort Sex = Male | .766 | .281 | 2.083 |
| N of Valid Cases | 53 | | |

**Table 6.16: LEH for Males vs. Females**

| | | Operation | | Total |
|---|---|---|---|---|
| | | Operation I | Other Operations | |
| Absent | Count | 8 | 11 | 19 |
| | % within LEH Present | 42.1% | 57.9% | 100.0% |
| | % within Status by Operation | 21.6% | 20.8% | 21.1% |
| Present | Count | 29 | 42 | 71 |
| | % within LEH Present | 40.8% | 59.2% | 100.0% |
| | % within Status by Operation | 78.4% | 79.2% | 78.9% |
| Total | Count | 37 | 53 | 90 |
| | % within LEH Present | 41.1% | 58.9% | 100.0% |
| | % within Status by Operation | 100.0% | 100.0% | 100.0% |

**Risk Estimate**

| | Value | 95% Confidence Interval | |
|---|---|---|---|
| | | Lower | Upper |
| Odds Ratio for LEH Present (Absent / Present) | 1.053 | .377 | 2.940 |
| For cohort Status by Operation = Operation I | 1.031 | .567 | 1.873 |
| For cohort Status by Operation = Other Operations | .979 | .637 | 1.504 |
| N of Valid Cases | 90 | | |

**Table 6.17: LEH for Operation I vs. Other Operations**

| | | Period | | |
|---|---|---|---|---|
| | | Formative | Classic | Total |
| Absent | Count | 16 | 3 | 19 |
| | Expected Count | 15.0 | 4.0 | 19.0 |
| | % within LEH Present | 84.2% | 15.8% | 100.0% |
| | % within Period | 22.5% | 15.8% | 21.1% |
| Present | Count | 55 | 16 | 71 |
| | Expected Count | 56.0 | 15.0 | 71.0 |
| | % within LEH Present | 77.5% | 22.5% | 100.0% |
| | % within Period | 77.5% | 84.2% | 78.9% |
| Total | Count | 71 | 19 | 90 |
| | Expected Count | 71.0 | 19.0 | 90.0 |
| | % within LEH Present | 78.9% | 21.1% | 100.0% |
| | % within Period | 100.0% | 100.0% | 100.0% |

**Risk Estimate**

| | Value | 95% Confidence Interval | |
|---|---|---|---|
| | | Lower | Upper |
| Odds Ratio for Period (Formative / Classic) | 1.552 | .401 | 6.003 |
| For cohort LEH Present = Absent | 1.427 | .464 | 4.394 |
| For cohort LEH Present = Present | .920 | .730 | 1.160 |
| N of Valid Cases | 90 | | |

**Table 6.18: LEH for the Formative vs. the Classic Period**

# Chapter Seven
## DISCUSSION AND CONCLUSIONS

The results of this study indicate that the prevalence of porotic hyperostosis at K'axob - present in 54.5% of 44 evaluable individuals - was closer to the prevalence reported for the sites of Copán, Honduras and the Pasión region of the Department of Petén, Guatemala than to Cuello, Belize. The prevalence of linear enamel hypoplasias for K'axob - present in 78.9% of evaluable individuals - was higher than the prevalence of hypoplasias reported for the Pasión region and Cuello, but lower than for Copán. Overall, the prevalence for both pathological conditions was higher than expected for the population of K'axob. There were no significant differences between groups with the population of K'axob based on sex, lineage, or time period.

### EVALUATION OF HYPOTHESES

The hypotheses for this study were:

1. The prevalence of porotic hyperostosis within a population is lower in ecological settings with a greater diversity of resources available compared to sites with less ecological diversity.
2. The prevalence of linear enamel hypoplasias within a population is lower in ecological settings with a greater diversity of resources available compared to sites with less ecological diversity.

Based on the results of the analyses on the people of K'axob, the null hypotheses for this study cannot be rejected for either pathological condition. In other words, the diversity of the availability of resources in a particular setting alone does not affect the prevalence of porotic hyperostosis and linear enamel hypoplasias based on this analysis. This is not to say that ecological factors and availability of resources had no influence on health and nutritional status at K'axob, but rather that there were most likely several other factors at play, as well. At K'axob, it seems that, even with the diverse animal protein resources, wider variety of plant foods available, and less dependence on maize agriculture, the population was still affected by iron deficiency anemia and other nutritional or illness-related stresses to a relatively high degree. This indicates that the prevalence of these conditions was affected not by diet, but rather by other factors, such as a high pathogen load in the wetland environment surrounding the site.

## NUTRITION AND HEALTH AT K'AXOB, BELIZE

Iron deficiency anemia and episodes of prolonged nutritional or disease stress represented by linear enamel hypoplasias were both fairly prevalent in the K'axob population, the former occurring in 54.5% of the population and the latter in 78.9%. If all individuals in the sample are included instead of only evaluable individuals, the percentages are about 25% lower in both cases, but this is considered to be less accurate. While the prevalence of porotic hyperostosis at K'axob was in fact slightly lower than figures reported for both Copán and the

Pasión region, it was much higher than the prevalence reported for the nearby site of Cuello, even though both sites were occupied from the Middle Formative period and shared similarities in environment, resources, and level of maize dependency. The prevalence of linear enamel hypoplasia was lower than that of the population at Copán, but higher than both Cuello and the Pasión region; however, hypoplasias occurred in greater than 50% of people from all of these samples, so overall it was quite prevalent regardless of ecological setting.

Since the sample from Cuello contains only individuals from the Preclassic period, it is helpful to compare the prevalence from only the Preclassic sample at K'axob to avoid any possible error due to difference between time periods. For Formative K'axob, the percentage of prevalence of porotic hyperostosis was 56.8%, slightly higher than that of the whole sample of evaluable individuals and much higher than at Preclassic Cuello, where the condition was observed in only two of 49 individuals (or about 4% of the sample). The percentage of prevalence of LEH for Formative K'axob was 77.5%, about the same as the overall figure, and almost 20% higher than the prevalence of LEH at Cuello.

The samples from Copán and the Pasión region consist mostly of Classic period individuals, so it may be helpful to look at just the Classic period of K'axob compared to these sites. The prevalence of porotic hyperostosis for the Classic period sample was 42.9%; however the number of evaluable individuals for this period was only seven, so this may not be a representative figure.

Nevertheless, it was lower than figures reported for both Copán and the Pasión region. LEH occurred in 84.2% out of 19 evaluable Classic period individuals, higher than for the overall sample. This percentage of prevalence is higher than figures for the Pasión region, where the prevalence was just over 60%, but lower than at Copán, where linear enamel hypoplasias were nearly ubiquitous.

Iron deficiency anemia can be caused not only by a low iron diet, but also by parasite activity and the consumption of compounds that can inhibit the absorption of iron in the digestive tract (Goodman and Armelagos 1989; Larsen 1995; Stuart-Macadam 1992; Wright and White 1996). Parasites dwelling in the digestive tract reduce the bioavailability of iron consumed by their hosts by absorbing it and using it themselves; they also often cause diarrhea, which causes nutrients such as iron to be lost because they can be absorbed. Compounds such as tannins, phytic acid, and calcium found in certain foods can also bind with iron and reduce its bioavailability.

It could be that the environment at K'axob, while providing agricultural advantages and an abundance of resources, may also have had features that were detrimental to the health of the population, as well. The warm, humid wetland environment, especially with the stagnant waters of Pulltrouser Swamp very close by, probably supported a high parasite load, such as tapeworms, hookworms, and bacteria. Lori Wright and Christine White (1996) suggest that regional variability in parasite load has more to do with the patterns of porotic hyperostosis than does variation in resource availability and overall diet, just as the results of this study seem to indicate. Fish also tend to be high in parasites (Walker 1986; Wright and White 1996), so if the typical diet at K'axob contained a great deal of fish, this could also account for the high prevalence of porotic hyperostosis. It could also help explain the difference between Cuello and K'axob, as Tykot, et al. (1996) found that consumption of fish was most likely fairly low based on stable isotope analysis. Another major difference between Cuello and K'axob is that Cuello is not located on a swamp like K'axob is, so less stagnant water around Cuello may have meant fewer pathogens at that site. Parasite activity could also account for the higher prevalence of enamel hypoplasias, as well, as intestinal parasites could cause loss of many types of nutrients, not just loss of iron.

Phillip L. Walker (1986) describes a situation for a population from the southern coastal area of California in which half of adults had *cribra orbitalia*, very close to the prevalence of porotic hyperostosis at K'axob. The population relied mostly on marine resources and had a high protein diet based on fish, shellfish, and sea mammals. Walker suggests that the prevalence of iron deficiency anemia in this population was most likely due to the prevalence of parasitic infection and prolonged breastfeeding. Bouts of illness and diarrhea probably occurred frequently as children were introduced to foods containing parasites for the first time during weaning. Additionally, Walker states that breast milk is low in iron, so young children still being breastfed would have been low in iron, further contributing to the high prevalence of *cribra orbitalia*.

These factors may help to explain the high prevalence of porotic hyperostosis and linear enamel hypoplasia at K'axob, as well.

Linear enamel hypoplasias occurred on average around 3-3 1/2 years of age, which may have been consistent with weaning age. This suggests that children experienced a severe, prolonged episode of ill health or nutritional stress around this age. This could have been caused by parasitic infection as children were introduced to solid foods for the first time. The intestinal worms and bacteria that they picked up from their environment when they were no longer buffered from these parasites by their mothers probably caused severe illness, including diarrhea, which would have resulted in nutritional losses at a critical time of growth and development. Additionally, there were two juveniles with partially active porotic hyperostosis at the time of their deaths, one aged 2-4 years and one aged 4-5 years. This may also support the idea that early childhood was a vulnerable time for the children of K'axob.

The fact that only one juvenile had linear enamel hypoplasias in the deciduous dentition implies that maternal health was probably relatively good at K'axob. The deciduous maxillary central incisor crowns, in which this single instance of deciduous LEH was found, are fully formed by approximately six months of age, and begin forming in utero. Before birth and within the first six months of life the child would have been fully dependent on the mother for nutrition, so in this case of deciduous LEH probably indicates an episode of stress for the mother, which also impacted the child. No other children with observable deciduous teeth had enamel defects, which may indicate that this circumstance was rare, and maternal health was at least adequate to meet the needs of the children before weaning in this population. However, it is important to note that stress episodes impacting the development of the deciduous teeth may more often be represented by hypocalcifications, which were not scored in this study, rather than hypoplasias (R. Storey, personal communication).

### Implications and Directions for Future Research

This study shows that pathological conditions are influenced by a number of different factors. While the diversity of available resources does play a part in the health and nutritional status of a population, there are other factors to consider as well. In the case of K'axob, it appears that diet was not the cause of porotic hyperostosis or enamel hypoplasias, but more likely these conditions were more prevalent because of other environmental factors, most likely a high pathogen load, which has also been suggested by Wright and White (1996).

The study of patterns of health in the Maya area would benefit greatly from more studies of paleopathology in human skeletal remains from a greater diversity of sites, including sites in a variety of ecological settings. Of course, larger sample sizes would also be preferable, but this is a major issue in the Maya area because preservation tends to be very poor and excavation often do not focus on the recovery of human remains. Finally, greater uniformity in the methods used to evaluate pathologies would help improve comparability between studies.

# Appendix A: Codes and Abbreviations

**Porotic Hyperostosis**

*(Based on Buikstra and Ubelaker, 1994)*

Degree:
1 = barely discernible
2 = true porosity
3 = coalescing pores
4 = coalescing pores with expansive changes

Activity:
1 = active
2 = healed
3 = mixture of active and healed

Location:
1 = only within the orbits (cribra orbitalia)
2 = localized near sutures
3 = away from sutures (more central on bone, i.e. near frontal or parietal bosses)
4 = within orbits and along suture of frontal
5 = both parietal bosses and/or squamosal portion of occipital

**Linear Enamel Hypoplasia**

*(Based on Buikstra and Ubelaker, 1994)*

Type:
0 = absence
1 = linear horizontal grooves
2 = linear vertical grooves
3 = linear horizontal pits
4 = linear vertical pits
5 = single pits
6 = discrete boundary opacity (hypocalcified enamel)
7 = diffuse boundary opacity (hypocalcified enamel)

Color (for hypocalcified enamel):
1 = yellow
2 = cream/white
3 = orange
4 = brown

Location: Distance in millimeters (mm) between the cement-enamel junction (CEJ) and the most occlusal edge of the defect

## Cranial Remains

Percentage Present [Percent-Cra]:
0 = none present, or mandible only
1 = less than 10%, few small fragments/pieces
2 = 10-20%, several-many small fragments
3 = 25-35%, several large frags, partial or 1/3 vault
4 = 40-60%, many large frags, 1/2 vault
5 = 65% or greater, 2/3 to 3/4 vault or more

## Abbreviations

Percent-Cra: Percentage of the cranium present

I/C Present: Number of incisors and/or canines present

LEH Max/Tooth: Maximum number of linear enamel hypoplasias per tooth

## Appendix B: K'axob Database Tables

| K'axob Burials | | | | |
|---|---|---|---|---|
| **Burial** | **Operation** | **Age** | **Sex** | **Phase** |
| 01-01a | 1 | Y-M adult | prob male | term katab |
| 01-01b | 1 | old adult | indeterminate | term katab |
| 01-01c | 1 | young adult | indeterminate | term katab |
| 01-01d | 1 | young adult | female | term katab |
| 01-01e | 1 | adol/y adult | indeterminate | term katab |
| 01-01f | 1 | middle adult | male | term katab |
| 01-01g | 1 | M-O adult | male | term katab |
| 01-02a | 1 | young adult | male | term katab |
| 01-02b | 1 | young adult | indeterminate | term katab |
| 01-02c | 1 | juvenile, 7-10 | juvenile | term katab |
| 01-02d | 1 | young adult | indeterminate | term katab |
| 01-02e | 1 | young adult | prob male | term katab |
| 01-02f | 1 | young adult | prob male | term katab |
| 01-02g | 1 | M-O adult | prob male | term katab |
| 01-02h | 1 | young adult | prob male | term katab |
| 01-03 | 1 | middle adult | prob male | late katab |
| 01-04 | 1 | child-adolesc | juvenile | late katab |
| 01-06a | 1 | middle adult | female | late katab |
| 01-06b | 1 | juvenile, 1-2 | juvenile | late katab |
| 01-06c | 1 | juvenile, 3-5 | juvenile | late katab |
| 01-06d | 1 | infant, newborn | juvenile | late katab |
| 01-10 | 1 | middle adult | female | late katab |
| 01-11 | 1 | M-O adult | female | late katab |
| 01-12a | 1 | young adult | female | late katab |
| 01-12b | 1 | juvenile, 5-7 | juvenile | late katab |
| 01-13 | 1 | old adult | poss female | late katab |
| 01-14 | 1 | juvenile, ~2 | juvenile | late katab |
| 01-15a | 1 | old adult | male | late katab |
| 01-15b | 1 | juvenile, 2-3 | juvenile | late katab |
| 01-16 | 1 | old adult | male | late katab |
| 01-17a | 1 | old adult | male | late katab |
| 01-17b | 1 | juvenile, 3-4 | juvenile | late katab |
| 01-17c | 1 | infant, ~1 | juvenile | late katab |
| 01-18 | 1 | juvenile, 4-5 | juvenile | early katab |
| 01-19a | 1 | M-O adult | female | early katab |

| K'axob Burials | | | | |
|---|---|---|---|---|
| **Burial** | **Operation** | **Age** | **Sex** | **Phase** |
| 01-19b | 1 | Y-M adult | female | early katab |
| 01-19c | 1 | juvenile, 8-10 | juvenile | early katab |
| 01-23 | 1 | adult | male | early katab |
| 01-24 | 1 | adult | female | early katab |
| 01-25 | 1 | adult | male | early katab |
| 01-26 | 1 | adult | male | early katab |
| 01-27 | 1 | juvenile | juvenile | late chaa |
| 01-28 | 1 | adult | female | late chaa |
| 01-29 | 1 | adult | male | early katab |
| 01-30 | 1 | Y-M adult | male | early katab |
| 01-30a | 1 | young adult | indeterminate | late chaa |
| 01-31 | 1 | old adult | male | early katab |
| 01-32 | 1 | juvenile | juvenile | early katab |
| 01-33 | 1 | young adult | male | late chaa |
| 01-34a | 1 | M-O adult | female | early katab |
| 01-34b | 1 | juvenile, 2-3 | juvenile | early katab |
| 01-35 | 1 | juvenile, 2-3 | juvenile | early chaa |
| 01-37a | 1 | juvenile, 11-13 | female | early chaa |
| 01-37b | 1 | perinate | juvenile | early chaa |
| 01-38 | 1 | young adult | male | early chaa |
| 01-39 | 1 | infant, ~9 mos. | juvenile | early chaa |
| 01-40 | 1 | juvenile, 5-7 | juvenile | early chaa |
| 01-41 | 1 | old adult | male | late katab |
| 01-42 | 1 | adult | prob female | early chaa |
| 01-43 | 1 | adult | male | early chaa |
| 01-44 | 1 | juvenile | juvenile | early katab |
| 01-45 | 1 | M-O adult | male | t katab |
| 01-46 | 1 | middle adult | female | early chaa |
| 07-01 | 7 | juvenile, 6-7 | juvenile | early nohal |
| 07-02 | 7 | Y-M adult | indeterminate | early nohal |
| 08-01 | 8 | M-O adult | female | late katab |
| 08-02 | 8 | older adult | female | late katab |
| 08-02a | 8 | young adult | male | late katab |
| 08-03a | 8 | young adult | male | term katab |
| 08-03b | 8 | middle adult | male | term katab |
| 08-04 | 8 | young adult | male | late katab |
| 08-04b | 8 | adult | indeterminate | late katab |

| K'axob Burials | | | | |
|---|---|---|---|---|
| **Burial** | **Operation** | **Age** | **Sex** | **Phase** |
| 08-05 | 8 | old adult | male | late katab |
| 08-06 | 8 | young adult | female | late katab |
| 10-01 | 10 | adol/y. adult? | female | late katab |
| 10-02 | 10 | middle adult | poss male | late katab |
| 10-03 | 10 | middle adult | female | term katab |
| 11-01 | 11 | M-O adult | male | term katab |
| 11-02 | 11 | young adult | male | term katab |
| 11-03 | 11 | young adult | male | late katab |
| 11-04 | 11 | M-O adult | female | late katab |
| 11-05 | 11 | M-O adult | male | late katab |
| 11-06 | 11 | middle adult | male | late katab |
| 11-07 | 11 | juvenile, 5-8 | juvenile | early katab |
| 11-08 | 11 | infant, ~6 mos. | juvenile | early katab |
| 11-09 | 11 | infant, 6-12 mos. | juvenile | early katab |
| 11-10 | 11 | old adult | male | early katab |
| 11-11 | 11 | infant, 6-12 mos. | juvenile | early katab |
| 11-12a | 11 | middle adult | female | early katab |
| 11-12b | 11 | perinate | juvenile | early katab |
| 12-01 | 12 | old adult | male | term katab |
| 12-02 | 12 | young adult | male | early nohal |
| 12-03 | 12 | middle adult | female | term katab |
| 12-04 | 12 | middle adult | male | early nohal |
| 12-06 | 12 | Y-M adult | male | term katab |
| 12-09 | 12 | M-O adult | indeterminate | late katab |
| 12-10 | 12 | adult | indeterminate | late katab |
| 12-11 | 12 | M-O adult | female | late katab |
| 12-12 | 12 | old adult | female | late katab |
| 12-13 | 12 | M-O adult | male | late katab |
| 12-14 | 12 | adult | prob male | late katab |
| 12-16a | 12 | middle adult | prob female | late katab |
| 12-16b | 12 | juvenile, 7-9 | juvenile | late katab |
| 13-01 | 13 | adult | indeterminate | early nohal |
| 13-02 | 13 | young adult | male | early nohal |
| 13-03a | 13 | juvenile, 8-10 | juvenile | early nohal |
| 13-03b | 13 | young adult | male | early nohal |
| 13-04 | 13 | juvenile, 2-4 | juvenile | early nohal |
| 14-01 | 14 | adult | indeterminate | early wits |

| K'axob Burials | | | | |
|---|---|---|---|---|
| Burial | Operation | Age | Sex | Phase |
| 14-02 | 14 | adult | indeterminate | early wits |
| 14-03 | 14 | adult | male | early wits |
| 14-04 | 14 | middle adult | prob female | early wits |
| 14-07 | 14 | M-O adult | indeterminate | early wits |
| 14-08 | 14 | Y-M adult | male | late nohal |
| 14-09 | 14 | juvenile, 2-4 | juvenile | term katab |
| 14-10 | 14 | juvenile, 4-5 | juvenile | late katab |
| 14-11 | 14 | infant, 6-8 mos. | juvenile | late katab |
| 15-01 | 15 | Y-M adult | indeterminate | early wits |
| 16-01 | 16 | young adult | indeterminate | late wits |
| 16-02a | 16 | old adult | indeterminate | early wits |
| 16-02b | 16 | juvenile, 2-4 | juvenile | early wits |
| 16-02c | 16 | middle adult | indeterminate | early wits |
| 16-03 | 16 | adult | indeterminate | early wits |
| 16-04 | 16 | juvenile, ~5 | juvenile | early wits |
| 16-05 | 16 | unknown | indeterminate | early wits |
| 16-06 | 16 | M-O adult | indeterminate | late wits |
| 16-07a | 16 | Y-M adult | indeterminate | early wits |
| 16-07b | 16 | juvenile, 3-5 | juvenile | early wits |
| 16-08 | 16 | adult | indeterminate | late wits |
| 16-09 | 16 | M-O adult | indeterminate | early wits |
| 16-10 | 16 | Y-M adult | indeterminate | early wits |
| 16-11 | 16 | juvenile, 3-5 | juvenile | early wits |
| 16-12 | 16 | adult | indeterminate | early wits |
| 16-13 | 16 | juvenile, 6-7 | juvenile | early wits |
| 16-14a | 16 | middle adult | indeterminate | early wits |
| 16-14b | 16 | adult | indeterminate | early wits |
| 16-15 | 16 | adult | indeterminate | early wits |
| 16-16 | 16 | adult | indeterminate | early wits |
| 16-17 | 16 | adult | indeterminate | early wits |
| 16-19 | 16 | juvenile, 4-6 | juvenile | early wits |
| 16-20 | 16 | middle adult | indeterminate | early wits |
| 16-21 | 16 | juvenile, 4-6 | juvenile | early wits |
| 16-22 | 16 | middle adult | indeterminate | early wits |
| 16-23 | 16 | adult | indeterminate | early wits |
| 16-24 | 16 | middle adult | female | early wits |
| 20-01 | 20 | adult | indeterminate | early nohal |

| K'axob Burials | | | | |
|---|---|---|---|---|
| **Burial** | **Operation** | **Age** | **Sex** | **Phase** |
| 20-02 | 20 | juvenile, 2-3 | juvenile | late katab |
| 20-03 | 20 | juvenile, 3-5 | indeterminate | late katab |
| 20-04 | 20 | juvenile | juvenile | late katab |
| 20-05a | 20 | adult | indeterminate | late katab |
| 20-05b | 20 | juvenile, 5-8 | juvenile | late katab |
| 20-06 | 20 | juvenile, 2-4 | juvenile | late katab |
| 20-07a | 20 | adult | indeterminate | late katab |
| 20-07b | 20 | old adult | indeterminate | late katab |

| K'axob - Porotic Hyperostosis | | | | | |
|---|---|---|---|---|---|
| **Burial** | **Cranium** | **Percent-Cra** | **PH Degree** | **PH Activity** | **PH Location** |
| 01-01a | several large frags | 3 | 0 | 0 | 0 |
| 01-01b | one small frag | 1 | 0 | 0 | 0 |
| 01-01c | none | 0 | 0 | 0 | 0 |
| 01-01d | partial vault | 3 | 0 | 0 | 0 |
| 01-01e | none | 0 | 0 | 0 | 0 |
| 01-01f | several large frags | 3 | 2 | 2 | 2 |
| 01-01g | few frags | 1 | 0 | 0 | 0 |
| 01-02a | several large frags | 3 | 1 | 2 | 2 |
| 01-02b | few small frags | 1 | 0 | 0 | 0 |
| 01-02c | two small frags | 1 | 0 | 0 | 0 |
| 01-02d | none | 0 | 0 | 0 | 0 |
| 01-02e | none | 0 | 0 | 0 | 0 |
| 01-02f | several small frags | 2 | 0 | 0 | 0 |
| 01-02g | few small frags | 1 | 0 | 0 | 0 |
| 01-02h | few small pieces | 1 | 0 | 0 | 0 |
| 01-03 | many small frags | 2 | 0 | 0 | 0 |
| 01-04 | none | 0 | 0 | 0 | 0 |
| 01-06a | partial vault | 3 | 1 | 2 | 3 |
| 01-06b | small frags | 1 | 0 | 0 | 0 |
| 01-06c | none | 0 | 0 | 0 | 0 |
| 01-06d | none | 0 | 0 | 0 | 0 |
| 01-10 | partial vault | 3 | 0 | 0 | 0 |
| 01-11 | partial vault | 3 | 1 | 2 | 2 |
| 01-12a | pieces | 1 | 1 | 2 | 2 |
| 01-12b | none | 0 | 0 | 0 | 0 |
| 01-13 | several small frags | 2 | 0 | 0 | 0 |
| 01-14 | few small pieces | 1 | 0 | 0 | 0 |
| 01-15a | partial vault | 3 | 2 | 2 | 3 |
| 01-15b | none | 0 | 0 | 0 | 0 |
| 01-16 | partial vault | 3 | 1 | 2 | 4 |
| 01-17a | several small frags | 2 | 1 | 2 | 3 |
| 01-17b | none | 0 | 0 | 0 | 0 |
| 01-17c | none | 0 | 0 | 0 | 0 |
| 01-18 | few small pieces | 1 | 3 | 3 | 3 |
| 01-19a | 3/4 vault | 5 | 1 | 2 | 2 |
| 01-19b | none | 0 | 0 | 0 | 0 |
| 01-19c | none | 0 | 0 | 0 | 0 |

| K'axob - Porotic Hyperostosis | | | | | |
|---|---|---|---|---|---|
| **Burial** | **Cranium** | **Percent-Cra** | **PH Degree** | **PH Activity** | **PH Location** |
| 01-23 | 100+ frags | 2 | 1 | 2 | 2 |
| 01-24 | few pieces | 1 | 1 | 2 | 2 |
| 01-25 | 1/2 vault | 4 | 0 | 0 | 0 |
| 01-26 | none | 0 | 0 | 0 | 0 |
| 01-27 | very few pieces | 1 | 0 | 0 | 0 |
| 01-28 | 214 small pieces | 2 | 1 | 2 | 2 |
| 01-29 | 3/4 vault present | 5 | 0 | 0 | 0 |
| 01-30 | none | 0 | 0 | 0 | 0 |
| 01-30a | very few tiny pieces | 1 | 0 | 0 | 0 |
| 01-31 | partial vault | 3 | 2 | 2 | 3 |
| 01-32 | only a few mand. pieces | 0 | 0 | 0 | 0 |
| 01-33 | none | 0 | 0 | 0 | 0 |
| 01-34a | several large frags | 3 | 2 | 2 | 2 |
| 01-34b | small pieces | 1 | 0 | 0 | 0 |
| 01-35 | only very tiny pieces | 1 | 0 | 0 | 0 |
| 01-37a | several large frags | 3 | 2 | 2 | 3 |
| 01-37b | none | 0 | 0 | 0 | 0 |
| 01-38 | none | 0 | 0 | 0 | 0 |
| 01-39 | only very tiny pieces | 1 | 0 | 0 | 0 |
| 01-40 | small fragments | 1 | 0 | 0 | 0 |
| 01-41 | several pieces | 2 | 1 | 2 | 3 |
| 01-42 | none | 0 | 0 | 0 | 0 |
| 01-43 | several large frags | 3 | 1 | 2 | 3 |
| 01-44 | none | 0 | 0 | 0 | 0 |
| 01-45 | several fragments | 2 | 2 | 2 | 2 |
| 01-46 | several large frags | 3 | 3 | 2 | 4 |
| 07-01 | couple of small frags | 1 | 0 | 0 | 0 |
| 07-02 | many small fragments | 2 | 1 | 2 | 2 |
| 08-01 | several large fragments | 3 | 0 | 0 | 0 |
| 08-02 | partial vault | 3 | 1 | 2 | 2 |
| 08-02a | many small fragments | 2 | 0 | 0 | 0 |
| 08-03a | several small fragments | 2 | 0 | 0 | 0 |
| 08-03b | few small fragments | 1 | 0 | 0 | 0 |
| 08-04 | 2/3 vault | 5 | 0 | 0 | 0 |
| 08-04b | none | 0 | 0 | 0 | 0 |
| 08-05 | 2/3 vault, mand | 5 | 0 | 0 | 0 |
| 08-06 | mandible only | 0 | 0 | 0 | 0 |

| K'axob - Porotic Hyperostosis | | | | | |
|---|---|---|---|---|---|
| **Burial** | **Cranium** | **Percent-Cra** | **PH Degree** | **PH Activity** | **PH Location** |
| 10-01 | several large pieces | 3 | 2 | 2 | 2 |
| 10-02 | few small fragments | 1 | 1 | 2 | 2 |
| 10-03 | none | 0 | 0 | 0 | 0 |
| 11-01 | several large pieces | 3 | 1 | 2 | 2 |
| 11-02 | partial vault | 3 | 0 | 0 | 0 |
| 11-03 | several large pieces | 3 | 2 | 2 | 2 |
| 11-04 | partial vault | 3 | 0 | 0 | 0 |
| 11-05 | many small fragments | 2 | 1 | 2 | 2 |
| 11-06 | 2/3 vault | 5 | 0 | 0 | 0 |
| 11-07 | 2/3 reconstructed vault | 5 | 0 | 0 | 0 |
| 11-08 | many very small pieces | 2 | 0 | 0 | 0 |
| 11-09 | many very small pieces | 2 | 0 | 0 | 0 |
| 11-10 | 2/3 vault | 5 | 0 | 0 | 0 |
| 11-11 | many very small pieces | 2 | 0 | 0 | 0 |
| 11-12a | partial vault, face | 3 | 1 | 2 | 2 |
| 11-12b | none | 0 | 0 | 0 | 0 |
| 12-01 | partial vault | 3 | 2 | 2 | 5 |
| 12-02 | many pieces | 2 | 0 | 0 | 0 |
| 12-03 | none | 0 | 0 | 0 | 0 |
| 12-04 | few small fragments | 1 | 0 | 0 | 0 |
| 12-06 | several large pieces | 3 | 2 | 2 | 3 |
| 12-09 | 2 small pieces (none) | 1 | 0 | 0 | 0 |
| 12-10 | none | 0 | 0 | 0 | 0 |
| 12-11 | few small pieces | 1 | 0 | 0 | 0 |
| 12-12 | few small pieces | 1 | 0 | 0 | 0 |
| 12-13 | several large fragments | 3 | 0 | 0 | 0 |
| 12-14 | few large fragments | 2 | 0 | 0 | 0 |
| 12-16a | several large fragments | 3 | 1 | 2 | 5 |
| 12-16b | several small pieces | 2 | 0 | 0 | 0 |
| 13-01 | few large fragments | 2 | 0 | 0 | 0 |
| 13-02 | several large fragments | 3 | 1 | 2 | 3 |
| 13-03a | none | 0 | 0 | 0 | 0 |
| 13-03b | few medium fragments | 2 | 1 | 2 | 2 |
| 13-04 | none | 0 | 0 | 0 | 0 |
| 14-01 | only one small piece | 1 | 0 | 0 | 0 |
| 14-02 | none | 0 | 0 | 0 | 0 |
| 14-03 | none | 0 | 0 | 0 | 0 |

| K'axob - Porotic Hyperostosis | | | | | |
|---|---|---|---|---|---|
| **Burial** | **Cranium** | **Percent-Cra** | **PH Degree** | **PH Activity** | **PH Location** |
| 14-04 | piece of temporal | 1 | 0 | 0 | 0 |
| 14-07 | none | 0 | 0 | 0 | 0 |
| 14-08 | several small pieces | 2 | 0 | 0 | 0 |
| 14-09 | partial vault | 3 | 3 | 3 | 3 |
| 14-10 | partial vault | 3 | 0 | 0 | 0 |
| 14-11 | many small fragments | 2 | 0 | 0 | 0 |
| 15-01 | several small pieces | 2 | 0 | 0 | 0 |
| 16-01 | several small fragments | 2 | 0 | 0 | 0 |
| 16-02a | several fragments | 2 | 0 | 0 | 0 |
| 16-02b | none | 0 | 0 | 0 | 0 |
| 16-02c | none | 0 | 0 | 0 | 0 |
| 16-03 | several med. fragments | 2 | 0 | 0 | 0 |
| 16-04 | none | 0 | 0 | 0 | 0 |
| 16-05 | none | 0 | 0 | 0 | 0 |
| 16-06 | several large pieces | 3 | 0 | 0 | 0 |
| 16-07a | several large frags | 3 | 1 | 2 | 3 |
| 16-07b | none | 0 | 0 | 0 | 0 |
| 16-08 | none | 0 | 0 | 0 | 0 |
| 16-09 | few small pieces | 1 | 0 | 0 | 0 |
| 16-10 | many large frags | 4 | 0 | 0 | 0 |
| 16-11 | several small frags | 2 | 0 | 0 | 0 |
| 16-12 | few fragments | 1 | 0 | 0 | 0 |
| 16-13 | none | 0 | 0 | 0 | 0 |
| 16-14a | none | 0 | 0 | 0 | 0 |
| 16-14b | none | 0 | 0 | 0 | 0 |
| 16-15 | none | 0 | 0 | 0 | 0 |
| 16-16 | several small frags | 2 | 0 | 0 | 0 |
| 16-17 | none | 0 | 0 | 0 | 0 |
| 16-19 | many small pieces | 2 | 0 | 0 | 0 |
| 16-20 | many small frags | 2 | 0 | 0 | 0 |
| 16-21 | none | 0 | 0 | 0 | 0 |
| 16-22 | few fragments | 1 | 0 | 0 | 0 |
| 16-23 | partial vault | 3 | 1 | 2 | 3 |
| 16-24 | many large frags | 4 | 0 | 0 | 0 |
| 20-01 | several large fragments | 3 | 0 | 0 | 0 |
| 20-02 | several small fragments | 2 | 0 | 0 | 0 |
| 20-03 | few small pieces | 1 | 0 | 0 | 0 |

| K'axob - Porotic Hyperostosis | | | | | |
|---|---|---|---|---|---|
| **Burial** | **Cranium** | **Percent-Cra** | **PH Degree** | **PH Activity** | **PH Location** |
| 20-04 | none | 0 | 0 | 0 | 0 |
| 20-05a | several large fragments | 3 | 0 | 0 | 0 |
| 20-05b | none | 0 | 0 | 0 | 0 |
| 20-06 | few small pieces | 1 | 0 | 0 | 0 |
| 20-07a | none | 0 | 0 | 0 | 0 |
| 20-07b | none | 0 | 0 | 0 | 0 |

| K'axob - Linear Enamel Hypoplasias | | | | | |
|---|---|---|---|---|---|
| **Burial** | **Teeth Present** | **I/C Present** | **LEH Teeth** | **LEH Type** | **LEH Max/Tooth** |
| 01-01a | 10 | 3 | 2 | 1 | 1 |
| 01-01b | 1 | 1 | 1 | 1 | 1 |
| 01-01c | 10 | 3 | 3 | 1 | 2 |
| 01-01d | 13 | 4 | 0 | 0 | 0 |
| 01-01e | 1 | 0 | 0 | 0 | 0 |
| 01-01f | 14 | 7 | 1 | 1 | 1 |
| 01-01g | 14 | 7 | 3 | 1 | 2 |
| 01-02a | 5 | 2 | 2 | 1 | 1 |
| 01-02b | 9 | 3 | 0 | 0 | 0 |
| 01-02c | 2 | 0 | 0 | 0 | 0 |
| 01-02d | 4 | 0 | 0 | 0 | 0 |
| 01-02e | 9 | 3 | 2 | 1 | 1 |
| 01-02f | 3 | 1 | 1 | 1 | 2 |
| 01-02g | 9 | 1 | 3 | 1 | 1 |
| 01-02h | 5 | 3 | 5 | 1 | 3 |
| 01-03 | 6 | 1 | 0 | 0 | 0 |
| 01-04 | 0 | 0 | 0 | 0 | 0 |
| 01-06a | 15 | 4 | 3 | 1 | 2 |
| 01-06b | 19 | 11 | 0 | 0 | 0 |
| 01-06c | 3 | 2 | 0 | 0 | 0 |
| 01-06d | 10 | 8 | 0 | 0 | 0 |
| 01-10 | 10 | 6 | 2 | 1 | 1 |
| 01-11 | 8 | 3 | 1 | 1 | 1 |
| 01-12a | 10 | 6 | 2 | 1 | 2 |
| 01-12b | 10 | 3 | 1 | 1 | 1 |
| 01-13 | 1 | 1 | 0 | 0 | 0 |
| 01-14 | 7 | 0 | 0 | 0 | 0 |
| 01-15a | 19 | 6 | 3 | 1 | 1 |
| 01-15b | 14 | 2p/4d | 0 | 0 | 0 |
| 01-16 | 20 | 8 | 4 | 1 | 1 |
| 01-17a | 5 | 5 | 3 | 1 | 1 |
| 01-17b | 16 | 2p/4d | 0 | 0 | 0 |
| 01-17c | 4 | 2 (decid) | 0 | 0 | 0 |
| 01-18 | 5 | 1 | 0 | 0 | 0 |
| 01-19a | 13 | 5 | 3 | 1 | 1 |
| 01-19b | 4 | 4 | 3 | 1 | 2 |
| 01-19c | 10 | 0 | 0 | 0 | 0 |

| K'axob - Linear Enamel Hypoplasias | | | | | |
|---|---|---|---|---|---|
| **Burial** | **Teeth Present** | **I/C Present** | **LEH Teeth** | **LEH Type** | **LEH Max/Tooth** |
| 01-23 | 4 | 1 | 2 | 1 | 2 |
| 01-24 | 1 | 1 | 0 | 0 | 0 |
| 01-25 | 8 | 2 | 2 | 1 | 2 |
| 01-26 | 5 | 4 | 2 | 1 | 2 |
| 01-27 | 1 | 0 | 0 | 0 | 0 |
| 01-28 | 2 | 1 | 0 | 0 | 0 |
| 01-29 | 18 | 8 | 5 | 1 | 2 |
| 01-30 | 0 | 0 | 0 | 0 | 0 |
| 01-30a | 4 | 0 | 0 | 0 | 0 |
| 01-31 | 15 | 4 | 1 | 1 | 1 |
| 01-32 | 6 | 3 | 1 | 1 | 1 |
| 01-33 | 2 | 0 | 0 | 0 | 0 |
| 01-34a | 10 | 2 | 2 | 1 | 1 |
| 01-34b | 1 | 0 | 0 | 0 | 0 |
| 01-35 | 22 | 6 | 0 | 0 | 0 |
| 01-37a | 28 | 8 | 2 | 1 | 1 |
| 01-37b | 0 | 0 | 0 | 0 | 0 |
| 01-38 | 12 | 6 | 4 | 1 | 1 |
| 01-39 | 6 | 2 (decid) | 0 | 0 | 0 |
| 01-40 | 32 | 13 | 4 | 1 | 1 |
| 01-41 | 10 | 2 | 1 | 1 | 2 |
| 01-42 | 0 | 0 | 0 | 0 | 0 |
| 01-43 | 11 | 0 | 0 | 0 | 0 |
| 01-44 | 0 | 0 | 0 | 0 | 0 |
| 01-45 | 18 | 7 | 3 | 1 | 1 |
| 01-46 | 23 | 7 | 4 | 1 | 1 |
| 07-01 | 2 | 0 | 0 | 0 | 0 |
| 07-02 | 17 | 5 | 2 | 1 | 2 |
| 08-01 | 15 | 3 | 5 | 1 | 2 |
| 08-02 | 4 | 0 | 0 | 0 | 0 |
| 08-02a | 21 | 5 | 0 | 0 | 0 |
| 08-03a | 9 | 4 | 1 | 1 | 1 |
| 08-03b | 14 | 5 | 4 | 1 | 1 |
| 08-04 | 26 | 9 | 6 | 1 | 3 |
| 08-04b | 0 | 0 | 0 | 0 | 0 |
| 08-05 | 16 | 5 | 4 | 1 | 3 |
| 08-06 | 20 | 8 | 6 | 1 | 1 |

| K'axob - Linear Enamel Hypoplasias | | | | | |
|---|---|---|---|---|---|
| Burial | Teeth Present | I/C Present | LEH Teeth | LEH Type | LEH Max/Tooth |
| 10-01 | 26 | 8 | 4 | 1 | 1 |
| 10-02 | 6 | 1 | 0 | 0 | 0 |
| 10-03 | 4 | 1 | 0 | 0 | 0 |
| 11-01 | 4 | 2 | 0 | 0 | 0 |
| 11-02 | 18 | 6 | 4 | 1 | 1 |
| 11-03 | 25 | 12 | 6 | 1 | 1 |
| 11-04 | 13 | 6 | 6 | 1 | 3 |
| 11-05 | 12 | 6 | 1 | 1 | 1 |
| 11-06 | 29 | 12 | 5 | 1 | 2 |
| 11-07 | 43 | 10p/10d | 10 | 1 | 2 |
| 11-08 | 22 | 12 (decid) | 0 | 0 | 0 |
| 11-09 | 16 | 9 | 0 | 0 | 0 |
| 11-10 | 19 | 4 | 3 | 1 | 1 |
| 11-11 | 24 | 1p/11d | 0 | 0 | 0 |
| 11-12a | 25 | 8 | 0 | 0 | 0 |
| 11-12b | 0 | 0 | 0 | 0 | 0 |
| 12-01 | 17 | 6 | 4 | 1 | 1 |
| 12-02 | 24 | 8 | 1 | 1 | 1 |
| 12-03 | 14 | 5 | 2 | 1 | 2 |
| 12-04 | 15 | 7 | 5 | 1 | 1 |
| 12-06 | 32 | 12 | 10 | 1 | 1 |
| 12-09 | 9 | 3 | 2 | 1 | 2 |
| 12-10 | 0 | 0 | 0 | 0 | 0 |
| 12-11 | 6 | 4 | 2 | 1 | 2 |
| 12-12 | 9 | 6 | 4 | 1 | 1 |
| 12-13 | 17 | 7 | 3 | 1 | 2 |
| 12-14 | 0 | 0 | 0 | 0 | 0 |
| 12-16a | 5 | 0 | 0 | 0 | 0 |
| 12-16b | 20 | 7 | 3 | 1 | 1 |
| 13-01 | 0 | 0 | 0 | 0 | 0 |
| 13-02 | 12 | 3 | 1 | 1 | 1 |
| 13-03a | 15 | 5p/2d | 5 | 1 | 2 |
| 13-03b | 4 | 1 | 1 | 1 | 1 |
| 13-04 | 2 | 1 | 1 | 1 | 1 |
| 14-01 | 3 | 1 | 1 | 1 | 1 |
| 14-02 | 0 | 0 | 0 | 0 | 0 |
| 14-03 | 0 | 0 | 0 | 0 | 0 |

| K'axob - Linear Enamel Hypoplasias | | | | | |
|---|---|---|---|---|---|
| **Burial** | **Teeth Present** | **I/C Present** | **LEH Teeth** | **LEH Type** | **LEH Max/Tooth** |
| 14-04 | 2 | 1 | 1 | 1 | 2 |
| 14-07 | 0 | 0 | 0 | 0 | 0 |
| 14-08 | 15 | 3 | 2 | 1 | 1 |
| 14-09 | 35 | 12p/11d | 0 | 0 | 0 |
| 14-10 | 48 | 12p/12d | 8 | 1 | 1 |
| 14-11 | 18 | 10d | 0 | 0 | 0 |
| 15-01 | 4 | 1 | 0 | 0 | 0 |
| 16-01 | 8 | 2 | 2 | 1 | 1 |
| 16-02a | 14 | 9 | 1 | 1 | 1 |
| 16-02b | 2 | 1d | 0 | 0 | 0 |
| 16-02c | 3 | 2 | 0 | 0 | 0 |
| 16-03 | 0 | 0 | 0 | 0 | 0 |
| 16-04 | 32 | 7p/7d | 0 | 0 | 0 |
| 16-05 | 0 | 0 | 0 | 0 | 0 |
| 16-06 | 14 | 6 | 3 | 1 | 2 |
| 16-07a | 11 | 6 | 0 | 0 | 0 |
| 16-07b | 14 | 4p/4d | 3 | 1 | 1 |
| 16-08 | 0 | 0 | 0 | 0 | 0 |
| 16-09 | 13 | 1 | 1 | 1 | 1 |
| 16-10 | 0 | 0 | 0 | 0 | 0 |
| 16-11 | 2 | 1d | 0 | 0 | 0 |
| 16-12 | 0 | 0 | 0 | 0 | 0 |
| 16-13 | 4 | 2d/1p | 0 | 0 | 0 |
| 16-14a | 27 | 11 | 7 | 1 | 2 |
| 16-14b | 0 | 0 | 0 | 0 | 0 |
| 16-15 | 0 | 0 | 0 | 0 | 0 |
| 16-16 | 0 | 0 | 0 | 0 | 0 |
| 16-17 | 0 | 0 | 0 | 0 | 0 |
| 16-19 | 0 | 0 | 0 | 0 | 0 |
| 16-20 | 10 | 3 | 1 | 1 | 1 |
| 16-21 | 15 | 4p/7d | 2p/2d | 1 | 1 |
| 16-22 | 14 | 4 | 2 | 1 | 1 |
| 16-23 | 0 | 0 | 0 | 0 | 0 |
| 16-24 | 24 | 5 | 7 | 1 | 1 |
| 20-01 | 16 | 6 | 1 | 1 | 1 |
| 20-02 | 10 | 2p/1d | 0 | 0 | 0 |
| 20-03 | 1 | 0 | 0 | 0 | 0 |

| K'axob - Linear Enamel Hypoplasias | | | | | |
|---|---|---|---|---|---|
| **Burial** | **Teeth Present** | **I/C Present** | **LEH Teeth** | **LEH Type** | **LEH Max/Tooth** |
| 20-04 | 0 | 0 | 0 | 0 | 0 |
| 20-05a | 20 | 3 | 0 | 0 | 0 |
| 20-05b | 6 | 2 | 1 | 1 | 1 |
| 20-06 | 10 | 2 | 0 | 0 | 0 |
| 20-07a | 11 | 3 | 2 | 1 | 1 |
| 20-07b | 3 | 2 | 1 | 1 | 1 |

Appendix C: Age of Hypoplasia Formation Worksheet

| Maxillary Teeth | Height (mm from CEJ) | Equation | Age of Occurrence |
|---|---|---|---|
| RI1 | | Age = -(.454 x Height) + 4.5 | 4.5 |
| RI2 | | Age = -(.402 x Height) + 4.5 | 4.5 |
| RC | | Age = -(.625 x Height) + 6.0 | 6 |
| RPM1 | | Age = -(.494 x Height) + 6.0 | 6 |
| RPM2 | | Age = -(.467 x Height) + 6.0 | 6 |
| Mandibular Teeth | | | |
| RI1 | | Age = -(.460 x Height) + 4.0 | 4 |
| RI2 | | Age = -(.417 x Height) + 4.0 | 4 |
| RC | | Age = -(.588 x Height) + 6.5 | 6.5 |
| RPM1 | | Age = -(.641 x Height) + 6.0 | 6 |
| RPM2 | | Age = -(.641 x Height) + 7.0 | 7 |

| Maxillary Teeth | Height (mm from CEJ) | Equation | Age of Occurrence |
|---|---|---|---|
| LI1 | | Age = -(.454 x Height) + 4.5 | 4.5 |
| LI2 | | Age = -(.402 x Height) + 4.5 | 4.5 |
| LC | | Age = -(.625 x Height) + 6.0 | 6 |
| LPM1 | | Age = -(.494 x Height) + 6.0 | 6 |
| LPM2 | | Age = -(.467 x Height) + 6.0 | 6 |
| Mandibular Teeth | | | |
| LI1 | | Age = -(.460 x Height) + 4.0 | 4 |
| LI2 | | Age = -(.417 x Height) + 4.0 | 4 |
| LC | | Age = -(.588 x Height) + 6.5 | 6.5 |
| LPM1 | | Age = -(.641 x Height) + 6.0 | 6 |
| LPM2 | | Age = -(.641 x Height) + 7.0 | 7 |

Adapted from Goodman and Rose (1990)

## References

Abrams, Elliot M., and David J. Rue

1988 The Causes and Consequences of Deforestation Among the Prehistoric Maya. Human Ecology 16(4):377-395.

Bartelink, E. J., and L. E. Wright

2011 Benign mandibular tumours: Two case studies from the Maya lowland site of Tikal, Guatemala. International Journal of Osteoarchaeology 21(3):351-359.

Buikstra, Jane E., and Douglas H. Ubelaker

1994 Standards for Data Collection from Human Skeletal Remains. Fayetteville: Arkansas Archaeological Survey.

Clutton-Brock, Juliet, and Norman Hammond

1994 Hot Dogs: Comestible Canids in Preclassic Maya Culture at Cuello, Belize. Journal of Archaeological Science 21:819-826.

Coe, Michael D.

2005 The Maya. New York: Thames and Hudson.

Coe, Michael D., and Rex Koontz

2008 Mexico: From the Olmecs to the Aztecs. London: Thames and Hudson.

Covich, Alan P.

1983 Mollusca: A Contrast in Species Diversity from Aquatic and Terrestrial Habitats. *In* Pulltrouser Swamp: Ancient Maya Habitat, Agriculture, and Settlement in Northern Belize. B.L. Turner and P.D. Harrison, eds. Pp. 120-139. Austin: University of Texas Press.

Coyston, Shannon, Christine D. White, and Henry P. Schwarcz

1999 Dietary Carbonate Analysis of Bone and Enamel for Two Sites in Belize. *In* Reconstructing Ancient Maya Diet. C.D. White, ed. Pp. 221-243. Salt Lake City: University of Utah Press.

Danforth, Marie Elaine

1999 Nutrition and Politics in Prehistory. Annual Review of Anthropology 28:1-25.

Demarest, Arthur

2004 Ancient Maya: The Rise and Fall of a Rainforest Civilization. Cambridge: Cambridge University Press.

Emery, Kitty F.

1999 Continuity and Variability in Postclassic and Colonial Animal Use at Lamanai and Tipu, Belize. *In* Reconstructing Ancient Maya Diet. C.D. White, ed. Pp. 61-81. Salt Lake City: University of Utah Press.

—

2003 The noble beast: Status and differential access to animals in the Maya world. World Archaeology 34(3):498-515.

Evans, Susan Toby

2008 Ancient Mexico and Central America: Archaeology and Culture History. London: Thames and Hudson.

Gerry, John P., and Harold W. Krueger

1997 Regional Diversity in Classic Maya Diets. *In* Bones of the Maya: Studies of Ancient Skeletons. S.L. Whittington and D.M. Reed, eds. Pp. 196-207. Tuscaloosa: University of Alabama Press.

Goodman, Alan H.

1994 Cartesian Reductionism and Vulgar Adaptationism: Issues in the Interpretation of Nutritional Status in Prehistory. *In* Paleonutrition: The Diet and Health of Prehistoric Americans. K.D. Sobolik, ed. Carbondale: Southern Illinois University.

Goodman, Alan H., and George J. Armelagos

1985 The Chronological Distribution of Enamel Hypoplasia in Human Permanent Incisor and Canine Teeth. Archives of Oral Biology 30(6):503-507.

—

1989 Infant and Childhood Morbidity and Mortality Risks in Archaeological Populations. World Archaeology 21(2):225-243.

Goodman, Alan H., et al.

1984 Indications of Stress from Bone and Teeth. *In* Paleopathology at the Origins of Agriculture. M.N. Cohen and G.J. Armelagos, eds. Pp. 13-49. Orlando: Academic Press.

Goodman, Alan H., and Jerome C. Rose

1990 Assessment of Systemic Physiological Perturbations from Dental Enamel Hypoplasias and Associated Histological Structures. Yearbook of Physical Anthropology 33:59-110.

Gordon, Claire C., and Jane E. Buikstra

1981 Soil pH, Bone Preservation, and Sampling Bias at Mortuary Sites. American Antiquity 46(3):566-571.

Götz, Christopher M.

2008 Coastal and inland patterns of faunal exploitation in the prehispanic northern Maya lowlands. Quaternary International 191(1):154-169.

Guderjan, Thomas H.

2007 The Nature of an Ancient Maya City: Resources, Interaction, and Power at Blue Creek, Belize. Tuscaloosa: University of Alabama Press.

Hallberg, Leif

2001 Perspective on Nutritional Iron Deficiency. Annual Review of Nutrition 21(1):1-21.

Hammond, Norman, ed.

1991 Cuello: An Early Maya Community in Belize. Cambridge: Cambridge University Press.

Harrigan, Ryan

2004 Mollusca of K'axob: For Supper and Soul. *In* K'axob: Ritual, Work, and Family in an Ancient Maya Village. P.A. McAnany, ed. Pp. 399-412. Los Angeles: Cotsen Institute of Archaeology at UCLA.

Headrick, Annabeth

2004 The Quadripartite Motif and the Centralization of Power. *In* K'axob: Ritual, Work, and Family in an Ancient Maya Village. P.A. McAnany, ed. Pp. 367-378. Los Angeles: Cotsen Institute of Archaeology at UCLA.

Henderson, Hope

2003 The Organization of Staple Crop Production at K'axob, Belize. Latin American Antiquity 14(4):469-496.

Hillson, Simon

1996 Dental Anthropology. Cambridge: Cambridge University Press.

Holland, Thomas D., and Michael J. O'Brien

1997 Parasites, Porotic Hyperostosis, and the Implications of Changing Perspectives. American Antiquity 62(2):183-193.

Hooton, E. A.

1940 Skeletons from the Cenote of Sacrifice at Chichen Itza. *In* The Maya and Their Neighbors. C.L. Hay, ed. Pp. 272-280. New York: Appleton-Century.

Jacobi, Keith P., and Marie Elaine Danforth

2002 Analysis of Interobserver Scoring Patterns in Porotic Hyperostosis and Cribra Orbitalia. International Journal of Osteoarchaeology 12:248-258.

Keita, S.O.Y., and A.J. Boyce

2001 Diachronic Patterns of Dental Hypoplasias and Vault Porosities during the Predynastic in the Naqada Region, Upper Egypt. American Journal of Human Biology 13:733-743.

Kirchhoff, Paul

1943 Mesoamerica, sus limites geograficos, composicion etnica y caracteres culturales. Acta Americana 1:92-107.

Klaus, Haagen D., and Manuel E. Tam

2009 Contact in the Andes: Bioarchaeology of Systemic Stress in Colonial Morrope, Peru. American Journal of Physical Anthropology 138:356-368.

Larsen, Clark Spencer

1995 Biological Changes in Human Populations with Agriculture. Annual Review of Anthropology 24:185-213.

—

1997 Bioarchaeology: Interpreting Behavior from the Human Skeleton. Cambridge: Cambridge University Press.

Lentz, David L.

1991 Maya Diets of the Rich and Poor: Paleoethnobotanical Evidence from Copan. Latin American Antiquity 2(3):269-287.

Lentz, David L.

1999 Plant Resources of the Ancient Maya: The Paleoethnobotanical Evidence. *In* Reconstructing Ancient Maya Diet. C.D. White, ed. Pp. 3-18. Salt Lake City: University of Utah Press.

Lohse, Jon C.

2010 Archaic Origins of the Lowland Maya. Latin American Antiquity 21(3):312-352.

Lopez Varela, Sandra L.

2004 Ceramic History of K'axob: The Early Years. *In* K'axob: Ritual, Work, and Family in an Ancient Maya Village. P.A. McAnany, ed. Pp. 169-191. Los Angeles: Cotsen Institute of Archaeology at UCLA.

MacNeish, Richard S., and Antoinette Nelken-Terner

1983 The Preceramic of Mesoamerica. Journal of Field Archaeology 10(1):71-84.

Mansell, Eugenia Brown, Robert H. Tykot, David A. Freidel, Bruce H. Dahlin, and Traci Ardren

2006 Early to Terminal Classic Maya Diet in the Northern Lowlands of the Yucatán (Mexico). *In* Histories of Maize: Multidisciplinary Approaches to the Prehistory, Linguistics, Biogeography, Domestication, and

Evolution of Maize. J. Staller, R. Tykot, and B. Benz, eds. Pp. 173-185. Burlington, MA: Elsevier Academic Press.

Marcus, Joyce

2003 Recent Advances in Maya Archaeology. Journal of Archaeological Research 11(2):71-148.

Martin, Simon, and Nikolai Grube

2008 Chronicle of the Maya Kings and Queens. London: Thames and Hudson.

Masson, Marilyn A.

2004 Contribution of Fishing and Hunting to Subsistence and Symbolic Expression. *In* K'axob: Ritual, Work, and Family in an Ancient Maya Village. P.A. McAnany, ed. Pp. 382-397. Los Angeles: Cotsen Institute of Archaeology at UCLA.

Mays, Simon

2010 The Archaeology of Human Bones. London: Routledge.

McAnany, Patricia A.

1989 Stone-tool Production and Exchange in the Eastern Maya Lowlands: The Consumer Perspective from Pulltrouser Swamp, Belize. American Antiquity 54(2):332-346.

—

1995 Living with the Ancestors: Kinship and Kingship in Ancient Maya Society. Austin: University of Texas Press.

—, ed.

1997 K'axob Project: Interim Report of the 1995 Field Season. Belmopan, Belize: Belize Department of Archaeology.

—

2004a K'axob: Ritual, Work, and Family in an Ancient Maya Village. Los Angeles: Cotsen Institute of Archaeology, University of California.

—

2004b Landscapes of K'axob in Deep and Current Time. *In* K'axob: Ritual, Work, and Family in an Ancient Maya Village. P.A. McAnany, ed. Pp. 11-17. Los Angeles: Cotsen Institute of Archaeology at UCLA.

—

2004c Situating K'axob within Formative Period Lowland Maya Archaeology. *In* K'axob: Ritual, Work, and Family in an Ancient Maya Village. P.A. McAnany, ed. Pp. 1-9. Los Angeles: Cotsen Institute of Archaeology at UCLA.

McAnany, Patricia A., and Sandra L. Lopez Varela

1999 Re-creating the Formative Maya village of K'axob: Chronology, ceramic complexes, and ancestors in architectural context. Ancient Mesoamerica 10:147-168.

McAnany, Patricia A., Rebecca Storey, and Angela K. Lockard

1999 Mortuary Ritual and Family Politics at Formative and Early Classic K'axob, Belize. Ancient Mesoamerica 10(01):129-146.

Méndez Collí, C., et al.

2009 Linear enamel hypoplasia at Xcambó, Yucatán, during the Maya Classic period: An evaluation of coastal marshland impact on ancient human populations. HOMO - Journal of Comparative Human Biology 60(4):343-358.

Miksicek, Charles H.

1990 Early Wetland Agriculture in the Maya Lowlands: Clues from Preserved Plant Remains. *In* Ancient Maya Wetland Agriculture: Excavations on Albion Island, Northern Belize. M.D. Pohl, ed. Pp. 295-312. Boulder: Westview Press.

—

1991 The Ecology and Economy of Cuello: The Natural and Cultural Landscape of Preclassic Cuello. *In* Cuello: An Early Maya Community in Belize. N. Hammond, ed. Pp. 70-84. Cambridge: Cambridge University Press.

Ortner, Donald J.

2003 Identification of Pathological Conditions in Human Skeletal Remains. San Diego: Elsevier Science.

Oxenham, Marc Frederick, and Ivor Cavill

2010 Porotic Hyperostosis and Cribra Orbitalia: The Erythropoitic Response to Iron-Deficiency Anemia. Anthropological Science 118(3):199-200.

Palkovich, Ann

1987 Endemic Disease Patterns in Paleopathology: Porotic Hyperostosis. American Journal of Physical Anthropology 74(4):527-537.

Pendergast, David M.

1981 Lamanai, Belize: Summay of Excavation Results, 1974-1980. Journal of Field Archaeology 8(1):29-53.

Pohl, Mary DeLand, ed.

1990 Ancient Maya Wetland Agriculture: Excavations on Albion Island, Northern Belize. Boulder: Westview Press.

Pohl, Mary DeLand, Paul R. Bloom, and Kevin O. Pope

1990 Interpretation of Wetland Farming in Northern Belize: Excavations at San Antonio Rio Hondo. *In* Ancient Maya Wetland Agriculture: Excavations on Albion Island, Northern Belize. M.D. Pohl, ed. Pp. 187-278. Boulder: Westview Press.

Robin, Cynthia

1989 Preclassic Maya Burials at Cuello, Belize. Oxford.

Robin, Cynthia, and Norman Hammond

1991 Ritual and Ideology. *In* Cuello: An Early Maya Community in Belize. N. Hammond, ed. Pp. 204-234. Cambridge: Cambridge University Press.

Saul, Julie Mather, and Frank P. Saul

1997 The Preclassic Skeletons from Cuello. *In* Bones of the Maya: Studies of Ancient Skeletons. S.L. Whittington and D.M. Reed, eds. Pp. 28-50. Tuscaloosa: University of Alabama Press.

Scherer, Andrew K., Lori E. Wright, and Cassady J. Yoder

2007 Bioarchaeological Evidence for Social and Temporal Differences in Diet at Piedras Negras, Guatemala. Latin American Antiquity 18(1):85-104.

Shaw, Leslie C.

1999 Social and Ecological Aspects of Preclassic Maya Meat Consumption at Colha, Belize. *In* Reconstructing Ancient Maya Diet. C.D. White, ed. Pp. 83-100. Salt Lake City: University of Utah Press.

Storey, Rebecca

1997 Individual Frailty, Children of Privilege, and Stress in Late Classic Copan. *In* Bones of the Maya: Studies of Ancient Skeletons. S.L. Whittington and D.M. Reed, eds. Pp. 116-126. Tuscaloosa: University of Alabama Press.

—

1999 Late Classic Nutrition and Skeletal Indicators at Copan, Honduras. *In* Reconstructing Ancient Maya Diet. C.D. White, ed. Pp. 169-179. Salt Lake City: University of Utah Press.

—

2004 Ancestors: Bioarchaeology of the Human Remains of K'axob. *In* K'axob: Ritual, Work, and Family in an Ancient Maya Village. P.A. McAnany, ed. Pp. 109-138. Los Angeles: Cotsen Institute of Archaeology at UCLA.

Storey, Rebecca, Lourdes Marquez Morfin, and Vernon Smith

2002 Social disruption and the Maya civilization of Mesoamerica: A study of health and economy of the last thousand years. *In* The Backbone of History: Health and Nutrition in the Western Hemisphere. R.H. Steckel and J.C. Rose, eds. Pp. 283-306. New York: Cambridge University Press.

Stuart-Macadam, Patty

1985 Porotic Hyperostosis: Representative of a Childhood Condition. American Journal of Physical Anthropology 66:391-398.

—

1987a Porotic Hyperostosis: New Evidence to Support the Anemia Theory. American Journal of Physical Anthropology 74(4):521-526.

—

1987b A Radiographic Study of Porotic Hyperostosis. American Journal of Physical Anthropology 74:511-520.

—

1992 Porotic Hyperostosis: A New Perspective. American Journal of Physical Anthropology 87:39-47.

Turner, B.L., and Peter D. Harrison, eds.

1983 Pulltrouser Swamp: Ancient Maya Habitat, Agriculture, and Settlement in Northern Belize. Austin: University of Texas Press.

Tykot, R.H., N.J. van der Merwe, and N. Hammond

1996 Stable Isotope Analysis of Bone Collagen, Bone Apatite, and Tooth Enamel in the Reconstruction of Human Diet: A Case Study from Cuello, Belize. *In* Archaeological Chemistry: Organic, Inorganic, and Biochemical Analysis. M.V. Orna, ed. Pp. 355-365. Washington: American Chemical Society.

Van der Merwe, Nikolaas J., Robert H. Tykot, Norman Hammond, and Kim Oakberg

2002 Diet and animal husbandry of the Preclassic Maya at Cuello, Belize: Isotopic and zooarchaeological evidence. *In* Biogeochemical Approaches to Paleodietary Analysis. S. Ambrose and M.A. Katsenberg, eds. Pp. 23-38. New York: Springer US.

Waldron, Tony

2009 Paleopathology. Cambridge: Cambridge University Press.

Walker, Phillip L.

1986 Porotic Hyperostosis in a Marine-Dependent California Indian Population. American Journal of Physical Anthropology 69(3):345-354.

Walker, Phillip L., et al.

2009 The Causes of Porotic Hyperostosis and Cribra Orbitalia: A Reappraisal of the Iron-Deficiency-Anemia Hypothesis. American Journal of Physical Anthropology 139(2):109-125.

Webster, David, AnnCorinne Freter, and Nancy Gonlin

2000 Copan: The Rise and Fall of an Ancient Maya Kingdom. Belmont, CA: Wadsworth.

White, Christine D., et al.

2001 Social Complexity and Food Systems at Altun Ha, Belize: The Isotopic Evidence. Latin American Antiquity 12(4):371-393.

White, Christine D., and Henry P. Schwarcz

1989 Ancient Maya Diet: as Inferred from Isotopic and Elemental Analysis of Human Bone. Journal of Archaeological Science 16:451-474.

White, Tim D., and Pieter A. Folkens

2000 Human Osteology. San Diego: Elsevier Academic Press.

—

2005 The Human Bone Manual. Burlington, MA: Elsevier Academic Press.

Whittington, Stephen L.

1999 Caries and Antemortem Tooth Loss at Copan: Implications for Commoner Diet. *In* Reconstructing Ancient Maya Diet. C.D. White, ed. Pp. 151-167. Salt Lake City: University of Utah Press.

Whittington, Stephen L., and David M. Reed, eds.

1997a Bones of the Maya: Studies of Ancient Skeletons. Washington, D.C.: Smithsonian Institution Press.

—

1997b Commoner Diet at Copan: Insights from Stable Isotopes and Porotic Hyperostosis. *In* Bones of the Maya: Studies of Ancient Skeletons. S.L. Whittington and D.M. Reed, eds. Washington: Smithsonian Institution Press.

Wing, Elizabeth S., and Sylvia J. Scudder

1991 The Ecology and Economy of Cuello: The Exploitation of Animals. *In* Cuello: An Early Maya Community in Belize. N. Hammond, ed. Pp. 84-97. Cambridge: Cambridge University Press.

Wright, Lori E.

1997a Ecology or Society? Paleodiet and the Collapse of the Pasion Maya Lowlands. *In* Bones of the Maya: Studies of Ancient Skeletons. S.L. Whittington and D.M. Reed, eds. Pp. 181-195. Tuscaloosa: University of Alabama Press.

—

1997b Intertooth Patterns of Hypoplasia Expression: Implications for Childhood Health in the Classic Maya Collapse. American Journal of Physical Anthropology 102(2):233-247.

—

1999 The Elements of Maya Diets: Alkaline Earth Baselines and Paleodietary Reconstruction in the Pasion Region. *In* Reconstructing Ancient Maya Diet. C.D. White, ed. Pp. 197-219. Salt Lake City: University of Utah Press.

—

2006 Diet, Health, and Status among the Pasion Maya: A Reappraisal of the Collapse. Nashville: Vanderbilt University Press.

Wright, Lori E., and Francisco Chew

1998 Porotic Hyperostosis and Paleoepidemiology: A Forensic Perspective on Anemia among the Ancient Maya. American Anthropologist 100(4):924-939.

Wright, Lori E., and Christine D. White

1996 Human Biology in the Classic Maya Collapse: Evidence from Paleopathology and Paleodiet. Journal of World Prehistory 10(2):147-198.

Zeitlin, Robert M.

1984 A Summary Report on Three Seasons of Field Investigations into the Archaic Period Prehistory of Lowland Belize. American Anthropologist 86(2):358-369.