MISSIONIZATION AND SHIFTING MOBILITY ON THE SOUTHEASTERN MAYA-SPANISH FRONTIER: IDENTIFYING IMMIGRATION TO THE MAYA SITE OF TIPU, BELIZE THROUGH THE USE OF STRONTIUM AND OXYGEN ISOTOPES

A Dissertation

by

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ABSTRACT

The early Colonial Period *visita* mission cemetery Tipu represents an important opportunity to understand the role mobility played in indigenous Maya resistance on the southeastern Maya-Spanish frontier. This dissertation seeks to identify the geographical origin of a subset (N=195) of the over 600 Postclassic and early Colonial period Maya buried at Tipu. As geographic and cultural frontier, Tipu experienced a dynamic history of fluctuating political alliances and was a pivotal player in frontier politics. Ethnohistorical records indicate that the remote frontier community of Tipu functioned as a place of refuge for a large southern exodus of indigenous Maya from the northern Yucatan escaping the hardships encountered in more populated regions under Spanish colonial control; to date little concrete evidence for this migration has been identified.

To test whether the frontier community of Tipu functioned as a haven for refugee Yucatec Maya, strontium ($^{87}Sr/^{86}Sr$) and oxygen ($\delta^{18}O$) isotopes are used as geologic and climatic tracers to estimate potential childhood homelands for individuals buried at Tipu. Individuals comprising the Postclassic sample are used as a proxy to help establish the "local" range and to aid in the identification of shifts in mobility from the Postclassic to the Colonial period. A comparison of $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ data from the Postclassic and Colonial period samples shows an increase in the quantity of Colonial period individuals falling within the "local" range, as well as a dramatic increase in the total variability and range of observed isotope values in the Colonial period. Nearly two-thirds of the Colonial Tipu population were classified as non-local, suggesting that Tipu was primarily composed of recent, first-generation migrants; a highly mobile population is consistent with ethnohistoric records for Tipu. These results indicate Spanish colonialism resulted in a significant and swift shift in mobility of the indigenous Maya, even in more peripheral frontier regions like Tipu, and underscores Tipu's importance as a refugee for fleeing Maya. The presence of migrants from both Spanish and Maya held territories provides evidence for the fluidity of the Maya-Spanish frontier and Tipu's importance as a gateway for trade between the two territories. Sex-based differences between migrants and locals are observed, and possible spatial patterns in the distribution of isotope values are explored. This research provides an increased realization of indigenous reactions to early European colonialism in frontier areas.

DEDICATION

This dissertation is dedicated to the memory of:

My sister, Angie Trask

My dad, Fred Schaak

My grandfather, Clyde East

My aunt, Michele East

And

Cricket

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CHAPTER I

INTRODUCTION

The arrival of the Spanish to the New World resulted in significant reorganization of the geopolitical landscape throughout Mesoamerica. This was represented by major shifts in population densities and trade networks, and the establishment of new, Spanish controlled political and religious centers. These factors, combined with Spanish policies towards the indigenous Maya people, resulted in significant alterations to existing migration patterns throughout Mesoamerica. The Colonial *visita* mission Tipu is located on the southeastern Maya-Spanish frontier and was an important player in frontier politics and trade. This research uses burials excavated from the Tipu mission cemetery to examine the impact of Spanish colonialism on Maya mobility, to identify migration from strongly Spanish-held territories to peripheral zones, and to estimate potential geographical places of birth for first-generation migrants to Tipu.

Immediately prior to the arrival of the Spanish in the northeastern portion of the Maya lowlands, the Late Postclassic period (1300 AD – 1521 AD) manifested the presence of few central political centers with monumental architecture and dispersed small communities. The transition from the Postclassic Period to the Contact period (1521 AD onward) was marked by the establishment of numerous primary and secondary Spanish political and religious centers and Spanish-driven centralization of population densities. Historical records suggest a subsequent southern migration of indigenous peoples from the northern Yucatan peninsula and northern Guatemala to less inhabited regions to the south as a form of resistance to the control of the Spanish.

After the conquest of the Yucatan peninsula by the Spanish in the 16th century, Maya peoples inhabiting the region were subjected to varying degrees of social, economic, and religious control under the new Spanish Colonial administration. Conquered Maya communities were required to pay tribute (often in the form of goods, money, or forced labor) to *encomenderos* (Spanish awarded royal grants allowing for the right of tribute from native peoples) (Farriss 1984; Jones 1989; Jones 1998). Many Maya sought refuge from the often oppressive Spanish Colonial rule by migrating to remote forest communities along the southern fringes of region. Later, periods of intermittent famine and increased depredations of pirates along the eastern coast also contributed to the exodus of Maya people into the southern fringes of the region (Farriss 1984; Graham 2011; Jones 1989; Jones 1998). The communities which arose in these remote frontier areas were often only subject to intermittent contact from Spanish missionaries, enabling these groups to maintain a greater sense of cultural identity than other regions.

The Colonial period town of Tipu is located in the foothills of the Maya Mountains, and was originally established as the last and most remote of a string of *visita* missions built by the Spanish in 1544 (Graham et al. 1989; Jones et al. 1986; Jones 1989; Jones 1998). *Visitas* were established as visiting stations for priests and other religious officials and would typically operate much like a mission, but without a permanent resident priest. Tipu was located in a volatile no-mans-land between two opposing frontiers – the Colonial Spanish controlled Yucatan to the north and west, and the indigenous Itzá Maya controlled Petén to the east. The forested Petén region of northern Guatemala and Belize was a relatively impenetrable frontier to Spanish occupation until quite late in the Spanish conquest, with the city of Tah Itzá (modern Flores, Petén) not conquered till 1707. Tipu's remote location in the forests of the Maya Mountain foothills, geographically distant from the Spanish Colonial administration in Merida, resulted in infrequent visits and a lack of strict supervision from religious or secular officials. This allowed Tipu's inhabitants to maintain a greater sense of cultural identity and made it an attractive locale for Maya fleeing from elsewhere in the region (Graham 1991; Graham 2011; Thompson 1990). During the late 16th and early 17th century, several remote frontier communities, including the community of Tipu, became strongholds of passive resistance and eventually core centers of violent rebellion against the Spanish in the struggle for Maya autonomy (Graham 2011; Jones 1989). Situated at a geographic and cultural frontier, Tipu experienced a dynamic history of fluctuating political alliances between the Itzá and Spanish and was a pivotal player in frontier politics and trade.

Movement, Migration, and Residence as a Field of Study

Anthropologists have long recognized migrations and population movements as an integrated part of the human story. Migration studies are integral to all four subfields of anthropology and related fields such as sociology, human geography, and biology. Migration is considered both a process and an agent of change in each anthropological subdiscipline, making it a research domain worth studying from as many angles as possible.

In the archaeological record, migration has historically been a confounding factor when attempting to characterize broad processes of culture change, largely due to the complex suite of sociocultural, linguistic, and biological impacts migration has on a population. As a result, migration theory in archaeology has experienced several major shifts in the last century. Early studies often relied on a cultural-historical approach that utilized migration as an explanation for the appearance of novel cultural traits or abrupt cultural changes identified in the archaeological record – effectively equating normative material "cultures" with "peoples" and eliminating any dimension of complexity to migration (Anthony 1990). In direct reaction to these abuses, processual archaeologists rejected the use of migration as an explanatory mechanism for most sociocultural change observed in the archaeological record, prompting a multi-decade hiatus in migration studies.

After a long period of neglect and de-emphasis within the discipline, migration studies have once again become a topic of vital interest in archaeology as a potential mechanism for social and culture change (Anthony 1990; Burmeister 2000). This broad theoretical and methodological approach is developed around the concept that migration is a socially bounded process that is undertaken by individuals, not cultures (Anthony 1990). Even though migration is a highly complex phenomenon, it has structured processes that act with predictable movements, and therefore a manageable field of study (Castles et al. 2014). Using a framework of predictable patterns in migration is ideal for the study of mobility to aid in the identification of subcultures, kinship networks, and trade relationships for both past and modern peoples (Anthony 1990; Anthony 1997; Castles et al. 2014).

Migration studies can be broken up into four broad research categories: 1) detection of occurrence and scale; 2) motivation; 3) logistics/organization during migration; 4) impact of migration on homelands and destination areas (Herr and Clark 1997). The identification of migration episodes and impact of migration will be briefly addressed below. The detection of a migration occurrence and the scale of that migration is largely a methodological issue, but potentially one of the most important (Clark 2011). Identifying migration by purely archaeological methods is difficult. Styles of material culture can spread and change without any true movement of people, confounding efforts to provide empirical data to identify migration using artifact classification. Thus multidisciplinary approaches to migration, utilizing methods and approaches from other anthropology subdisciplines and life sciences, are the most useful for answering questions about migration in the archaeological record (Cabana and Clark 2011; Cowgill 2013; Friedlaender 2007; Jablonski and Paul 2002).

Identifying the impact of migration on a population and the destination community through multiple lines of evidence is crucial for obtaining a more holistic understanding of migrations. Multidisciplinary methods and theory are important to overcome biases, short comings of single disciplines, and to aid in combining multiple datasets to build a complex picture of migration. The age and sex structure of a migrant population provides information on the nature of migration. A degree of age-based and sex-specific mobility has been identified in ethnographies and in the historical record. Young people, primarily men, have been found to be significantly more likely to be involved in early stages migrations than women (Amin 1995; Brown 1983; Davis 1977; Jacobson 1988; Lefferts 1977), however, circumstances have been identified where women may become more mobile (Castles and Miller 2014; Liu 2012). Migration can have a variety of impacts on the mental (Bhugra and Gupta 2012; Ingleby 2005) and physical health (Boas 1912; Frisbie et al. 2010; Smith et al. 2003) of immigrants. In the archaeological record, identifying patterns in migration using variables such as health, demography, and socioeconomic status is methodologically difficult, as individual migrants are not usually easy to identify without biogeochemical techniques. Identifying demographic disparity in a prehistoric population is somewhat complicated and often focuses on age and sex frequencies in a recovered skeletal population. Although mental health is not demonstrable in the archaeological record, bioarchaeological methods have been proven to be useful for indicators of biological stress in an immigrant population.

Frontiers and Borderlands

Frontier communities like Tipu are often located at the intersection between two or more clashing cultures, offering an interesting way to look at the impact of Colonialism on indigenous migration and identity. Frontier studies provide a framework for interpreting the complex sociocultural changes and interactions that occur where two or more groups come together as an interconnected open and fluid social system (Black 1995; Lightfoot and Martinez 1995; Parker and Rodseth 2005; Waselkov and Paul 1980). In anthropology, frontier models have proved useful to aid in forging a relationship between historical documents, archaeological record, and ethnographic record of historical and Colonial period sites (Black 1995; Parker and Rodseth 2005; Rice and Rice 2005). Waselkov and Paul (1980) asserted that in anthropology, frontier models must deal with “the dynamic interrelationships of intrusive and indigenous societies, where they meet in zones of mixture and interaction” (Waselkov and Paul 1980). Lightfoot and Martinez (1995) later argued that archaeologists need to step away from these core-periphery models that marginalize the critical role indigenous communities played in cultural transformations. Instead, they argued that frontiers should be conceptualized as socially charged places; a location of culture change and syncretism that cross-cut social networks. Approaches that reduce complex social and political frontier interactions into a basic dichotomy (e.g. colonist and indigenous, core and periphery, savage and civilized) may end up obscuring critical social divisions, ethnic divisions, or political alliances (Lightfoot and Martinez 1995).

Frontiers in Colonial Mesoamerica have found to be fluid zones where complex social relations and population dynamics play out (Angel 1995; Black 1995; Rice and Rice 2005). Prior to conquest, the Petén region of Guatemala was an arena occupied by many cultural groups with distinct historical, social, and political identities (Rice and Rice 2005). These cultural distinctions still existed after the Spanish arrival, resulting in internal geopolitical struggles between the Itzá and other Maya groups, however become obscured when the Maya are presented as a uniform resistance front. During the Yucatan Caste wars of the late 1800s, individuals residing in the militarized zone (or frontier) between the rebel and Spanish forces were found to have developed a new way of existing “in between” these competing zones of power in order to navigate their survival and exercise freedom of movement between territories; ultimately the villages along this military "frontier” would play a pivotal role in the ongoing conflict between government troops and rebel forces (Angel 1995). Tipu’s history of fluctuating political alliances may have been for similar reasons.

Isotopic Approaches to Migration

Strontium ($^{87}Sr/^{86}Sr$) and oxygen ($\delta^{18}O$) isotopes obtained from human enamel can be used to help determine an individual's birth place. Strontium isotope analysis are a useful geologic tracer to aid in the estimation of possible locations an individual may have lived during a specific period of tissue formation. Similarly, oxygen isotopes are utilized as a measure of an individual's drinking water location as a function of meteoric rain-out. Stable oxygen and radiogenic strontium isotope studies are invaluable because they provide fine-grain information about within-life migrations at the scale of the individual, regardless of their material culture or language (Knudson 2011).

At the most basic level, some of the atoms that make up the food and water consumed by an organism become deposited in its tissues. With archaeological skeletal remains, bones and teeth are often the only tissues remaining. During life, bone has a rejuvenation rate of between a few years to a few decades depending on the type, location, and physiological age of the bone. On the other hand, tooth enamel is only deposited during dental development and does not undergo subsequent remodeling. As such, the isotopic composition of enamel is reflective of a finite period of time early in an individual's life when enamel is being laid down. Sampling of younger, recently remodeled bone may give insight into recent migrations or provide data that could be interpreted to infer how long an individual with a non-local signal has been at a site (Bentley 2006).

Stable isotopes have proved to be very useful indicators for movements of ancient Maya people, as well as identifying patterns in mortuary treatment for individuals based on birth place (Price et al. 2007; Price et al. 2008; Price et al. 2010; White et al. 2002; Wright

2005b; Wright 2012). In Mesoamerica they have proved to be especially useful since most traditional, macroscopic skeletal analyses are hampered by poor preservation. Oxygen and strontium isotopes have been demonstrated to be effective in identifying individuals in the archaeological record who were not born locally (Bentley 2006; Buikstra et al. 2004; Price et al. 2010; White et al. 2007). Thus, the use of a combination of isotopic approaches, like both strontium and oxygen, provides a higher resolution for the detection of population movements, as both geologic and climatic variables are taken into consideration (Price et al. 2007; Wright et al. 2010).

Research Design

The proposed study seeks to examine population movements in the southern Maya frontier within the greater political, cultural, and socioeconomic climate during the early contact time period, through the use of isotope analyses to track inter-regional, first generational migration. Tipu and the northern Maya Mountains are an area of the Southern Maya Lowlands that is often considered geographically and culturally peripheral to the primary Spanish interaction sphere. The maintenance of a distinct Maya identity and core location of Maya resistance make it a very interesting area to study this question.

My research tests the model established by previous archaeological and historical studies by using stable and radiogenic isotopes as geologic and climatic tracers to establish the childhood homelands for those individuals buried at Tipu. I am testing the null hypothesis that the early Colonial period population increase seen at Tipu is the result of local growth or of centralization of people from the immediately surrounding areas, and that the arrival of the Spanish had little impact on the Tipu population. This hypothesis will be supported if the Colonial oxygen and strontium isotope data show few non-locally born individuals, or no significant difference between the ranges of isotope values for between the Postclassic and Colonial time periods. If supported, this would indicate that the archaeologically observed changes were the result of endogenous developments, rather than foreign incursion, and that the Spanish had little impact on previously existing migration patterns. I expect to reject this hypothesis if there is a significant increase in the number of foreign-born individuals buried at Tipu during the Colonial period, or a large proportion of foreign-born individuals buried in the cemetery as a whole. This result would support the ethnohistoric model that individuals who fled the Spanish Yucatan moved south to Tipu. Subsequently, I will utilize the isotopic data to estimate the places of birth of any skeletons recognized as being foreign-born individuals. If the primary research hypothesis is rejected, I will investigate spatial and demographic patterns in foreign-born individuals compared to those of local birth.

Isotope studies of migration and identity are important for identifying individuals and their roles in the population history of past settlements. Contact period Maya sites represent a remarkably understudied period in Maya history. To date, most studies in the Maya area have been undertaken on prehistoric Maya sites, all but ignoring post-contact populations. Although there is no question that investigations of major pre-Columbian sites are important, the current emphasis on these sites overshadows the importance of explaining the effects of Spanish arrival on indigenous Maya experience and identity – specifically the role the Spanish played in inter-regional movements. In particular, Tipu offers a unique perspective because it is a frontier community. Tipu maintained a population with a distinct Maya identity and acted as a core location of Maya resistance.

This research also further demonstrates the importance of interpreting direct evidence for migration to the Colonial Maya frontier through a broad multidimensional approach. The sub-field of bioarchaeology provides a uniquely inter- and intra- disciplinary approach that synthesizes data obtained from human biological data with data obtained from archaeological, historical, and/ or linguistic contexts (Buikstra et al. 2000; Larsen 1997; Perry 2007; Stojanowski 2005). Recent studies have highlighted the necessity of caution when using historic records as a primary source of information for recreating life histories of individuals, as they may not provide a total or accurate depiction of the experiences of subjugated or marginalized peoples (e.g. Buzon 2006; Perry 2007; Rose 1985; Saunders 1989; Saunders 1992; Saunders et al. 1993). Strontium and oxygen isotopes provide critical, yet complimentary, sources of information that will allow for the synthesis of new, direct evidence for Colonial period migration with extensive archaeological, osteological and odontological, and ethnohistoric research to provide a more holistic view of frontier Maya experience at Tipu.

CHAPTER II

THE TIPU MAYA

The arrival of the Spanish to the New World resulted in significant reorganization of the Mesoamerican geopolitical landscape, in marked shifts in population densities, the establishment of Spanish political and religious centers, and altered trade networks (Jones 1989). The conflict between Spanish and indigenous cultures was complex and violent, and the consequences of these interactions on population and social dynamics are still poorly understood.

General Postclassic and Colonial Maya Background

Maya on the Eve of Conquest

Maya political, economic, and population dynamics prior to the arrival of the Spanish provide a crucial context for Maya-Spanish interactions. Without an understanding of population movements prior to the Spanish arrival, it is not possible to adequately interpret how migration changed after the arrival of the Spaniards.

A population that can be culturally designated as “Maya” has been identified as occupying the lowlands as early as around 2000 BC (Hammond 1979). Figure 2.1 shows the geographical range of the Maya area. The Preclassic period, extending from around 2000 BC to AD 250 saw the rise of a vibrant culture and development of an advanced civilization. The Classic period, defined by the presence of the long count calendar carved on stelae and spanning ~ AD 250 to AD 900, saw a marked population expansion, technological and artistic innovation, and development of complex city states. The Postclassic period began roughly around AD 900 in the Maya lowlands, after a collapse of socio-political institutions and depopulation of many of the Classic period political centers. Despite the depopulation of large political centers, aspects of Maya culture persisted throughout the Postclassic. Both sea and overland trade routes were used in complex networks of long distance trade and exchange, which included the movement of goods like cacao, salt, cotton, and obsidian. Many Postclassic settlements were located along coastal or riverine environments, highlighting the importance of water-based trade during this time period (Chase and Rice 1985; Roys 1957; Sabloff and Rathje 1975).

Contact and Spanish Colonialism in Mesoamerica

Unlike the conquest of the Aztecs in Central Mexico, the Spanish conquest of the Mayan Yucatán was a lengthy affair. After unintentional contact was made in 1511 when a lifeboat from a sunken Spanish vessel washed up on the eastern coast of the Yucatán, Spain's first official attempts at conquest were in 1517 and 1518. The Spanish were met with stiff resistance by the Maya, and returned to Cuba after sustaining significant causalities. They later made brief contact with the Yucatán peninsula on several occasions between

Figure 2.1. Map of the Maya area, with pertinent sites and regions.

1517-1519; the lack of resources of interest to the Spanish caused them to turn their attention elsewhere in the region until 1527, after Cortez and others had first made successful campaigns through Mexico, the Petén and highlands of Guatemala, and into Honduras (Farriss 1984; Jones 1998).

Several factors made the conquest of the greater Maya area much more difficult for the Spanish than elsewhere in the Americas. Unlike the overarching imperial structure seen in the Aztec and Incan empires, the Maya in the Yucatán region appear have been split up into at least 16 autonomous provinces with varying degrees of internal unity (Farriss 1984; Roys 1957). This prevented the Spanish from conquering the region with one blow to the capital, like with the Aztecs, instead forcing them to negotiate or defeat each province separately over the course of decades (Farriss 1984:12). The region was also very difficult to travel with horses, and ill-suited for the preferred style of Spanish warfare. Although unsuccessful as a conquest, the early contact did succeed in introducing new European diseases like smallpox to the Maya world, which significantly diminished Maya populations and destabilized Maya kingdoms over the next several decades until the Spanish again turned their sights on the Yucatán.

The successful conquest of the greater Maya region did not begin until 1524-1527, with Pedro de Alvarado's conquest of the K'iche' Maya in the southern highlands at Utatlan and the establishment of the first Spanish capital in Central America at the Kaqchikel capital, Iximche' in what would become Guatemala (de Alvarado 1978). The Spanish did not subdue much of the northern and eastern Yucatán until 1540-1546. However, at tribute paying time in 1546, a series of resistance uprisings occurred across the eastern Yucatán peninsula. These uprisings were a "last gasp" of concerted resistance against the Spanish for the Maya in the region (Farriss 1984:68). With the help of military forces sent from Merida, the so-called "Great Revolt" was eventually suppressed in 1547 after several months (Chamberlain 1948; de la Garza et al. 1983; Farriss 1984). The Maya refused to submit to Spanish control, and rebellions continued to erupt even in pockets of strongly Spanish held territories. For example, the Chikinchel Maya, located on the northeastern Yucatán coast, continued to resist and enticed other groups in the region to join in resistance for decades to follow (Chamberlain 1948; Kepecs 2005). Much of the central Yucatán, as well as the Petén, remained un-subjugated and the source of continued revolts until the end of the 17th century. Furthermore, pockets of Maya throughout Quintana Roo continued to mount successful revolts against the Spanish and later Mexican overlords until as late as the Yucatán Caste Wars in the 19th century (Reed 1964).

Contact and Early Colonial Period in the Maya Area

The Yucatán was seen as something of a Colonial backwater to the Spanish, lacking many of the goods and precious metals in demand in Europe (Farriss 1984). The hot, wet climate, teeming with noxious insects and parasites, was deemed inhospitable by the Spanish. Crops and livestock often fared even worse than the Spanish who brought them to the New World (Farriss 1984). Human resources, obtained in the form of labor, and goods tribute under the *encomienda* system, became the only resources the Spanish could readily exploit, forming the economic base for the colonists in the region. Under the *encomienda* system, tribute officially took the form of goods or labor paid to the *encomenderos* (Spanish

Colonials awarded royal grants allowing for the right of tribute from native peoples) (Jones 1989; Farriss 1984). Although the crown officially insisted that indigenous people should not be forced to work against their will, in the Yucatán peninsula and elsewhere, every able-bodied adult member of a community would be subject to a variety of forced *repartimiento* labor drafts in addition to those required under the *encomenderos* system (Farriss 1984). These labor demands, often made by the government or church, were sanctioned by law, custom, or occasionally were completely unsanctioned (Farriss 1984). *Servico personal* was designed to satisfy the Spanish colony's private labor requirements. In theory, it functioned as a government regulated work exchange for communities; in practice, few would argue that it was anything less than forced labor. Throughout the Spanish empire, both the *servico personal* and *repartimiento* labor requirements quickly became the most detested aspect of Spanish rule (Farris 1984:48).

Spanish missionary activity in the Yucatán peninsula began in 1544 with the arrival of Franciscan friars. After building several main convents in Campeche, Merida, and Maní between 1545-1547, they spent the next 30 years slowly venturing out into rural areas and establishing an additional 16 convents (Andrews 1991). Figure 2.2 shows the extent of Spanish chapels and churches Yucatán Peninsula during the 16th and 17th centuries. Friars would use these convents as a base to venture out into rural areas and establish dozens of missions with smaller churches and chapels throughout the portions of the Yucatán peninsula held by the Spanish (Andrews 1991). The friars would use Maya labor and building supplies (often repurposed from existing structures) to construct chapels and churches with thatched roofs (Andrews 1991). Few of these missions had friars in-residence full time, and the more remote missions, like Tipu, were so inaccessible that the friars would rarely visit them. Many

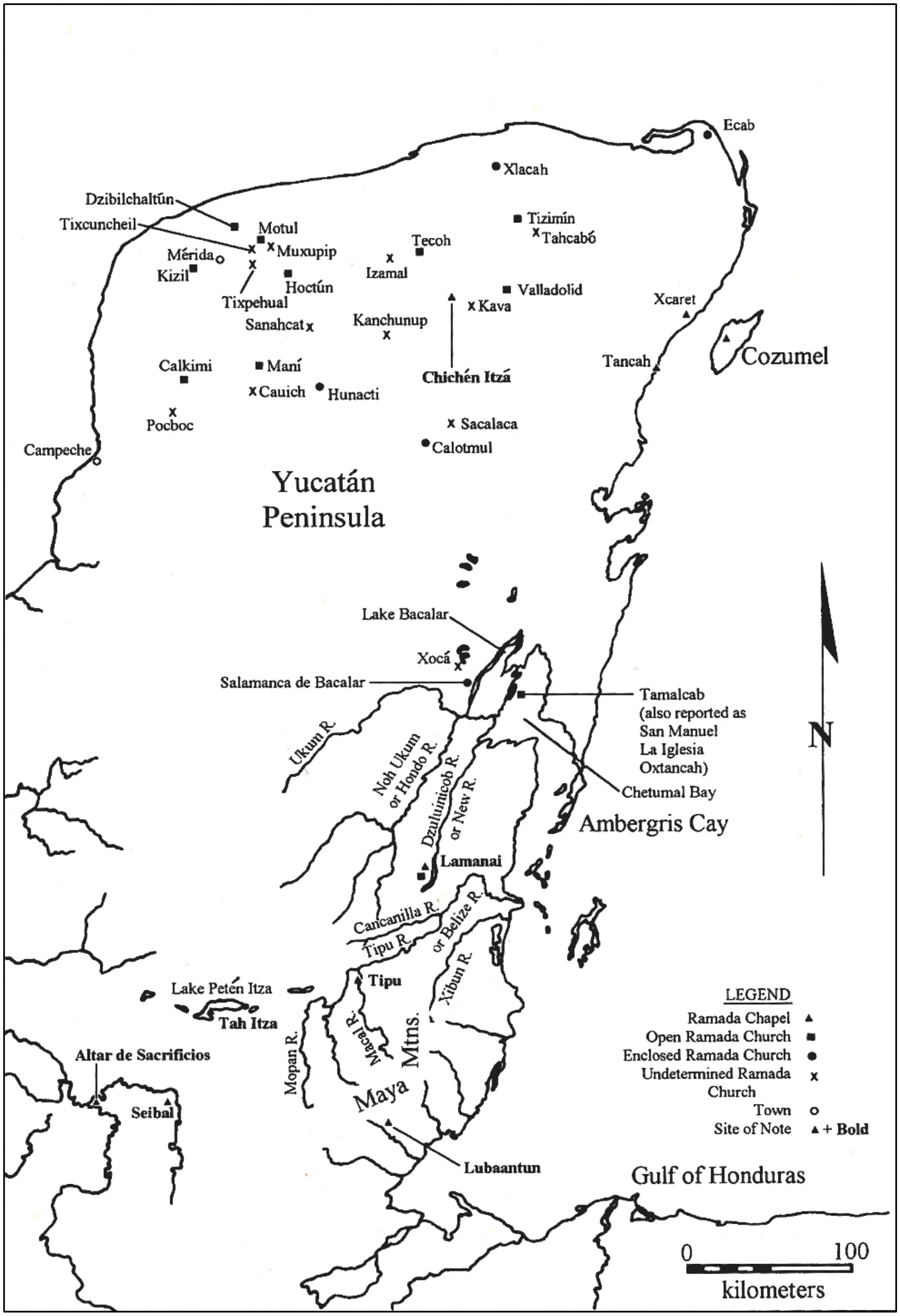


Figure 2.2. Map of the Colonial period churches of the Yucatán. Reprinted from Jacobi 2000: Figure 1.1.

of the smaller and more remote churches and chapels were referred to as *visitas* because they would receive only occasional visits by the Franciscan friars (Jones 1989). By 1582 there were 22 main missions in the Northern Lowlands, housing more than 60 friars serving 186 *visitas*. Many of the early missions were deliberately placed on Postclassic Maya temples and structures (Perry and Perry 1988). Tipu was the last and furthest south in a string of 22 *visita* missions administered by a parish priest in Bacalar (Jones 1989; Andrews 1991).

The Catholic missionization of the Yucatán peninsula played a crucial role in the initial acculturation process of the Maya and other subjugated peoples by the Spanish through the total restructuring of the way they lived. The Spanish priests started the acculturation process by venturing into remote communities, establishing missions, erecting churches and chapels, proselytizing to the locals, and, through various means, convincing the Maya to relocate to the missions (Andrews 1991; Jones 1989). The missionization process was most successful in the northern and western portions of the Yucatan where the Spanish had a secure presence early on in the Colonial period (Andrews 1991). The Spanish didn't establish enough military and administrative presence to keep secure control over the eastern and southern areas of the peninsula; these regions often became neglected while pirates controlled the coasts. By 1650 many of these mission outposts were abandoned (Andrews 1991; Farriss 1978; Farriss 1984; Jones 1989). It was these remote missions on the frontier that would eventually become havens for refugees and centers of rebellion.

The Spanish missionization process also often accompanied the *reducción* and *congregación* settlement programs (Farris 1984; Jones 1989). The *reducción* programs acted to round up Maya locals and refugees from remote or dispersed communities and force them to resettle into a single town under Spanish control. The *congregación* programs would force several settlements and native communities to resettle to a newly created town, usually one laid out in a grid with a church and town square (Farriss 1984; Jones 1989). These two policies helped simplify indigenous political and territorial organization, while helping to maintain more effective control over conquered populations. “Settlement formed a part of a dyadic code, in which the world was divided into two opposing parts, town and forest. The town represented Christianity, civilization, and indeed all that was human life, in contrast with the forest, where wild beasts lurked and where man risked being overwhelmed morally as well as physically by the untamed forces of nature” (Farriss 1984:160).

Disease Consequences of Conquest

The arrival of the Spanish to the New World was accompanied by a tremendous and rapid decline in the populations of many of the native peoples. Epidemics of European diseases were a primary cause of depopulation throughout the Americas, even before direct contact was made. The exact extent of population losses will never be known due to inadequate historical documentation and limitations of studying disease on skeletal populations. The acute infectious diseases known to have decimated Native American populations (e.g. smallpox, measles, etc.) do not leave any diagnostic evidence on skeletons (Ortner 1992).

In Mesoamerica, the populations declined dramatically in the first 100 years after the arrival of the Spanish; with the largest losses likely occurring before or soon after conquest, and prior to any official census being recorded (Farriss 1984). Estimates suggest that famine and pandemics may have resulted in the decline of the Yucatan peninsula population from 800,000 to 140,000 individuals (Cook and Borah 1971). During the early Colonial period the Yucatán peninsula saw multiple waves of epidemics diseases including smallpox, measles, yellow fever, and influenza (Jones 1989, Farriss 1984). In addition to diseases, periodic famines during the early Colonial period served to further weaken populations (Farriss 1984).

Contact and the Early Colonial Period in Southeast Yucatán

Initial Conquest of the Southeast Frontier

Tipu was officially conquered by Alonso and Melchor Pacheco, during their particularly harsh and violent campaign in 1543-1544 to subdue the three southern Yucatán provinces of Uaymil, Chetumal, and Dzuluinicob (Jones et al. 1986; Jones 1989), and potentially extending into the Cochua province (Jones 1989:43). Around 1544, the Pachecos and a small handful of Spanish followers established a small headquarters at Salamanca de Bacalar for two purposes: 1) for governing the entire southeastern Yucatán peninsula (including Tipu), and 2) with the intent of bringing this area under the umbrella of Spanish control through a series of *congregación* efforts and the establishment of *encomiendas* (Jones 1989). Through subduing the region today known as northern and central Belize, the Spanish hoped to establish a trade route along the coast between the Yucatán peninsula and the Gulf of Honduras to prevent the flow of runaways from highly populated provinces to the north, and most importantly, to provide a clear route for the eventual conquest of the Petén (Graham et al. 1989; Graham 2011; Jones 1989).

The new villa of Bacalar was located around 70 leagues from the Spanish Capital of Merida, a journey that would traditionally take several days (Jones 1989; Figure 2.3). Bacalar's remote location as a "wilderness outpost" located far from Merida, resulted in its leaders experiencing difficulty maintaining control over the *encomenderos* in its jurisdiction from the beginning (Jones 1989). Vast distances, difficult travel between the newly formed *encomienda* towns, and populations primarily comprised of Maya forcibly congregated from distant towns, resulted in a relatively rapid dissolution of many of the first *encomiendas* established by the Pachecos (Jones 1989).

Bacalar never gained firm control over the southern provinces, the "farthest native frontiers of a Colonial frontier" (Jones 1989:52). Uprisings throughout the eastern proveniences occurred as early as 1546-1547 during the "Great Revolt", an anti-Spanish rebellion focused on removing Spanish influence from the region (Farriss 1984; Jones et al. 1986; Jones 1989). During this time, events escalated to the point that the Maya living at Chanlacan (near Progresso Lagoon and Lamanai in northern Belize) killed their *encomendero* (Jones 1989). This uprising would mark the beginning of a several decades long period of rebellion and hostility against the Spanish for the region around Tipu and throughout the greater eastern provinces (Jones, et al. 1986; Jones 1989:45-49). The remote and little understood proveniences of Chetumal, Uaymil, and Dzuluinicob were finally "conquered and 'pacified' not for the tribute income they might produce, but rather in their interests of pacifying the backyard of the nascent colony of Yucatán" (Jones, et al. 1989:52).

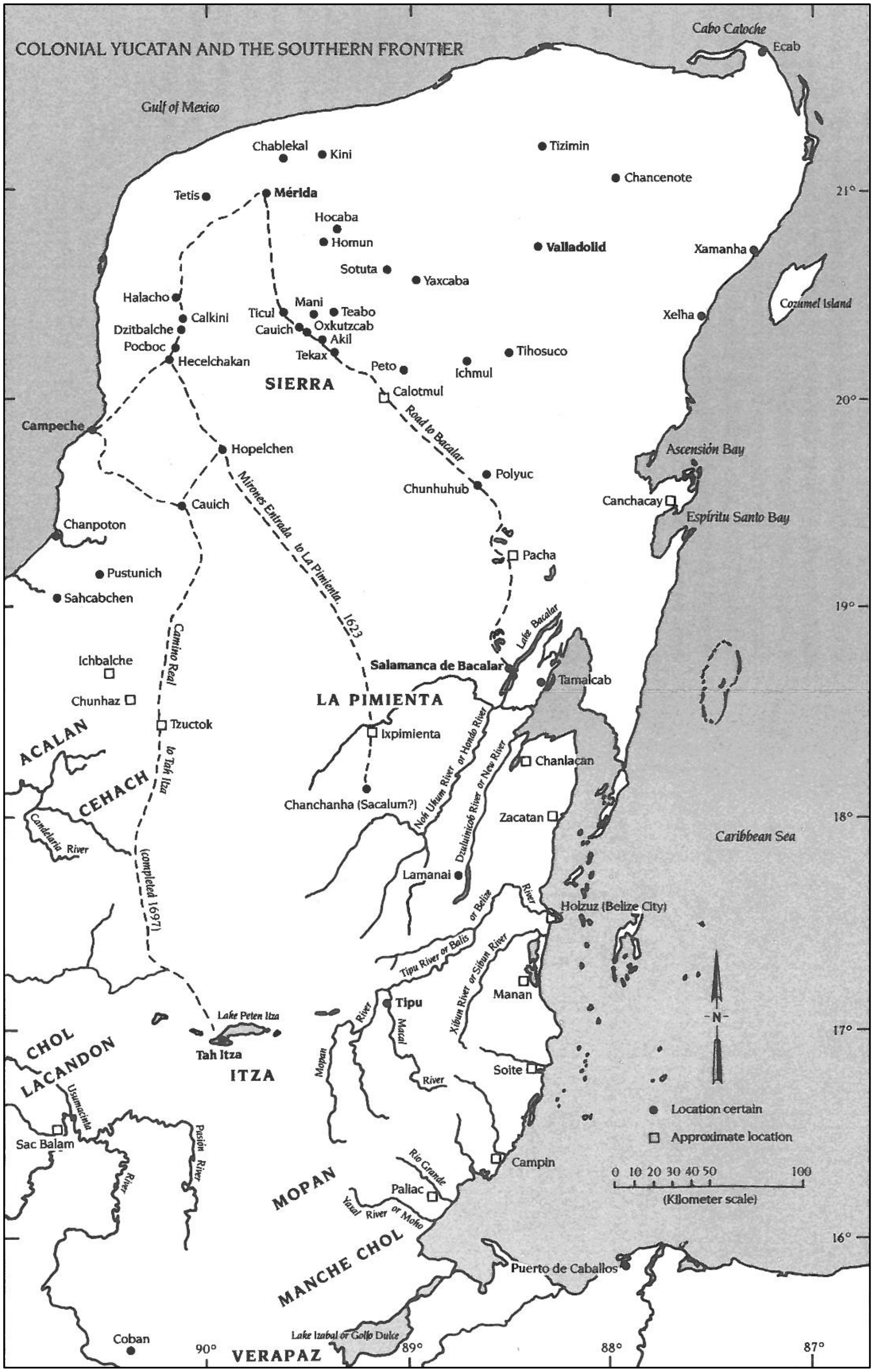


Figure 2.3. Colonial period Maya and Spanish villages, and Spanish roads of the Yucatan peninsula. Reprinted from Jones 1989: xiv-xv.

In 1567 -1568 the Lieutenant Governor of the Yucatán, Juan Garazon, reconquered the Bacalar provenance through two *entradas* into the region, during which he forcefully resettled many Maya from as far as the Alacan province north of Lake Petén Itzá (including many in La Pimienta) to "friendly" communities near Salamanca de Bacalar (Jones 1989:48-49). By this time Tipu had already established itself as a center of rebellion in the region, and was reconquered by Garazon during his second *entrada* in 1568, during which the Spanish searched out and burnt many idols and native books in the village (Jones, et al. 1986; Jones 1989:49.) Once control over Tipu was again established, Garazon and his men used Tipu as a base while undertaking extensive searches of the surrounding countryside and forests. Garazon referred to these excursions, which would last up to 15 days long, as his "third *entrada*", where they would capture everyone they encountered until "there was no notice of more people" (Jones 1989:49). Historical records suggest that several *entradas* traveled southward across the Maya Mountains, potentially going as far as the Manche Chol territory in southern Belize, in their efforts to capture runaways (Jones 1989:50). Records suggest the Maya captured during Garazon's *entradas* were relocated to more "peaceful" territory near Bacalar (Jones 1989:50).

There is some evidence that around the time of Garazon's campaign, Maya rebels living around Tipu and La Pimienta began to execute their own *entradas* into congregation towns in the Chetumal province with the intent of bringing Maya into a "Maya sphere of power around Tipu" (Jones, et al. 1986:41). In Spanish documents, these kidnappings and raids were referred to as the work of murderous apostates; however, this is unlikely. The attacking parties were primarily composed of unconquered Maya, Maya from distant towns, and baptized runaways returning to aid in the kidnapping. It is more likely that the supposedly peaceful Maya living at the congregation towns were voluntary participants in the flights, using the rebels as a form of protection to aid in their escape (Jones, et al. 1986:42; Jones 1989:48).

As is detailed above, there were several villas, communities, and/or political centers in the southeastern Yucatan that were especially integral to the history of Tipu during the early Colonial period, specifically regarding regional movements of individuals. Figure 2.4 shows three of these communities or areas: Salamanca de Bacalar, La Pimienta, and Tah Itzá. Each will be discussed in further detail below.

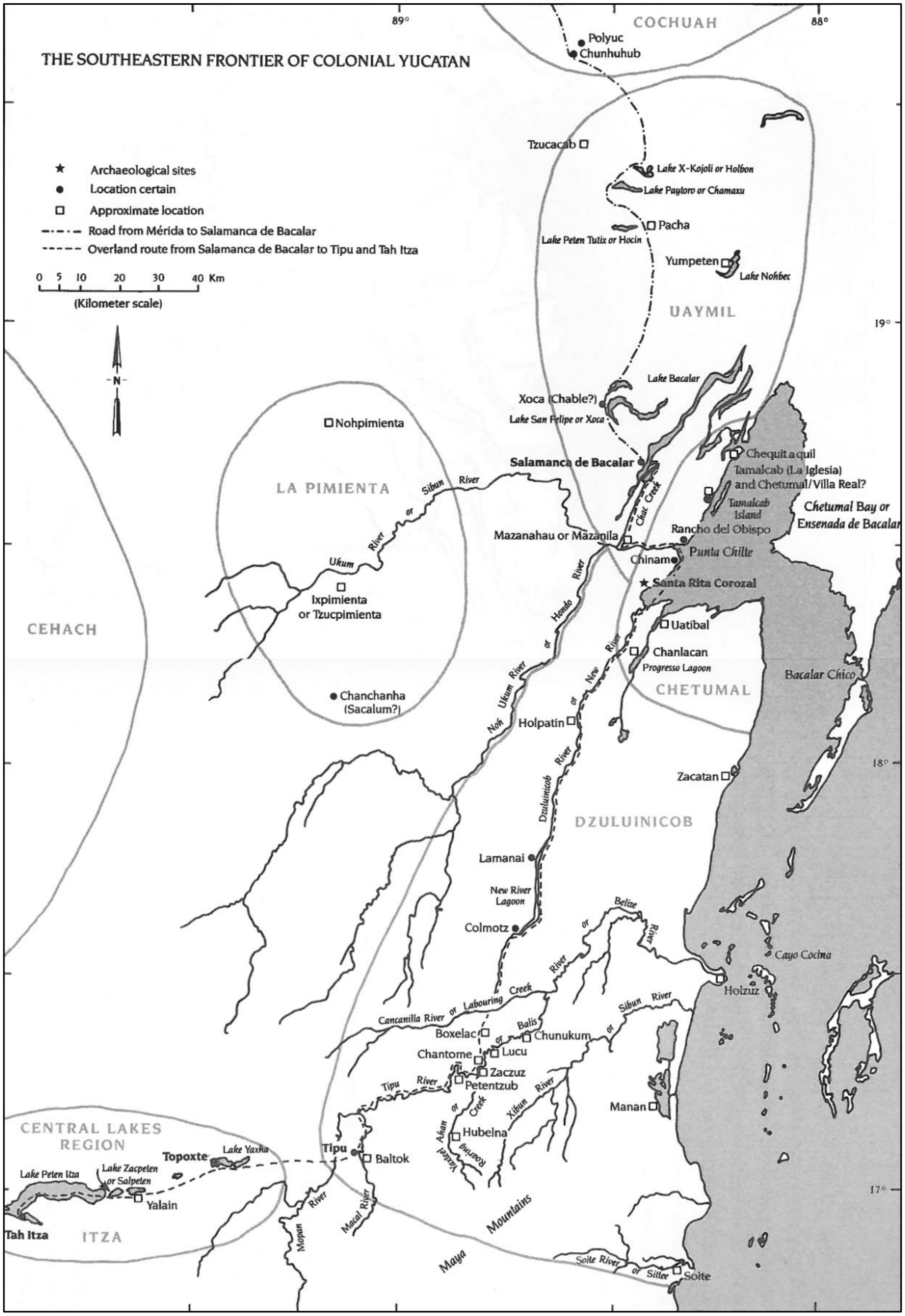


Figure 2.4. Southeastern frontier of Colonial Yucatan. Reprinted from Jones 1989: xvi-xvii.

Salamanca de Bacalar

During its approximately 100-year occupation, the villa of Salamanca de Bacalar would continuously struggle against all odds to maintain some sort of a semblance of European civilization. “From its beginnings then, the Bacalar province – the Spanish territory that encompassed these three native provinces and their immediate neighbors – comprised a tiny, often corrupt and virtually disenfranchised Spanish population in the midst of a great green sea of widely scattered, rebellious, and nativistic Mayas” (Jones 1989:53). Bacalar’s remote location from the Spanish capital in Merida and the scattered settlement pattern of the Maya towns under its control resulted in it continuously struggling to maintain a tenuous control over the region (Jones 1989:6). For the Spanish empire, the purpose of Bacalar was to act as a watchdog for runaway Maya from the north, as a signal point to communicate signs of potential indigenous rebellion to Merida, and to monitor the conversion efforts in Maya communities under its jurisdiction (Jones 1989:52). The area Bacalar governed was so large and vast it was extremely difficult to accomplish these tasks without aid from Merida, and many of the original Spanish inhabitants would not stay long.

In 1620 Julio Sarmiento Palacio described Bacalar with the comment, “That villa is inhabited by the most miserable people in all the Indies, in a region so remote and poor that there is scarcely anyone who knows how to read and write, and where a mulatto, the son of an *alcalde,* was *alcalde ordinario*. And it is lucky that there is anyone who wants to inhabit that villa” (from Jones 1989:55). Compared to other Spanish villas in the Yucatán, Bacalar suffered from extreme poverty, and was often described as having an “incestuous inbred quality" by the Spanish who visited. It is possible that at times the population of Salamanca de Bacalar may have been even smaller than Tipu (Jones 1989).

Repeated attacks by pirates along the coast, combined with widespread resistance and fleeing of Maya populations, resulted in the abandonment of Salamanca de Bacalar in 1648 and the loss of Spanish control over both the Chetumal and Dzuluinicob provinces (Jones 1989:230)

La Pimienta

La Pimienta was a region to the west of Bacalar which attracted thousands of runaway Maya from norther towns and *encomiendas*. La Pimienta was likely a pre-Columbian province (with a different name), however, the boundaries are unknown as its remoteness from Spanish contact prevented many direct historical references (Jones 1989:99). It likely consisted of a broad band of refugee populations, with its population estimated to be as high as 20,000 by 1629. In the absence of any Colonial constraints its inhabitants pursued an active role in peninsular trade and commodity production, local forms of religious expression, and political activity controlled by a local priestly elite (Jones 1989:5-6). Although La Pimienta did not have an ancient independent center driving its rebellion against the Spanish, like seen with groups in the Petén, it did have highly organized intercommunity hierarchies and political alliances (Jones 1989:99). The inhabitants of the La Pimienta region were in contact with the Itzá throughout the early Colonial period and likely significantly hampered the Spanish's efforts with the conquest of the Petén. La

Pimienta and its central town of Ixpimienta “comprised an autonomous expression of Maya frontier resistance that posed a considerable problem to the Spanish governing of Maya subjects throughout the peninsula” (Jones 1989:6).

Itzá Maya and the Central Petén Lakes Region

The Maya groups living in the central region during the early Colonial period remained fiercely independent and were successful in resisting Spanish control until the end of the 17th century. The largest of these ethnic groups, the Itzá Maya, was the final independent Maya kingdom, and played an important role in political dynamics during the early Colonial period. The Itzá Maya territory included a portion of the Petén Lakes region. The Petén Lakes region consists of a chain of eight lakes of varying sizes formed along a fault line in the limestone bedrock, the largest of which is Lake Petén Itzá (Rice and Rice 2005). Several of the largest Classic period Maya sites were located in the Petén, north of Lake Petén Itzá, however, during the Postclassic the greater Petén region saw widespread decentralization of populations (Rice and Rice 2005). Archaeological evidence suggests that several sites, located along the shores or on islands in the Petén Lakes, were continuously occupied through the Postclassic and Contact period (Pugh et al. 2012; Rice and Rice 2005). By the time the Cortez expedition traveled through the region in 1524, the Petén lakes and surrounding region were home to multiple Maya ethno-political groups, including the Itzá Maya and the Kowoj Maya (Jones 1998; Rice and Rice 2005). These two groups will be briefly discussed below.

The Itzá Maya are mentioned in several prophecies, which suggest they were a group of political elites that fled political turmoil in Chichén Itzá (northern Yucatan) sometime between the early 1200's and the 1400's (Farriss 1984; Jones 1998; Rice and Rice 2005). This group was purported to have headed south until ending up at Lake Petén Itzá, where they established the capital of Nojpeten on an island in the lake (Rice and Rice 2005; Jones 1998). During the contact period many Itzá Maya resided at the site of Tah Itzá or Tayasal, along the southwest shore of the lake.

The Kowoj Maya are believed to have occupied the eastern Petén lakes region, possibly centered in the Topoxté islands in Lake Yaxhá. They are purported to have migrated to the Petén, possibly from Mayapan, at some point in time during the Postclassic, most likely before 1450 (Rice and Rice 2005; Rice and Rice 2009). Although the nature of the relationship between the Kowoj Maya and the Itzá Maya prior to the Spanish arrival is not fully understood, the two groups were in no way friendly by the end of the 17th century (Rice and Rice 2005; Rice and Rice 2009).

The Petén lakes region was the final area of Maya independence and resistance against domination by the Spanish (Jones 1998, Rice and Rice). Similar to Tipu and the La Pimienta regions, the Petén received a lot of immigration from Maya fleeing Spanish control elsewhere in the Yucatan (Rice and Rice 2005). Unlike elsewhere in the Maya area, the Itzá were able to resist Spanish control and efforts of Christianization until remarkably late in the Colonial period, and were the last major Maya group to be conquered by the Spanish. During the early Colonial period in Mesoamerica, the Petén lakes region was quite hostile to the Spanish, allowing the groups living there to maintain their independence and Maya culture until much later than other Maya regions (Jones 1989; Rice and Rice 2005). As a result, the

Petén became a refuge for many Maya fleeing Spanish control elsewhere in the Yucatan Peninsula. Maintaining control over Tipu was important to the Spanish because it not only was an important stepping stone for the conversion of the Itzá Maya in the Petén by Spanish missionaries, but because it also was an important base location for their attempts to subdue the independent Maya in the Petén (Jones 1990). Around the middle of the 17th century, the Spanish started actively moving towards conquering the Itzá Maya; this move was largely prompted by large losses of Maya labor due to flight of Northern Yucatan Maya to the Petén (Farriss 1984; Jones 1989; Jones 1998). During this time widespread illicit trade is believed to have occurred between the Itzá Maya and Maya living in Spanish occupied regions (Farriss 1984:18).

The Spanish finally succeeded in conquering the Itzá Maya in 1697 (Rice and Rice 2005; Jones, et al. 1998). Beginning in 1702, missions were built around the lake to support the Presidio, which was built on the Itzá capital of Nojpeten, and as part of an effort to round up and control local Maya populations (Jones 1998). During the early 18th century, at least 12 missions are recorded to have been built around Lake Petén Itzá and other nearby lakes; the Spanish then populated these missions through *reducciones* of Maya from the Petén, and elsewhere in Guatemala and Belize (Jones 1989). Several instances of native resistance and rebellion occurred during the 1700s, and by the late 1700s the populations of most mission began to decline, largely believed to be due to flight (Jones 1998).

San Bernabe mission was one of two missions established on the Tayasal peninsula (former location of Tah Itzá) and appears to have been constructed on top of prior Postclassic and Contact period occupations (Pugh et al. 2012). Recent archaeological excavations of the San Bernabe mission site are seeking to understand both the Prehispanic and Colonial period occupation of the area. The recovery of 22 individuals from the San Bernabe mission found similar burial positioning and mortuary treatment as has been identified at other Colonial Maya sites, like Tipu. Interestingly, many of the San Bernabe graves had evidence of repeated use over time (Pugh et al. 2012).

Colonial Period Migration in the Maya Area

The arrival of the Spanish in Mesoamerica prompted a significant transformation of the nature of migration throughout the Maya area. Within a relatively short period of time, new stressors prompted large groups of individuals from the northern Yucatan to travel considerable distances in search of new residences. By the middle of the 16th century, Dzuluinicob, in particular Tipu, is reported to have experienced a rapid influx of Yucatec Maya speakers from the north (Jones 1989). A similar influx was also reported in La Pimienta at Ixpimienta, except this occurred in the absence of any control by the Spanish (Jones 1989). This southern flight of individuals from the northern Yucatan continued through the 1600's. The fear of piracy and kidnappings that accompanied the increased pirate activity along the coast from Bacalar to Gulfo Dulce during the mid-1600's may have also acted as an additional motivator for the migration of many Maya over considerable distances inland (Jones 1989).

In the Yucatán peninsula, migration was an important and powerful form of resistance to Spanish control, possibly even more important and effective than direct conflict or fights with the Spanish. During the early Colonial period there were surprisingly few full-scale violent rebellions, despite the widespread disdain most Maya felt towards the Spanish and the presence of numerous rebellions elsewhere in Mesoamerica and the Spanish empire (Farriss 1984). The Maya are believed to have utilized population movement as both a response and form of resistance to Spanish control. Farriss (1984) has identified three related but distinct types of population movements in the Maya region: flight, drift, and dispersal; these are defined here:

> Flight refers to the escape of Maya from Colonial rule across the frontier into unpacified territory; drift refers to the migrations to other communities within the area under more or less effective Spanish domination; and dispersal indicated the creation of satellite settlements by population spinoff from nucleated or congregated 'parent' towns. None of these was an example of mass migration except in the aggregate. Yet, although individually small scale and uncoordinated, the cumulative effect of these movements on Maya social patterns was profound. Farriss 1984:200.

Although Farriss's research was primarily focused on the northern Yucatan, these are also very pertinent to Maya life in the southern Yucatan. Each of these three forms of population movement and how they may have impacted Maya migration in the Bacalar province will be discussed in further detail below.

Flight was considered a lot less risky and a more attractive alternative to fighting or rebellion (Farriss 1984:71). Historical records suggest that during the Colonial period, the Maya frequently responded to crises, such as famines, epidemics, and political or personal conflicts, through either temporary or permanent flight of individuals, families, or whole villages (Farriss 1984). The Spanish were very aware that many Maya chose to "vote with their feet" against Colonial rule (Farriss 1984:76), and that they only had themselves to blame if the Maya under their control fled. For example, in 1630, a new governor, Juan de Vargas, had formal charges brought against him by the royal officials of Yucatán; these charges accused him of misuse and *repartimiento* exploitation, which was claimed to directly result in a flight of *encomienda* Mayas into the fugitive zones, with as many as 20,000 relocating to La Pimienta (Jones 1989:197). Maya fleeing from working *encomiendas* resulted in a significant loss of labor power for the Spanish. This labor loss eventually became a motivating factor for the Spanish begin their final conquest of all Maya territories, with them realizing that only the conquest of Tah Itzá would bring an end to the flood of runaways from northern *encomiendas* (Jones 1989:127). The Spanish started this conquest as early as 1616 or 1617, but the final Maya resistance at Tah Itzá (in central Petén) was not conquered until 1697 (Jones 1989:125).

The second form of population movements that had an impact on Maya migration and the distribution of populations is drift. Rather than leaving the Spanish held territories entirely, many of the Maya who left their communities chose to simply move, or drift, to a more preferable community within the Spanish held territory (Farriss 1984).

> A large portion, perhaps most, of the Maya who left their communities chose not to escape from Colonial domination; they simply moved to another community within the pacified zone. These much more conservative moves within the same shared universe seem so aimless that they warrant the title of "drift". They are among the more mystifying phenomena of Colonial Maya history. Why should people have taken the trouble to uproot themselves to move from one community to another, a community that was essentially a

> carbon copy of the one left behind, offering the same way of life, the same rights, and the same obligations? What was gained, or what did people at least expect to gain from such a move? (Farriss 1984:200).

Drift was often apparently disorderly, and the actual impact it had on the populations on the frontier is unknown, however it is likely that individuals would move freely between many of the communities in Bacalar province (Jones 1989).

Dispersal represented a "serious challenge to the *congregación* program" (Farriss 1984:206) as it was effectively a reversal of the *congregación* process; families and individuals would move from congregated towns to rural hamlets (Jones 1989). The criteria and motives of the *congregación* system went against many of the norms of Maya society, and the territorial integration imposed on the Maya by the Spanish was not maintainable and would slowly fragment (Farriss 1984:206). There are records of the Maya reversing the friars' *congregación* system as early as the 1580s, where Maya would move to the bush and just reestablish previously congregated settlements or hamlet clusters (Farriss 1984:206-207). There was a proliferation of these satellite communities in the 1600s and 1700s (Farriss 1984:207). Many of these hamlets were consisted of one or more nuclear family groups, often with patrilineally-related males who cultivated *milpas* and land adjacent to one another (Farriss 1984:210). *Congregación*, and in turn dispersal, occurred most often in densely settled areas of the Yucatán; as such, dispersal was not believed to have been practiced frequently in the more sparsely populated Bacalar province, and there was likely little need for it at Tipu (Jones 1989).

There was a steady communication across the southern frontier, with a two-way movement of people, trade items, and information. The frontier was highly permeable in both directions, where “refugees, raiding parties, delegations from the Itzá, and other groups, and above all traders moved back and forth in steady if often clandestine contact” (Farriss:1984:18). This resulted in a single cultural system that had gradients of Spanish influence, with Maya areas not under Spanish control experiencing Spanish influence long before the fall of Tah Itzá (Farriss 1984). The frontier provided a sort of safety valve, where “the ease of escape may have lowered the Mayas level of tolerance, and it may also have checked their pugnacity predisposing them to a certain docility, but one with definite limits” (Farriss 1984:75-76).

Many of the towns in Belize and the Bacalar province were located on or near navigable waterways, which “provided ease of trade, communication, and primary economic activities (e.g. cacao production) above river banks considerable distances upstream and maritime activities on protected estuaries along the coast” Jones 1989:122). This also allowed for the passage of various Spanish personnel (priests, *encomenderos*, and traders) and others for travel (Jones 1989:122). “Their relatively easy accessibility – although it took several days to reach Tipu from Bacalar – makes us wonder how many more Maya towns there must have been in the more remote locations, on smaller rivers further upstream from the main branches.” (Jones 1989:122). Given that many records of the frontier were very poor, there were a lot of yet unknown factors contributing to the population movements of the Maya, and there potentially may be additional villages that do not appear on records that may be impacting the population of Tipu through factors like drift.

Tipu: Study Area and Skeletal Sample

Physical Setting

Tipu is located on the western bank of the Macal River, in the foothills of the Maya Mountains, near the modern village of Negroman, Belize (Figure 2.5). Tipu was a small, dispersed community, situated on two river terraces, with a Colonial period settlement that extended out over 40,000 square meters (Graham et al. 1985). Surveys of the areas around Tipu identified fertile floodplains suitable for farming cacao, and hillside terraces dating to the Classic or Postclassic that likely were used for farming *milpas* (Muhs et al. 1985); it is likely that the Tipu settlement extended significantly beyond the extent of the surveyed historic area.

The Macal River has an extensive tributary system and helps drain the eastern portion of the Maya mountains (Wright et al. 1959). Tipu's annual rainfall is around 1,400mm of rain a year (Wright et al. 1959). Many of the fertile floodplain and terrace soils at Tipu are a combination of granitic and metamorphic alluvium, largely derived from the Maya Mountains. There are small areas of alluvial fan deposits that are composed of local, limestone alluvium; however, the shallow, rocky nature of these deposits makes it unlikely they were used for agriculture (Muhs et al. 1985). The geology of Tipu and the surrounding areas are discussed in further detail in Chapter 3.

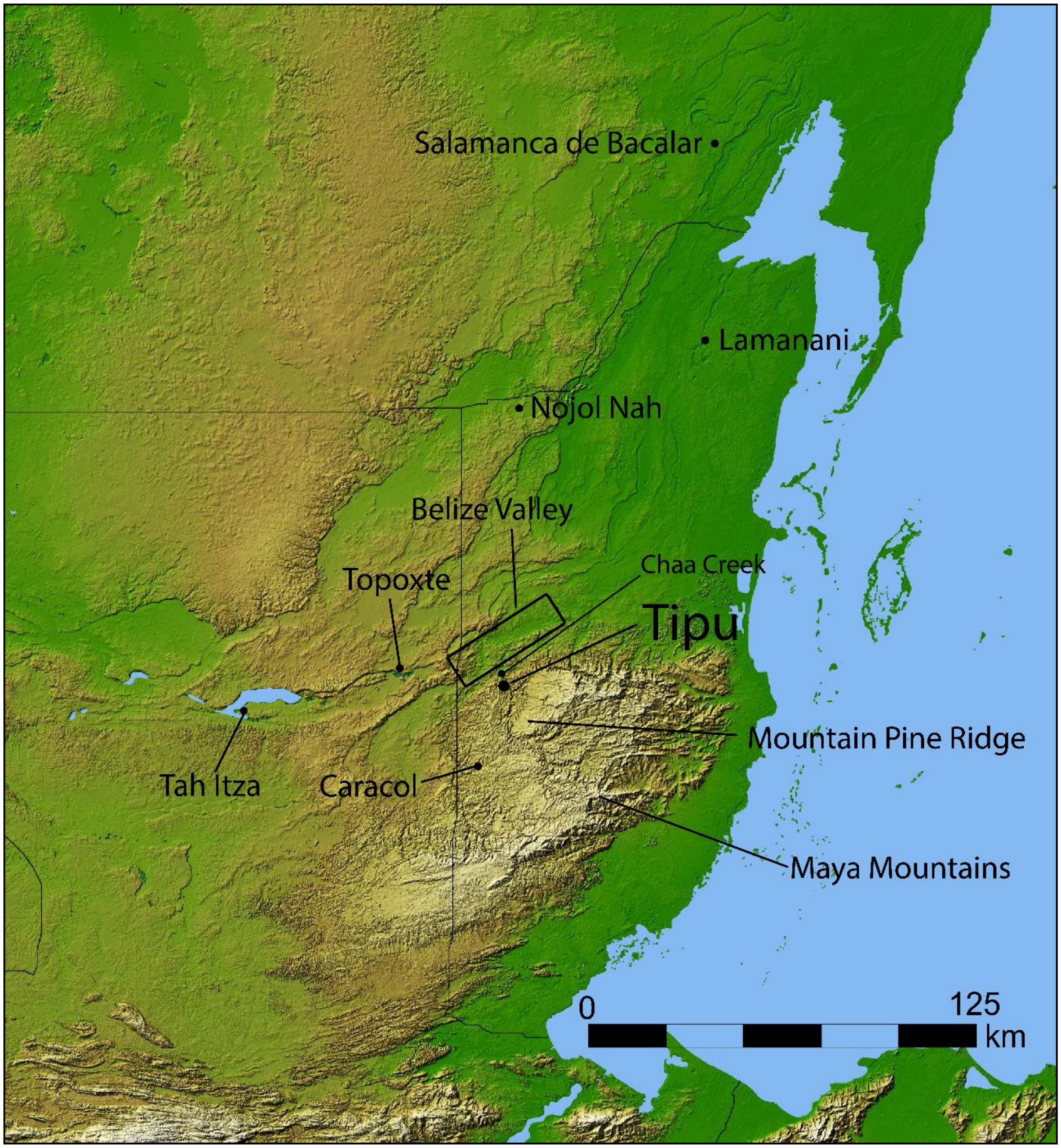


Figure 2.5. Topographic map of central Maya Lowlands showing several sites of interest. Map created using original open-source image provided by NASA JPL 2002 (photojournal.jpl.nasa.gov/catalog/PIA03364).

Contact Period and Spanish Interactions

Early Contact at Tipu

At the time of the Spanish arrival to the new world, Tipu is thought to have had an active and thriving population. Tipu, also referred to as Tipuj in some historical documents, is believed to be the likely location of the pre-Columbian political center of the Dzuluinicob provenience. There is scant historical documentation of the Dzuluinicob boundaries, although evidence suggests it may have spanned from the Sibun River to the Lower New River (Jones 1989:98). Ethnohistoric work by Jones (1989) found Tipu to be a consistent presence as an important regional cultural and political center during the span of the early Colonial period. The consistency of Maya political boundaries suggests it was likely an important political center before the arrival of the Spanish (Jones 1989:98), although it is possible that Tipu's presence as an important political center could have been more recent, and could have been established via similar processes seen with the Itzá in the Petén, where an exiled political group relocated to a region that was previously lightly populated (Jones 1989:99).

Tipu was the last in a string of *visita* missions extending south-southwest from Salamanca de Bacalar. The missions were along a river and land route that extended over 200 kilometers southeast of Bacalar. Around 100 kilometers to the west of Tipu was the headquarters of the Can Ek dynasty at Tah Itzá on Lake Petén Itzá. Ethnohistoric records are unclear about what was happening at Tipu immediately following the 1544 conquest of the Yucatán, or when the Spanish formally established a Spanish settlement and church at the already existent village of Tipu (Graham 2011:204; Jones 1989). Historic records from the late 1560’s indicate Tipu was already part of a tribute paying *encomienda* by 1543-44, and that the purpose of Garazon’s visit to Tipu in 1568 was with the intent of reconquering it and executing a major *reducción* effort before the town was lost completely (Jones 1989:51; Graham 2011:224). The church may have either been raised during a single construction event during Garazon’s *reducción* efforts of the late 1560s (Graham et al. 1989), or, it may have been initially built sometime between 1542 and 1550 and continued to remodeled through reconstructions, repairs, and additions to the building over time (Graham 2011:225).

Reducciones, Resistance, and Rebellion at Tipu

In the early 1600s, under threat of total collapse of the Bacalar province, the mostly absent *encomenderos* attempted to re-secure their control over the more remote villages in the province, particularly in the region of Tipu (Jones 1989:132). The increase in Maya resistance to the Spanish is likely the result of the rise of *reducciones* elsewhere on the frontier. The first documented *reducción* at Tipu occurred around 1608, suggesting that Tipu and many of the other more remote mission towns in the Bacalar province had once again fallen out of Spanish control (Jones, et al. 1986; Jones 1989:132). In 1615, *reducciónes* carried out in the Belize River area near Tipu created the *reducción* towns of Petentzub and Zaczuz (Jones 1989:132, 193). Recognizing the need to better control the region and secure the frontier to aid in the westward expansion to the Petén, the Spanish combined Tipu and the two newly formed *reducción* towns into a single *encomienda*, sending a new *encomendero* to help control the towns and collect tribute (Jones 1989).

This time period also marked the beginning of concerted attempts by the Spanish to extend their control into the Petén, and Tipu's strategic position on the frontier was critical for the Spanish to achieve this. Franciscan priests that stayed at Tipu from 1618-1619, used the town as a base for visits to the Itzá ruler Can Ek in an attempt to convince him to give up the worship of the indigenous gods and convert to Catholicism under Spanish rule, as was foretold by several Maya k'atun prophecies (Jones, et al. 1986; Jones 1989:142-148). The Franciscans visiting Tipu saw it as a "spiritual garrison", critical for the conversion of the infidels in the area (Jones 1989:138.) A later 1623 expedition from Tipu to Lake Petén Itzá resulted in a rather violent death for the Spaniards and all 80 Tipuans that traveled with them to help carry their baggage (Jones 1989:176-178). These efforts to convince the Itzás to come under Spanish control were highly unsuccessful, and actually acted to strengthen the Maya resistance in the Tipu area, leading to a resurgence in traditional Maya culture at Tipu and the establishment of a powerful anti-Spanish truce between the Tipuans and Itzás (Jones, et al. 1986; Jones 1989:142-148).

In 1638, the alliance Tipu formed with the Itzá helped lead to a widespread rebellion centered at Tipu. This rebellion would be successful in removing all Spanish presence (both civil and ecclesiastical) from the region between Salamanca de Bacalar and Tipu for over 50 years (Jones, et al. 1986; Jones 1989:189). By this time several factors, including poor management, caused the Spanish control over their remote frontier region to once again become tenuous. Maya representatives from both Tipu and villages around Bacalar had traveled to Merida to log complaints detailing serious mistreatment at the hands of the Spanish officials (Bacalar) and priests (Tipu) (Jones 1989:205). This time also coincided with k'atun prophesies made by Maya priests, which predicted the K'atun 3 Ahau (which began in 1638) was a time of “natural disaster and rebellion” (Jones 1989:190). During this period, the Tipu Maya leaders employed a strategy of passive resistance against the Spanish by spreading word in the *encomendero* towns throughout the province, encouraging them to abandon their towns and to join the resistance at Tipu, resulting in widespread loss of Spanish control throughout the Bacalar province (Jones 1989:190-191). Sometime during late 1639-1642 the passive anti-Spanish resistance movement centered at Tipu (basically encouraging resistance through flight) developed into an outright active rebellion involving the destruction and burning of towns and resettlement of fugitives around Tipu (Jones 1989:210, 213-240). Tipu would soon be established as the Maya political center of the region in 1642 (Jones 1989:190), and with apparent military and moral support from the Petén Itzá, became a semi-independent Maya ritual, military, and political center for the next three k’atuns (until 1695) (Jones 1989:214). “By 1658 the Maya frontier had taken on an identity of its own, with indications of wide spread religious millenarianism and movements towards greater independence from Spanish control” (Jones 1989:25).

Despite the strengthening of Tipu as an independent Maya center, during the late 1600s the Spanish presence once again began to be felt in the region, as the governor in Merida pushed to regain control of the old Bacalar province and finally defeat the Itzá Maya. A Spanish entrada into the region in 1678-80 resulted in several, mostly peaceful, *reducciones*, including one at Tipu (Jones 1989:245-48). Jones (1989) believes that the Tipuans move to temporarily allow missionaries into Tipu to baptize around 600 individuals may have been a strategy to allow just enough external contact with the Spanish to temporally stave off a permanent Spanish presence in the town (Jones 1989:248). The inhabitants of Tipu did not actively try to make peace with the Spanish until 1695, now understood to be somewhat tied to the k'atun prophecies predicting the fall of the Itzá Maya in 1697. The Spanish would use Tipu as a base from which to launch their attack on Tayasal, thus conquering the Itzás in the Petén. The Spanish attacked and successfully conquered Tah Itzá in March of 1697 (Jones 1998).

After Tipu sustained multiple attacks by both the British for slaves and by groups of Mopan Maya, Spanish troops relocated the entire community to the shores of Lake Petén Itzá in 1707 (Jones, et al. 1986; Jones 1999). A settlement referred to as "de los Tipues" somewhere near the presidio was recorded in early 1708; however, its exact location and further information on the fate of its inhabitants are unknown (Jones 1999:408).

Colonial Migration to Tipu

Tipu was a key player on the frontier between the Spanish held Yucatán peninsula and the Itzá Maya held Petén. The population of Tipu was influenced by several different forces and players. Many of the processes Farriss (1984) identifies in the Northern Yucatán are also at work in the southern frontier. Following the conquest of the Yucatán peninsula the frontier became a place of refuge for those who sought to flee, hide, or escape from Spanish religious and economic domination (Jones 1989). During the early Colonial period, flight was one of the most important forms of population movements on the southern frontier, and acted to directly impact the ability of the Spanish to govern the entire southern lowlands (Jones 1989).

Beginning in 1615, a series of events resulted in an increase of flight to the Bacalar province, and dramatically disrupted the lives of the Maya living there; these included the multiple *reducción* measures attempted by the Spanish in the Yucatán, a dramatic increase in the degree of flight from northern Yucatán towns, a four year famine in the north caused by a four years of consecutive failed harvests due to massive locust infestations, and the continued allure of the Pimienta region for refugees throughout the Yucatán (Jones 1989:198-199). During the 1630's migration strategy shifted in favor of migration to more inaccessible inland locations toward the Tipu region. Motivation for this may have been to avoid resettlement near Bacalar, or to avoid capture by the pirates on the coast (Jones 1989:122).

As a frontier town, Tipu also experienced the periodic efforts by Maya to centralize the population of the Bacalar province by periodically moving people to Tipu. During the 1630's and 1640's these efforts by the Maya worked to shift the control of the Tipu region from the Spanish to being controlled by the Maya. "This pattern of population movement was the obverse of the Spanish practice of *reducción* or *congregación* and may have had some of the same nonvoluntary aspects as the Colonial version of population centralization" (Jones 1989:121).

In 1638 a letter from the Governor of the Yucatán to the Spanish king documented the beginnings of the collapse of control in Bacalar, likely the result of mistreatment and exploitation by mestizos living in the region, by a tyrannical priest, and the Bacalar *vecinos*. The Tipuans would end up resisting against the Spanish in control of Bacalar in 1637, marking the beginning of a period of flight from Tipu; by 1638 nearly a quarter of the Tipu population had abandoned their homes out of fear of the inhabitants of Bacalar. By 1642 this resistance grew into a full rebellion, and eight towns or over 300 families are believed to have congregated to Tipu. During this rebellion, the Tipuans and other Maya of the Bacalar province destroyed Spanish and Christian artifacts, and are believed to have returned to more traditional Maya cultural practices (Jones 1989).

Population Fluctuations on the Southeastern Frontier

After the arrival of the Spanish the population reduction of the Yucatán Peninsula was swift and dramatic. There is little direct evidence for prehistoric population sizes, however, some ethnohistoric documents do provide insight into initial population declines. Early historical records from 1531 describe numerous densely populated towns of several thousand people in the Cochua, Uaymil, and Chetumal provinces. One Spanish observer, Bienvendia, witnessed marked declines in several villages by 1548, where towns went from 500 to 1000 houses to less than 100 houses in a little over a decade (Jones 1989). The economic impacts of these marked population declines were felt by the Spanish *encomenderos* as early as 1551. Tributary estimates for 1582 calculate the entire population of the province of Salamanca de Bacalar was around 856 Maya (Jones 1989:45). Even taking into account flight into unconquered territories after the region was concurred in 1544, this population loss was substantial (Jones 1989). Although some population decline may have been the result of warfare with the Spanish, the majority was likely the result of the introduction of European diseases to the region. Furthermore, despite continuous migrations of northern Maya to the southeast frontier, there appears to have overall been little growth in the tributary populations of the area during the Colonial period – certainly not enough to match the number of Maya reported to be fleeing from the north (Jones 1989:110). Periodic disease epidemics and malaria that plagued certain regions of the Yucatán in Colonial times may provide one possible explanation for the disparity in these numbers (Jones 1989:110; Farriss 1984:57-63).

The apparent continuity between the Tipu Postclassic and Colonial occupations suggests much of the initial population at Tipu were likely descendent from those living there in Prehispanic times. Most early historical records for Tipu do not make mention of actual population estimates. When population estimates were recorded for Tipu they usually are from tributary population counts from *encomendero* records. Table 2.1 summarizes population estimates for Tipu derived by Jones (1989: 114-116). The earliest population estimate for Tipu was made during the *reducciones* of 1618 and suggest a population of around 343 individuals living at Tipu. An apparently rapid population reduction occurred in the following years, likely a result of inhabitants of Tipu fleeing the towns for the surrounding forests, and by 1622 the population had dropped to approximately 30 people total. *Reducción* efforts instituted by friars coming to collect tributes in 1622-23 were successful in rounding up Maya living in the surrounding forests, and it is believed the population may have reached numbers similar to 1618 population counts. In 1623 as many as 80 men from Tipu were killed while accompanying the Spanish to Tah Itzá, which would have reduced the population to around 263. The population at Tipu exploded after the 1638 rebellion, believed to in large part due to the *reducción* efforts lead by the Tipu rebels throughout the Bacalar province, relocating Maya from throughout the province to Tipu. By 1643 the population of Tipu is believed to have reached over 1,000 people. A 1655 Spanish census taken at a nearby town estimates that there were over 1,000 people living at Tipu and the surrounding area. Between 1678-80 Franciscans were permitted to visit Tipu and baptized around 600 individuals; Jones (1998) suggests this indicates a population of around

700 individuals. By 1696 kinship and political ties between Tah Itzá and Tipu reach a high point, and there is record of Tipuans establishing residence in the Yalian, a town east of Petén Itzá. By 1697 the population of Tipu and the adjacent community of Baltok was around 400 individuals (Jones 1989; Thompson 1972).

Tipu's population was very fluid, and experienced wide fluctuations in population throughout the 1600's. These population figures and fluctuations do not accurately portray the populations throughout the greater region, but rather reflect a highly dynamic and volatile political climate resulting in large scale and dramatic movements of peoples within a relatively short period of time. Tipu's location on the boundary between two important, major spheres of regional power is reflected in its highly mobile population. The major modes of migration that may have impacted the populations at Tipu and other Maya resisting Spanish rule are flight, fight, and drift (Farriss 1984); these are addressed previously.

Table 2.1. Seventeenth century Tipu population estimates based on ethnohistoric data (from Jones 1989:116).

Year	Population
1618	340
1622	30
1623	340
1643	1,100
1655	1,000
1680	700
1697	400

Trade and Subsistence at Tipu

During the Colonial period, Tipu's strategic position as a riverine town between Bacalar and the Petén allowed it to be an important node for long distance trade in many items, including cacao. Tipu functioned as an important stop in trade along riverine and overland routes between the Petén and Salamanca de Bacalar, and from the upper Belize River area, through La Pimienta, and to the northern Yucatán (Jones 1989:103).

Many of the towns in the southeastern Yucatán produced maize, beans, squash, and other horticultural products for subsistence. Certain goods, such as cacao, salt, and other goods, did not grow as well in all regions and so became an important trade item. During the Spanish Colonial period, Tipu was one of a number of communities in the Dzuluinicob province that grew cacao for both tribute and trade in plantations along the rich soils of the riverbank (Jones 1982; Jones 1989; Muhs et al. 1985). Many of the Maya settlements in the Dzuluinicob province were situated along rivers or streams, ideal locations for the production of cacao. Cacao does not grow well in the Petén, and historical accounts from Cortez's visit to Tah Itzá indicate that the Itzá and their neighbors had to rely on the importation of cacao from elsewhere (Jones 1989; Villagutierre Soto-Mayor 1983), most likely from allies to the south and the Dzuluinicob province to the east (Jones 1989:102). Visits to Tipu by two Franciscan priests in 1688 described an orchard of over 8,000 cacao trees grown by the *masestro de capilla*, an apparent immigrant from a town north of Campeche (Jones 1982). Geoarchaeological investigations in the Tipu floodplains have identified buried soils and sediments with ideal chemical and physical composition for cacao cultivation, as well as buried demarcation walls on the floodplain believed to have been constructed during the Late Classic or Postclassic (Muhs et al. 1985).

Archaeology of Tipu

Archaeological Investigations of the Macal-Tipu Site

Initial efforts to determine the location of Tipu were made by the British archaeologist Sir J. Eric S. Thompson, who investigated Spanish records to identify information on the Spanish in what is today the Cayo District of Belize (Graham 2011; Jones et al. 1986; Jones 1989; Thompson 1972). Thompson identified a community, once located at a specific bend in the Macal River, as being a likely location of an early Spanish period church (Thompson 1972:11). Grant Jones later followed Thompson's advice (Jones et al. 1986), and in 1978, along with David Pendergast, surveyed an area approximately nine kilometers south of the town of San Ignacio in an attempt to locate the church and surrounding community (Jones et al. 1986). The area surveyed, known today as Negroman by the locals, is a cattle ranch and farm owned by the Espat family (Jones 1989, Graham 2011). During the 1970-80s this land was used as a cattle pasture, however, more recently has been used as a papaya farm (Jones, et al. 1986; Graham 2011). During the course of this survey, Jones and Pendergast identified a series of pre-Columbian mound structures, as well as a distinctive, undulating area in one of the cattle pastures at Negroman. Jones and Pendergast believed these undulating depressions to potentially represent the ruins of Colonial Tipu (Graham 2011, Graham 1991, Jones, et al. 1986).

The first archaeological investigations at Negroman-Tipu were conducted from 1980-1982 and were directed by Robert Kautz and Grant Jones, with the assistance of Claude Belanger. During this period the entire site was surveyed and mapped. Classic and Postclassic structures at the site were investigated, and quadrants were sampled in an attempt to locate Colonial buildings, however, most structures sampled during this time were found to be pre-historic (Graham 1991; Jones, et al. 1986; Jones 1989). It was not until the end of the 1980 season that portions of the first historic structure, the church (structure H12-13), were identified with excavation of the church not beginning until 1981 (Graham, et al. 1985, Graham 1991). Several test pits placed in the church exposed burials, which were excavated by students under the direction of Mark Cohen (Graham 2011:191).

In 1984, Elizabeth Graham assumed the direction of archaeological excavations at Tipu, with fieldwork being conducted during the 1984, 1986, and 1987 field seasons (Jones, et al. 1986, Graham 2011). For this phase of excavations, Graham focused on the excavation of the buildings surrounding what appeared to have been a historic-period community center or central plaza, as well as features directly relating to the church construction (standing walls, collapse debris, sacristy, altar area, and nave features) (Graham 2011; Jones, et al. 1989). The ruins of a Postclassic ceremonial center to the east of the church were also investigated at that time (Graham 1991). Mark Cohen led the excavation of the burials located in and around the church.

Excavations at Tipu were again resumed for several weeks in 2006 by Ran-Ju Song (Song and Zubrzycki 2007; Song 2008). The focus of Song’s investigations centered on further elucidating the extent of Colonial activity at Tipu through the use of test-pits and excavations (Song and Zubrzycki 2007). These units were also placed in the interest of potentially locating those portions of the population notably underrepresented in the church skeletal assemblage- the infants and elderly (Song 2008). These excavations identified at least one new Colonial period structure at the site (likely domestic), along with artifacts dating to the Postclassic and Colonial periods. No additional burials were encountered during these excavations (Song 2008).

Tipu Archaeology: Previous Archaeological Research

The excavations at Tipu resulted in the discovery of a church structure, its associated plaza, and multiple Postclassic and Colonial period structures (Graham 2011). The pre-Columbian Maya buildings at Tipu were built on low, faced platforms. These platforms were either bordered by a single row of stones or were elaborately terraced structures. Both types of structures were only constructed and used during the Postclassic period. Excavations discovered evidence of some Colonial structures built upon earlier Postclassic strictures, utilizing the older building to add height to the structure (Graham 1991). Although archaeological evidence indicates there was a probable continuity in population from the Postclassic to the Colonial period, there is a major distinction in the archaeological styles between the two periods. The Colonial period brought in major changes in architectural styles, changes in building design, and construction techniques (Graham 1991).

The church was located on a terrace, near the western bank of the Macal River, above the floodplain and overlooking the river. The mission at Tipu consisted of a small church bordering a courtyard and a semi-detached church related structure, possibly a residence, which was built near the edge of the terrace. These buildings and others were arranged around a rectangular plaza area. These buildings and various cobblestone pavements concealed a considerable spread of debris from Postclassic occupation, as well as the late Postclassic buildings; excavations found the foundations of the Postclassic buildings were incorporated into the Colonial period construction to add height to the structure. This mingling of pre and post Columbian constructions affected community character and stability over the years between 1544 and 1707 as Tipu passed back and forth between Maya and Spanish control (Graham, et al. 1989, Graham 1991, Jones 1995).

Figure 2.6 shows the excavation plan view and section view of the Tipu church structure. The church itself was an open *ramada* chapel, with a thatched roof, and with short, 1.5 meter tall walls on the west, south, and north sides, while the walls around the altar were ceiling tall. The church was 23 meters long, 8 meters wise, with polygonal east and west ends. The eastern portion of the church building contained the altar and chancel, with several steps leading up to the circular stone altar (Graham 2011).

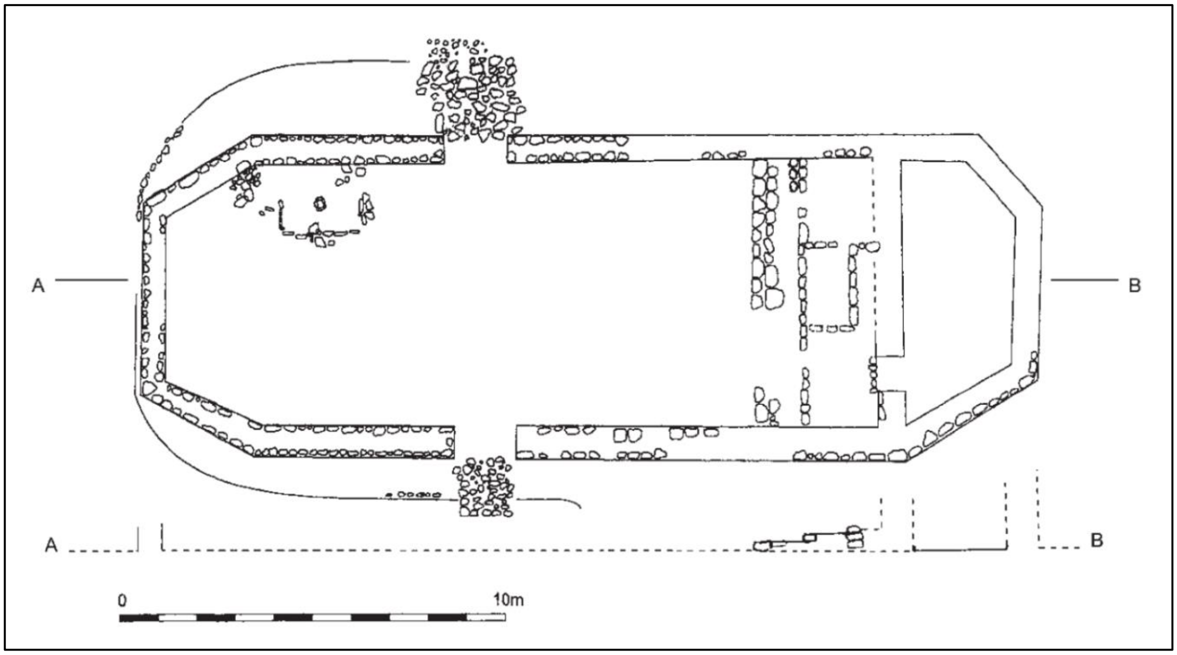


Figure 2.6. Tipu plan view and section of the Tipu church structure, Str. H12-13. Drawing by Claude Belanger, reprinted from Graham 2011:225.

Overall, the church architecture and associated mortuary contexts clearly represents behavior consistent with “post Colombian, non-Maya practices” (Graham 2011). Over 585 burials were recovered from under or to the north, west, or south of the church at Tipu; no burials were recovered from the region to the east of the church. Many of the skeletons were buried in traditional Christian pattern, extended and supine, with their heads oriented to the west, and with their hands positioned over their abdomen or chest. The presence of iron nails for several burials indicates they may have been buried in coffins (Graham 2011). Very few deviations to this pattern were observed. There were a few flexed burials, one prone burial, and two females were buried apparently holding hands.

There is evidence that the cemetery may have continued to be in use even after the church itself was demolished. Excavations north of the church located a possible courtyard or atrium (churchyard) located directly north of the church. Many of the burial features in this area appear to have cut through the pavement stones, indicating deposition after the Colonial period construction of the church (Graham 2011). Several burials also appear to have cut through the foundations of the structure directly north of the church that may have functioned as a rectory residence. As elsewhere in the cemetery, most of these individuals were interred in a traditional Christian fashion (head to the west, facing east, and with the arms usually folded over the chest) (Graham 2011). The presence of church collapse debris over the rectory and associated buildings indicates that the Maya were continuing to bury their dead in accordance with Spanish Christian tradition, after the church and all its associated buildings had collapsed (Graham 2011:18).

There is continuity in the artifact inventory from the Postclassic to the Colonial period. The conquest seems to have had very little effect on local pottery styles and production. Graham (2011) found that the stylistic changes that are noted are within what normally occurs through time, even if the conquest had not occurred. Several Postclassic-style animal and human figurines were found in midden deposits reused as construction material. Graham (1991) suggests their presence in Colonial deposits may suggest the Tipuans continued activities frowned upon by the Spanish, potentially collaborating evidence of idolatry reported in ethnohistoric documents.

Changes in lithic technology and production at Tipu appear to be minimal. Chert continued to be the main material used in tool production for both the Postclassic and Colonial time periods. The point types identified largely consisted of side notched points and small bipointed bifaces (Graham 1991). Granite is the primary raw material type used for groundstone at Tipu (Graham, personal communication 2018).

A variety of European trade items, including European majolica ware and olive jars, iron artifacts, and glass beads were recovered, suggesting use of the site continued into the late 16th and early 17th century (Graham 2011). The majolica and olive jars were only present in small quantities, and their location near the church and the plaza suggest that their use may have been limited to visiting Spanish or higher status Christianized Maya (Graham 2011).

Limited mortuary artifacts were recovered from the Tipu Colonial burials; however, what was recovered clearly showed European manufactured goods had travelled as far as Tipu (Graham 2011). Needles were the most common grave good, many of which were brass, and may have been used to fasten burial shrouds (Graham 1991). Needles, along with other gifts like crosses, knives, rosaries, and glass beads were common gifts that priests carried with them from Merida and would hand out while proselytizing with locals (Jones

1989). Other metal burial goods were present in the form of copper, silver, and brass rings, silver earrings, pendants, lacetags, glass bead necklaces and bracelets, iron nails, and pre-Columbian style bells (Graham 1991, 2011). Locally made *Spondylus* shell jewelry was also found. One individual (MT-446) was buried with a storage chest, represented by the nonperishable lock plate, hinges and nails (Graham 2011:233), and a young adult female (MT-96) was buried with a thurible, or censer, believed to be of local origin (Graham 2011:154). Beads made from jet and amber were also recovered; chemical analysis of the amber bead suggest it is of Baltic origin, while the jet beads are consistent with Spanish origin (Lambert et al. 1994). Many of the children buried at Tipu are more elaborately adorned than the adults. Only 23 of the 585 burials contained jewelry; of these 16 are children. This may be a result of the catechizing efforts of the priests at Tipu (Graham 1991).

Bioarchaeology of Tipu

The Tipu skeletal population consists of over 600 individuals excavated from both Postclassic (~900 AD to 1521 AD) and early Colonial period (1521 AD until the early 1700s) contexts. The excellent skeletal preservation and large sample size makes Tipu one of the most important skeletal assemblages in the Maya area, and offers a rare opportunity to use a data driven methodology as a means to investigate indigenous resistance through wide-scale population migrations. Because the skeletal sample size and preservation seen at Tipu is much better than usually seen in the Maya area, previous research has extensively documented the skeletal and dental health (Danforth 1989; Danforth 1994; Danforth et al.

1997; Emery 1990; Farriss 1984; Harvey 2011; Wrobel et al. 2002), long bone metrics and functional morphology (Ballinger 1999; Wrobel et al. 2002), demography (Ballinger 1999; Jacobi 1996; Jacobi 2000; O'Connor 1995), biological distance and genetic structuring (Jacobi 1996; Jacobi 2000; Lang 1990; Wrobel 2003).

The importance of Tipu's skeletal population is demonstrated by the number of successful undergraduate, masters, and doctoral level research projects that have been completed using it as a resource. Until recently the collection has been housed at SUNY Plattsburgh under the care of Mark Cohn and at the University of Vermont. In 2013 Marie Danforth agreed to provide a permanent curation space at the University of Southern Mississippi and is currently in the process of updating the storage system used for the collection, including a full re-inventory of the remains and rectifying other curation issues that have accumulated over the last thirty years.

Health and Paleopathology

Numerous studies undertaken over the last 30 years have thoroughly documented the health of the Tipu population. Frequencies and patterns of early childhood stressors are relatively low. Moderate frequencies of enamel hypoplasias were documented in the Tipu Colonial population; however, most enamel defects are relatively mild (Danforth et al. 1997; Harvey 2011), and Tipu females have lower frequencies of enamel hypoplasias and Wilson bands than Tipu males (Danforth 1989; Danforth et al. 1997). Overall, the above indicators are not generally associated with severe nutritional distress or epidemic infections, suggesting that the Tipu population was generally healthy and did not suffer from an extremely high level of childhood malnutrition such as would leave evidence on the dentition. Males have significantly higher frequencies of porotic hyperostosis and cribra orbitalia than females (Cohen et al. 1994; Danforth et al. 1997); because porotic hyperostosis and cribra orbitalia can be used as general indicators of childhood metabolic stress, this suggests females experienced less metabolic stress during childhood.

Frequencies of pathology on the adult skeletons are also relatively low. The adult skeletons show relatively few lesions relating to systemic infection, localized infection, and trauma (Armstrong 1989; Danforth et al. 1997). Males tend to have higher frequencies of periosteal reactions than females (Danforth et al. 1997).

During the early Colonial period, Tipu's remote location on the Maya-Spanish frontier may have helped to act as a buffer against the negative health consequences experienced in more easily accessible locations in the Yucatán peninsula, allowing for a continuity in many of the lifeways practiced prior to the arrival of the Spanish. Comparisons between the Colonial population at Tipu and pre-contact populations in the Petén show that the two populations have similar mean statures and incidences of indicators of childhood stressors like Wilson bands and enamel hypoplasias (Danforth 1989; Danforth et al. 1997). Tipu also has fewer incidences of enamel hypoplasias than the contemporaneous Colonial period site of Campeche, located in the northern Yucatán (Harvey 2011). Similar frequencies of caries between pre-contact sites and Colonial Tipu have also been identified, providing potential evidence for a minimal impact of the Spanish on the diet of the Tipuans (Danforth et al. 1997). Indicators of metabolic stress, such as porotic hyperostosis and anemia are also significantly lower at Tipu than observed at pre-contact sites in the Petén (Danforth et al. 1997); Lamanai also has lower rates of anemia than Prehispanic sites, indicating this change may be due to lower population densities in the Colonial period (White 1986, Danforth, et al. 1997). Overall the pathology data suggest the individuals in the Tipu population had adequate access to resources and relatively low incidence of epidemic diseases than seen in areas of the Yucatán peninsula with greater Spanish influence.

Biological Distance

To date, the biological comparison of Tipu individuals to other Maya groups has provided little concrete evidence to support the idea that the 588 interred individuals were of northern Yucatán origin (Jacobi 1996; Jacobi 2000; Wrobel 2003). Biological distance analyses have led to two main conclusions: (1) Tipu individuals may be significantly biologically divergent from other Maya populations (Jacobi 1996; Jacobi 2000); and (2) little, if any genetic admixture occurred between the Spanish and Tipu population (Jacobi 1996; Jacobi 2000).

The analysis of the Tipu dental remains provides some biological distance information for the individuals living at Tipu. Jacobi (1996); Jacobi (1997); Jacobi (2000) found that the dental morphology of Tipu individuals differed significantly from many comparative samples, including those from the historic period at nearby Lamanai. This may be due to several factors, including more admixture from northern Yucatán migrants at Lamanai than Tipu and the presence of mestizos buried within the population (Jacobi 2000). While the Tipu population as a whole appears quite homogenous, the presence of clusters of individuals with rare morphological dental traits may suggest familial groupings within the placement of burials in the church (Jacobi 1996; Jacobi 2000). Lang (1990) compared the dental morphology of a subset of the Tipu population to Postclassic and Colonial period samples from nearby Lamanai and found there to be a weaker expression for many traits in the historic populations compared to the prehistoric, potentially suggesting an intrusion from a foreign or biologically different population to the region during the historic period.

Armstrong (n.d.) conducted an unpublished study examining the robusticity of the Tipu population through the use of a robusticity index and measurements from the femur, tibia, and humerus (Cohen et al. 1989; Jacobi 2000). Armstrong found that the Tipu males buried at the front of the church were significantly different than those buried outside for 17 different measurements, with the mean values of measurements for males buried inside the church being higher than males buried outside. Males buried at the front of the church were significantly different than those buried at the back of the church for several measurements of the femur and tibia. Fewer significant differences were present between the males at the back of the church and those outside (Cohen et al. 1989; Jacobi 2000). Overall the females appeared to represent a homogenous population (Cohen et al. 1989; Jacobi 2000). A possible implication of this work is that the male individuals at the front of the church may represent a different population than the rest of the church, potentially the earliest or original Tipu population (Jacobi 2000:175). A more recent study of musculoskeletal stress markers using 3D scanning found Tipu males to be fairly homogenous throughout the cemetery, with only minor evidence that males inside the church were more gracile than those outside (Noldner 2013). Males and females varied in overall robusticity, however similarities in upper long bone cross section morphology suggest males and females were likely doing similar upper arm activities (Noldner 2013). For females, those buried near the nave in the front of the church and in the atrium to the north of the church were the most gracile when compared to females from the rest of the cemetery and those from several pre-contact Maya sites. Similarities between musculoskeletal stress markers between the Colonial period individuals at Tipu and the pre-contact Maya buried at nearby Cavesbranch Rockshelter suggest that there was no discernable increase in activity patterns with the arrival of the Spanish (Noldner 2013).

More recently Elwess and colleagues (2015) have sequenced the aDNA of 25 individuals at Tipu. All 25 individuals sampled have haplotypes B, C, or D, all strongly indicative of Native American ancestry (Elwess et al.). Although this sample size is small, it provides additional evidence for the lack of European genetic admixture in the population.

An important consideration to any study looking at the Tipu population is that Tipu was not a closed population. Ethnohistoric records document both Maya from the northern Yucatán fleeing to the frontier region, including Tipu, as well as the relocation of individuals from smaller, surrounding communities to Tipu by the Itzá Maya (Jones 1998, Graham 2011). All of this may have contributed to the heterogeneity observed at Tipu.

Cultural Modifications

Culturally modified dentition was documented on the teeth of eight Colonial individuals at Tipu (MT4, MT67B, MT81, MT124, MT141, MT174, MT279, MT317); none of the Postclassic period individuals have modified dentition (Havill et al. 1997). The modifications primarily consist of single or double v-shaped grooves on the occlusal surface of maxillary and mandibular central and/or lateral incisors. Two individuals had grooves on the medial and distal portions of their canines (Jacobi 2000). Following Romero's classification system, Types A-1, A-2, C-2, C-5, and C-9 are represented (Havill et al. 1997). Six of the eight individuals were buried inside, under the church (Jacobi 2000). Jacobi (2000) suggested that the individuals with culturally modified dentition may represent the earliest population or original “native” Tipu population that was converted by the Spanish, with the practice of cultural modification becoming more infrequent as more people living at Tipu came under Catholic influence (Jacobi 2000).

Culturally modified cranial shape was mostly absent or unobservable in the Tipu skeletal population (Cohen et al. 1997). Possible cranial modification was only observed on one individual, MT-301X.

Diet

The excavations at Tipu yielded a plethora of faunal remains from both Postclassic and classic period contexts. Analysis of the faunal assemblages found that the Tipu population experienced a relatively stable diet from the middle Postclassic period through to the Colonial period; this stability was not seen at other mission sites, including Lamanai (Emery 1999). This suggests that the patterns of subsistence at Tipu was not markedly affected by the arrival of the Spanish.

Trace element analysis to examine diet has been undertaken on a small population of individuals from Tipu (Bennett 1985). Although preliminary, the results indicate the individuals examined were eating a diet composed of cereals, grains, and meat.

Paleodemography

A paleodemographic analysis was undertaken on the Tipu skeletal sample to better understand patterns in mortality at the site (O'Connor 1995). Hazard models conducted on the skeletal sample suggested mortality increased during the first few years of life, remained high during childhood and adolescence, and declined through middle adulthood (O'Connor 1995). She found the Tipu age of death pattern was consistent with the ethnohistoric documents, and suggested that the Tipu skeletal population was consistent with a “declining, largely refugee population which experienced relatively intermittent but oscillating cycles of infectious disease epidemics” (O'Connor 1995). This interpretation may be a little simplistic. Paleodemographic studies rely on an assumption of population stability (Hoppa and Vaupel 2002); historical records suggest Colonial Tipu experienced a significant amount of in and out migration, which would mean Tipu was in no way a stable population. Although there is no direct evidence of epidemics in the Tipu skeletal assemblage, there were at least 10 widespread epidemics in the Yucatán peninsula and Guatemala between 1566 and1699. Even though Tipu was a very remote and low population density community, there is no reason to believe that infectious diseases didn’t also reach the inhabitants of Tipu, albeit less frequently than in more densely populated or urban areas (O'Connor 1995).

CHAPTER III

METHODS FOR DETECTING MIGRATIONS AND POPULATION MOVEMENTS IN THE ARCHAEOLOGICAL RECORD

Identifying Migration in the Archaeological Record

An essential aspect of archaeological research on migration is to provide empirical data for the occurrence of migration. Anthropologists have explored a variety of means to identify evidence of migrations in past societies using linguistic, material culture, biological evidence, and ethnohistoric records. In archaeology, foreign goods and abrupt changes in material culture have been used as proxies to identify.

The biological analysis of populations provides some of the most important empirical data for identifying migrations. Genetic data, when available, allows molecular anthropologists to study population movements and gene flow through either the examination of genetic similarities between two modern populations or by comparing genetic data among ancient populations (Bolnick 2011; Hunley 2011). Phenotypic data obtained from metric and nonmetric observations of the skeleton or dentition may also be used to estimate the genetic similarity between groups. Commonly referred to as biological distance analysis, the analysis of phenotypic human biological variation is utilized as a proxy for investigating gene flow, the origins of populations, micro and macroevolution, and long-distance migrations in the past (Buikstra et al. 1990; Larson 1997). Biological distance analysis has also been applied to investigate intra-cemetery differences within a population

(Stojanowski and Schillaci 2006) and has been a mainstay of bioarchaeological research for many decades.

Techniques developed in life sciences and geosciences have recently been utilized by biological anthropologists, archaeologists, and bioarchaeologists to provide the data required to identify migrants. Biogeochemical analyses are now a robust method in biological anthropology that provides a tool to directly identify individual migrants at an archaeological site, rather than relying on cultural remains as proxies. Studies in biology, geology, ecology, and anthropology have demonstrated the usefulness of stable isotope ratios to spotlight migrants through a diverse range of applications. In archaeology, biogeochemical analyses have proved to be very powerful and useful indicators for movements of ancient people, as well as identifying diverse patterns in mortuary treatment for individuals based on birth place (Bentley et al. 2007; Buikstra et al. 2004; Knudson 2004; Knudson et al. 2009; Knudson et al. 2015; Price et al. 2007; Price et al. 2008; Price et al. 2010; White et al. 2007; Wright 2005b; Wright et al. 2010; among others). Stable isotope ratios are useful for identifying migration in the archaeological by comparing values obtained from skeletal and dental tissues to local geology and climate in order to provide information about place of residence during enamel or bone formation (Ericson 1985; Ericson 1989; Ezzo et al. 1997; Krueger 1985; Price et al. 1994). Strontium and oxygen isotopes provide a tool to directly identify individuals who were not born locally (Bentley 2006; Bentley et al. 2007; Knudson et al. 2009; Knudson et al. 2015; Price et al. 2007; Price et al. 2010; Price et al. 2012a; White et al. 2007; Wright 2005b; Wright et al. 2010; Wright 2012). In contrast to the multiple generations that are needed to see migrations with genetics, demography, and archaeology, stable oxygen and radiogenic strontium isotope studies are invaluable because they provide finely grained information about the first generation of individual migrants, regardless of their material culture or language (Knudson 2011).

Isotopes as Biogeochemical Tracers

Correlating $^{87}Sr/^{86}Sr$ Values and Migration

Strontium Geochemistry

The radioactive decay of ^{87}Rubidium (^{87}Rb) to ^{87}Strontium (^{87}Sr) provides the foundation for a method utilized by scientists as a natural tracer of geologic processes. Strontium has four naturally occurring stable isotopes: ^{84}Sr, ^{86}Sr, ^{87}Sr, and ^{88}Sr. Of the four naturally occurring strontium isotopes, ^{88}Sr is the most abundant isotope (82.58%), followed by ^{86}Sr (9.86 %), ^{87}Sr (7.0%), and finally ^{84}Sr (0.56%). Strontium-87 is radiogenic, meaning that it is formed over time by the β-decay of the radioactive isotope of rubidium, ^{87}Rb, which has a half-life of around 48.8 billion years (Dickin 2005; Faure 1986). Because of their similar ionic radii and valence, strontium often substitutes for calcium, and rubidium will often substitute for potassium in minerals (Faure and Powell 1972). Accordingly, it often replaces calcium in bone hydroxyapatite.

The $^{87}Sr/^{86}Sr$ value of a rock is contingent on several factors. The first factor is the rubidium to strontium ratio (Rb/Sr) the time the rock was crystalized. Differences in strontium and rubidium abundance impact isotopic fractionation of magma during the crystallization process; granites contain high levels of rubidium relative to strontium so have high Rb/Sr ratios, while rocks like basalt are low in rubidium and will have very low Rb/Sr ratios (Faure and Powell 1972). The second factor is the ^{87}Rb/^{86}Sr ratio, or the ratio of the amount of ^{87}Rb that has the potential to decay to the daughter isotope ^{87}Sr, normalized to non-radioactive ^{86}Sr; the ^{87}Sr/^{86}Sr ratio is usually directly proportionate to the Rb/Sr ratio. Using ^{86}Sr as a normalizer acts to cancel out natural variations in total strontium, allowing for comparisons of the relative abundance of ^{87}Sr to be made. Finally, the third factor is the time elapsed since initial formation of the rock (Bentley 2006; Faure and Powell 1972). Rocks in the Earth's mantle tend to have relatively low Rb/Sr content while the earth's crust has higher Rb/Sr ratios. Rubidium and strontium isotopes fractionate differently during various geologic processes (Faure and Powell 1972). As a result, the ^{87}Sr/^{86}Sr content of a rock may be modified by tectonic, metamorphic or sedimentary processes any number of times during the Earth's history. Therefore, very young and recently formed volcanic rocks should have very low ^{87}Sr/^{86}Sr ratios (~0.703 – 0.704), while very old continental rocks, like granite, may have much higher ^{87}Sr/^{86}Sr ratios (>0.715). Phanerozoic marine limestone and dolomite will usually have ^{87}Sr/^{86}Sr values reflecting the ^{87}Sr/^{86}Sr composition of the ocean during their deposition (Dasch 1969; Dickin 2005; Faure and Powell 1972; Turekian and Kulp 1956). Furthermore, individual minerals within a single rock or locality can have significant variability in ^{87}Sr/^{86}Sr ratios (Faure and Powell 1972).

Strontium is released from bedrock via weathering and cycled through soils in a complex mixing system. In soils and sediments, ^{87}Sr/^{86}Sr is generally a function of depth, where deeper soils located closer to the original parent bedrock material will more closely reflect ^{87}Sr/^{86}Sr values of that bedrock. The ^{87}Sr/^{86}Sr values of more shallow soils have been influenced by bioturbation and other processes, resulting in an averaging ^{87}Sr/^{86}Sr values with both sediment weathered from other local bedrock sources, and biomass introduced by the decay of plants and animals (Bentley 2006; White 2015). Minerals may weather at different rates, and if they have different $^{87}Sr/^{86}Sr$ concentrations, this may result in the total $^{87}Sr/^{86}Sr$ values of a specific rock not actually reflecting the $^{87}Sr/^{86}Sr$ value of the soil it produces. The overall strontium concentration of sediment weathered from a specific rock will also impact the influence of its $^{87}Sr/^{86}Sr$ value on the local soil value. Rocks with high $^{87}Sr/^{86}Sr$ values often have low strontium content, and if mixed with material weathered from a rock with low $^{87}Sr/^{86}Sr$ values but high strontium content, the high $^{87}Sr/^{86}Sr$ value may be significantly muted due to differences in strontium content between the rocks (Beard and Johnson 2000; Bentley 2006; Faure and Powell 1972).

Groundwater and surface water both impact the $^{87}Sr/^{86}Sr$ values in soil and contribute to the strontium mixing process (White 2015). The atmosphere may also have an impact on soil $^{87}Sr/^{86}Sr$ values within a given area. Wind may transport foreign strontium into a system via deposition of dust, sea water, and pollution (Bentley 2006). Soil in coastal areas can be influenced by windblown sea spray and rainwater distilled from evaporative ocean water, which would have $^{87}Sr/^{86}Sr$ values reflecting the current ocean $^{87}Sr/^{86}Sr$ value (Bentley 2006).

There are several processes that contribute to the strontium isotopic composition of natural water. Rivers carry the majority of the products of continental weathering to the oceans. Strontium in rivers is primarily present in suspended form, however, a small fraction of the strontium in rivers is dissolved strontium (White 2015). Rivers are believed to be a more accurate representation of strontium biologically available to organisms than bedrock. Overall, $^{87}Sr/^{86}Sr$ values in river water are consistent over a wide range of water flow rates

(Bain et al. 1998). Rivers located at high elevations tend to have water ^{87}Sr/^{86}Sr values that closely match those of the local bedrock, while rivers at lower elevations may contain upstream rocks, sediment, in addition to precipitation and local runoff, potentially causing more pronounced deviations more from the local bedrock ^{87}Sr/^{86}Sr values (White 2015). Sediment transported downstream and deposited in floodplains may also influence the soil ^{87}Sr/^{86}Sr values.

The strontium content of the modern ocean is influenced by runoff and river discharge, groundwater run out, oceanic crust-seawater interaction, and diagenetic reflux of strontium into the oceans (Dickin 2005; Veizer 1989). The ^{87}Sr/^{86}Sr ratio of sea water represents the worldwide average of weathered continental crust at any given time, and is essentially homogenous throughout the oceans. The modern ^{87}Sr/^{86}Sr value of seawater is 0.7092; however, in ancient oceans it has varied between 0.707 – 0.709. This wide range is largely believed to be caused by variations in weathering of continental crust and runoff (Dasch 1969; Dickin 2005). The strontium isotopic composition of deep-sea sediments and sedimentary rocks is based on the ^{87}Sr/^{86}Sr values of the ocean during their formation and reflects the geologic sources of the sediments of which they are composed. Marine carbonates precipitated from seawater that are found within these sediments reflect the actual ^{87}Sr/^{86}Sr values of the ocean water at the time of their formation (Dasch 1969; Dickin 2005; Veizer 1989). Given the long half-life of rubidium, however, soil and seawater strontium isotope ratios can be considered to have been stable during the Quaternary Period.

Strontium Biogeochemistry

Strontium isotopes (^{87}Sr/^{86}Sr) reflect local geology, consisting of weathered bedrock and sediment inputs, thus are a very useful geologic tracer for humans and other mammals. Strontium present in bedrock, soils, and water is in turn incorporated into plants and animals. Because the mass differences are relatively small among isotopes of heavier elements like strontium, there is no measurable biological fractionation as strontium passes from the original source material though the food chain. This means that, in theory, the flora and fauna of the same food web will have similar values to the original ^{87}Sr/^{86}Sr ratio present in local bedrock (Ericson 1985; Sillen 1981; Sillen and Kavanagh 1982). Although no trophic fractionation occurs, the strontium isotope ratio in an organism reflects ^{87}Sr/^{86}Sr values for all strontium ingested from food and water sources during tissue development. Thus, the ^{87}Sr/^{86}Sr value of biologically available strontium, not bedrock, in a given environment is most helpful for assessing homelands in animal provenience studies (Bentley 2006).

Strontium and calcium are both alkaline earth metals with similar ionic radii and chemical properties, allowing strontium to enter the skeleton as a substitution for calcium during mineralization of the hydroxyapatite of bones and teeth (Boyde et al. 1958). During dental and skeletal development, strontium ingested as food is subsequently deposited into bone or enamel apatite. Enamel undergoes very little chemical alteration once amelogenesis is complete (Bentley 2006). Thus, the strontium isotope ratios of enamel reflect the geological area inhabited during childhood, whereas bone strontium isotope ratios may serve as an indicator of the geological location inhabited later in life (Bentley 2006; Price, et al. 2008).

Cultural and regional differences in diet or food preparation may cause deviations between the local geologically available strontium and the skeletal matrix (Bentley et al. 2004; Bentley et al. 2007; Burton and Wright 1995; Killgrove 2010; Shaw et al. 2010). Wright (2005a) suggests that Sr/Ca ratios and thus $^{87}Sr/^{86}Sr$ of Mesoamerican skeletons could be determined by the use of limestone in the processing of maize. Both in Mesoamerica and elsewhere, imported limestone, freshwater mollusks, salt, water, or other food items have also been suggested to significantly alter the $^{87}Sr/^{86}Sr$ ratios obtained from archaeological skeletal remains (Burton and Wright 1995; Killgrove 2010; Trask et al. 2012; Wright 2005a), however, the degree to which $^{87}Sr/^{86}Sr$ values in human tissues are impacted by these imported condiments is still not fully understood (Fenner and Wright 2014). Consideration for how food preparation may impact the $^{87}Sr/^{86}Sr$ values at Tipu will be discussed later in this chapter.

Strontium Isotope Ratio Variability in the Maya Area

The highly variable geology of the Yucatan peninsula and greater Maya region makes it a particularly interesting area to employ $^{87}Sr/^{86}Sr$ isotopes as a means to investigate human migration. Studies establishing baseline strontium $^{87}Sr/^{86}Sr$ values for broad regions in the Maya area (Hodell et al. 2004; Price et al. 2008; Price et al. 2012a; Price et al. 2012b) as well as local biologically available $^{87}Sr/^{86}Sr$ ranges for specific sites (e.g. Buikstra et al. 2004; Freiwald 2011; Miller 2014; Price et al. 2000; Price et al. 2002; Price et al. 2007; Price et al. 2008; Price et al. 2010; Price et al. 2012a; Somerville 2010; Somerville et al. 2016; Thornton 2011a; Thornton 2011b; Trask et al. 2012; White et al. 2007; Wright 2005a;

Wright 2005b; Wright et al. 2010; Wright 2012) allow for a broad understanding of the isotopic variability within the Maya region.

Hodell et al. (2004) characterized local bedrock, water, plant, and soil samples along major roadways through the Maya area, providing a baseline for the entire Yucatan peninsula. Although some variation in strontium values is found within each area, they were able to define five broad strontium "clusters" based on general ranges for larger regions. Figure 3.1 shows the broad patterning in $^{87}Sr/^{86}Sr$ values across the Maya area shown by Hodell et al.'s data. More recent studies undertaken on both the local and regional level have primarily used faunal samples to further define the biologically available strontium values for each of these regions, with each discussed in detail below.

The Yucatan peninsula is largely composed of a carbonate platform with outcropping marine limestone. Geologic uplift and tilting of this carbonate platform has resulted in the exposed outcrops of limestone progressively increasing in age from north to south. More recent Eocene-Pleistocene deposits are located on the northern coast of the Yucatan Peninsula lowlands, and older late Cretaceous to Paleocene carbonates are found in the lowlands of Belize and northern Guatemala (Bentley 2006; Hodell et al. 2004). As the strontium isotopic composition of limestone and other marine carbonate rocks is determined by the $^{87}Sr/^{86}Sr$ value of seawater during formation, $^{87}Sr/^{86}Sr$ values of these areas also decrease from north to south, with the highest values (closest to modern day seawater) on the northern coast of the Yucatan peninsula.

The biologically available strontium range for the northern lowlands (Mexico's Yucatan Peninsula) has been found to have a $^{87}Sr/^{86}Sr$ range of ~0.7080 - ~0.7092, with an average of 0.7088 (Hodell et al. 2004; Thornton 2011a; Thornton 2011b). This region

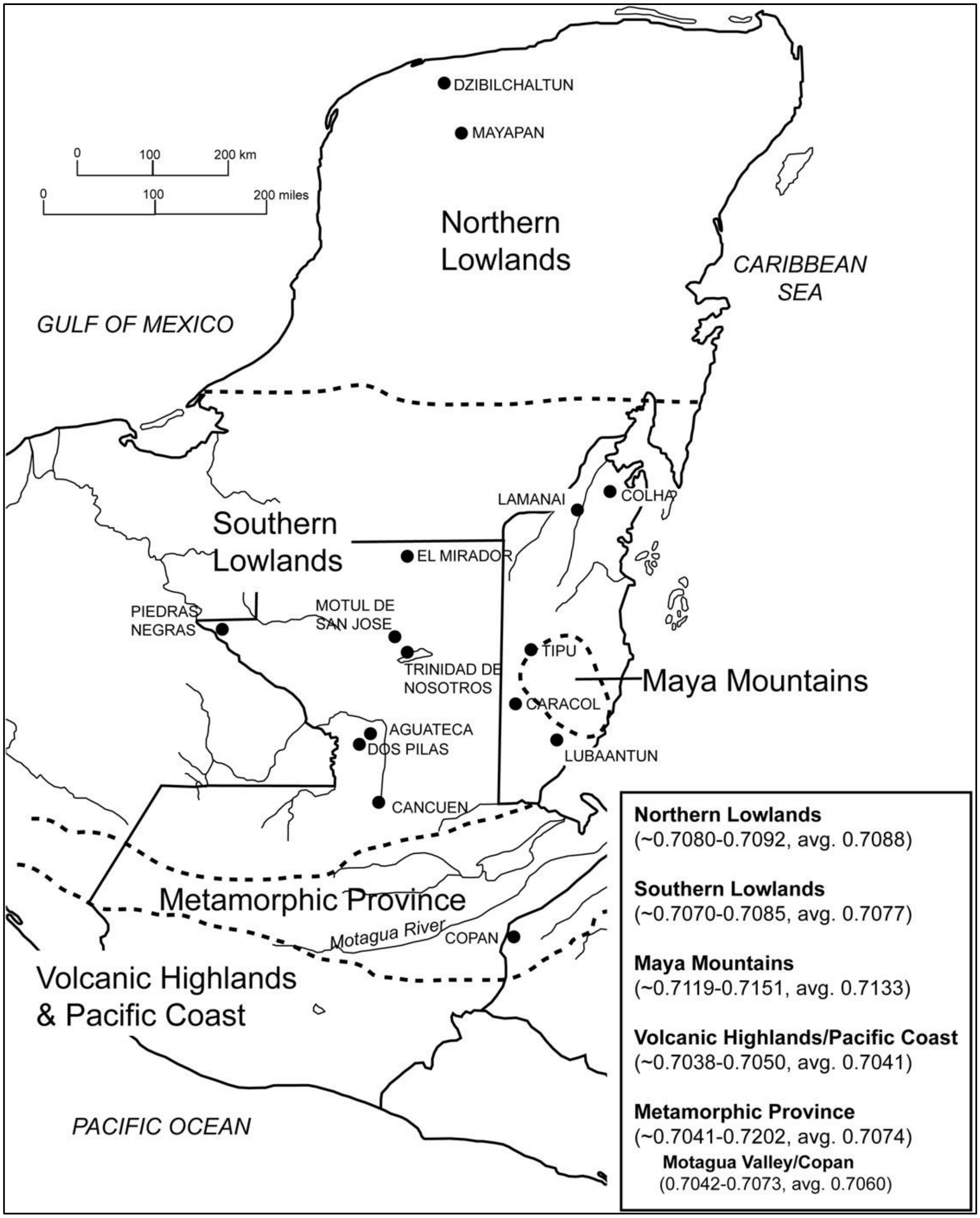


Figure 3.1. Map of the Maya area showing major strontium isotope regions. Reprinted from Thornton 2011: Figure 1, Strontium isotope ranges are defined according to Hodell et al. 2004.

contains both the Spanish capital, Merida, as well as the highest density of Spanish occupants during the early Colonial period. Anecdotal ethnohistorical records list the Yucatan as the probable source for migrants at Tipu (Jones 1989).

The southern lowlands, which is composed of the southernmost portion of the Yucatan peninsula, the lowlands of Belize, and northern Guatemala, have a $^{87}Sr/^{86}Sr$ range of 0.7070 – 0.7085, with an average of 0.7077 (Hodell et al. 2004; Thornton 2011a; Thornton 2011b). The southern portions of the Yucatan peninsula, and northern Belize also had a strong Spanish presence, and the Maya living along the Caribbean coast in this region frequently endured pirate attacks (Jones 1989), all potential motivators for the migration of individuals inland to Tipu. Farther inland, but still part of the southern lowlands, is northern

Guatemala; this the location of the Itzá controlled Petén and another possible source of migrants to Tipu (Jones 1989; Jones 1998). The Itzá Maya capital, Tah Itzá, is on the shore of the largest Petén lakes, Lake Petén Itzá; these lakes lie along a fault line with Paleocene bedrock to the north and Late Cretaceous bedrock to the south (Wright 2005a). Large domesticated mammal bone (*Bos taurus*, *Sus scrofa*, and *Equus* sp.) recovered from excavations of the San Bernabé Mission, located on the shores of Lake Petén Itzá and near the capital of Tah Itzá, yielded $^{87}Sr/^{86}Sr$ range of 0.70763±0.00017; preliminary $^{87}Sr/^{86}Sr$ values obtained from 21 burials from San Bernabé (mean $^{87}Sr/^{86}Sr=0.70767$) are very similar to the values of indigenous archaeological faunal species (Freiwald and Pugh 2017). Four terrestrial snails also recovered from sites bordering lakes in the Petén lakes region (Lake Salpetén, Lake Yaxha, and Lake Machanché) have yielded $^{87}Sr/^{86}Sr$ values ranging from 0.70759-0.70784 (Freiwald and Pugh 2017). Although there is some overlap between the northern and southern lowlands, the range is wide and variable enough to allow for the rough approximation of homelands for non-local ^{87}Sr/^{86}Sr isotope values from Tipu.

The Maya Mountains are located near the eastern coast of the southern lowlands, in the middle of present day Belize, and are potentially the most pertinent to the present study. The Maya mountains are primarily composed of older plutonic igneous rocks (granite and diorite) and metamorphic rocks (Hodell, et al. 2004). This region is geologically distinct from the remainder of the Maya lowlands and surrounded by much younger marine carbonates. A wide range of ^{87}Sr/^{86}Sr values have been documented for the Maya Mountains, ranging from around 0.7100 – 0.7202 with an average of 0.7133 (Hodell, et al. 2004; Thornton 2011), providing the Maya Mountains with a ^{87}Sr/^{86}Sr isotopic signature that is distinctly higher than anywhere else in Mesoamerica. This variation comes in part from the variable geology within the mountains, with higher values reported towards the center, and in the river valleys that drain the eastern portion of the mountains. Tipu is located on the northern border of the Maya mountains, and represents the lower portion of this range in terms of elevation. Freiwald (2011) and Thornton (2011a); Thornton (2011b) have collected additional faunal and human samples from the northern Maya Mountains and surrounding areas (including the area immediately surrounding Tipu) and have further documented and refined the range of biologically available strontium for the region.

Two additional regions are less likely to contribute migrants to Tipu but bear mention. The volcanic highlands and Pacific coast of Central America consist of both Tertiary and Quaternary volcanic belt of the Guatemalan highlands as well as the Quaternary alluvium along the Pacific coast, formed as a result of erosion of the volcanic highlands (Hodell, et al. 2004). The ^{87}Sr/^{86}Sr range for the volcanic highlands and Pacific coast is

0.7038 – 0.7050, with an average of 0.7041 (Thornton 2011b). A metamorphic band is located between the southern lowlands and the volcanic highlands, and exhibits a wide range of geologic diversity, resulting in an overall $^{87}Sr/^{86}Sr$ range of 0.7041 – 0.7202, with an average of 0.7074 (Hodell et al. 2004; Thornton 2011b). It should be noted that the higher $^{87}Sr/^{86}Sr$ values above 0.7075 are based on bedrock samples, and thus may reflect local geologic variation, not biologically available strontium. Within the metamorphic provenience, Hodell, et al. (2001) reported a narrower $^{87}Sr/^{86}Sr$ range of 0.7042 – 0.7073 for the Motagua River Valley (near the major Classic period site of Copan); additional studies have been working to further characterize the biologically available strontium of this region (e.g. Miller 2014).

Estimating Local Strontium Isotope Ranges for Tipu

Expected Strontium Isotope Ratios for Tipu: Geologic Data

The geology of central Belize (Figure 3.2) is very heterogenous, with significant geologic and geographic variation occurring over relatively small distances (Cornec 2008; Wright et al. 1959). Tipu is located on the banks of the Lower Macal River, south and upstream of the Belize River Valley and in the foothills of the Maya Mountains (see Figure 3.2, Figure 3.3, 3.4). The site is positioned on the southern portion of the Yucatan peninsula, on the Cretaceous aged Barton Creek formation, which is composed of rudist limestones, dolomite, and collapse breccias (Cornec 2008). This geologic formation extends to the west, southwest, and east of Tipu, however, much of these regions are heavily karsified. Using a

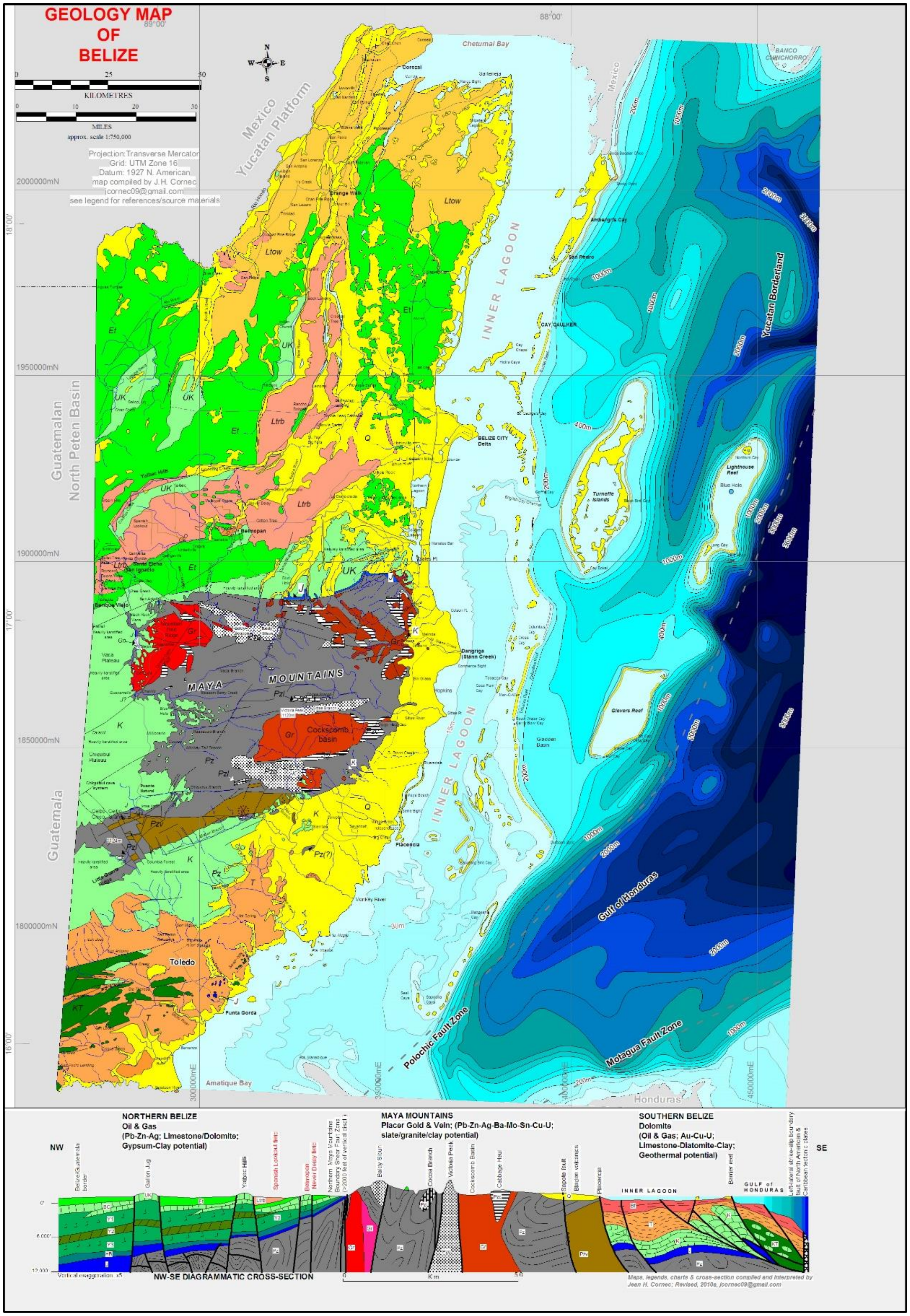
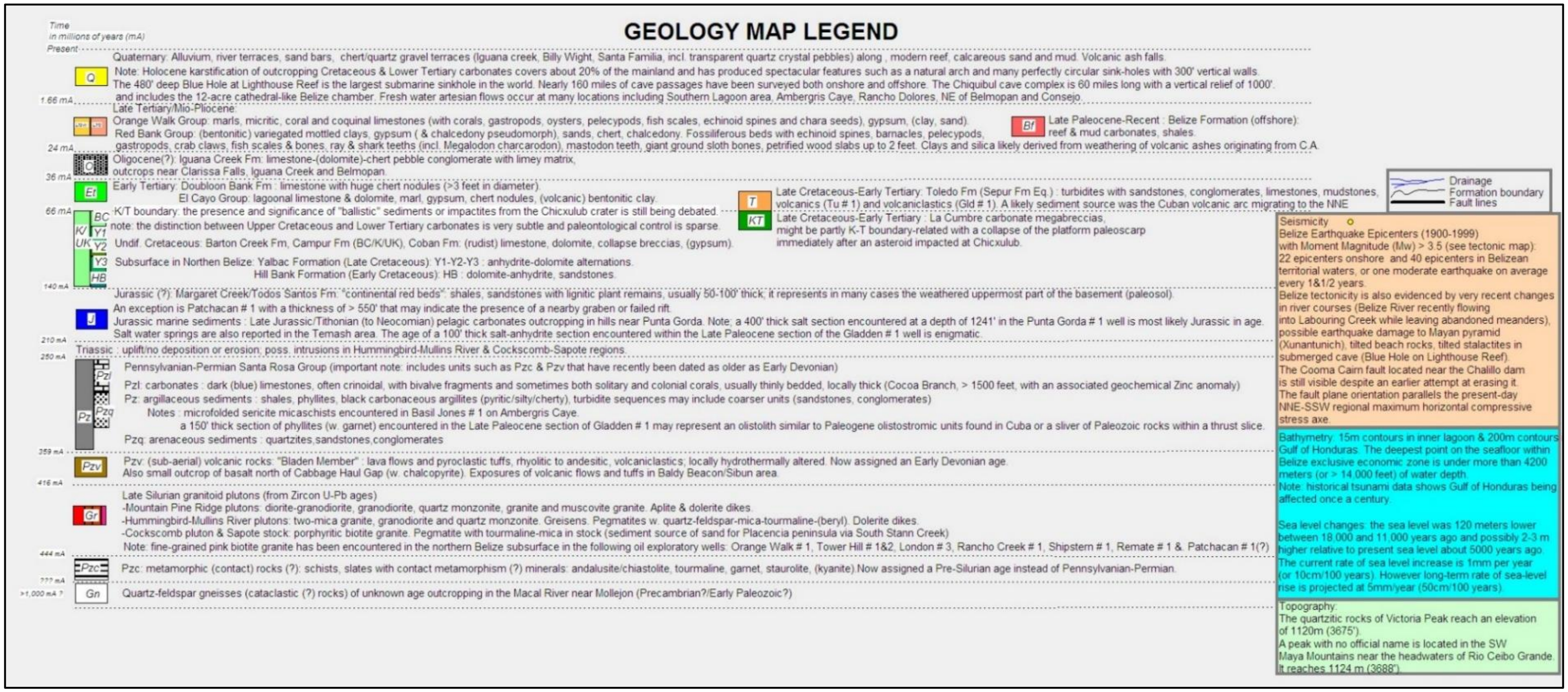


Figure 3.2. Bedrock geology of Belize. Reprinted from Cornec 2008.



GEOLOGY MAP LEGEND

Quaternary: Alluvium, river terraces, sand bars, chert/quartz gravel terraces (Iguana creek, Billy Wight, Santa Familia, incl. transparent quartz crystal pebbles) along , modern reef, calcareous sand and mud. Volcanic ash falls.
Note: Holocene karstification of outcropping Cretaceous & Lower Tertiary carbonates covers about 20% of the mainland and has produced spectacular features such as a natural arch and many perfectly circular sink-holes with 300' vertical walls.
The 480' deep Blue Hole at Lighthouse Reef is the largest submarine sinkhole in the world. Nearly 160 miles of cave passages have been surveyed both onshore and offshore. The Chiquibul cave complex is 60 miles long with a vertical relief of 1000'.
and includes the 12-acre cathedral-like Belize chamber. Fresh water artesian flows occur at many locations including Southern Lagoon area, Ambergris Caye, Rancho Dolores, NE of Belmopan and Consejo.

Late Tertiary/Mio-Pliocene:
Orange Walk Group: marls, micritic, coral and coquinal limestones (with corals, gastropods, oysters, pelecypods, fish scales, echinoid spines and chara seeds), gypsum, (clay, sand).
Red Bank Group: (bentonitic) variegated mottled clays, gypsum (& chalcedony pseudomorph), sands, chert, chalcedony. Fossiliferous beds with echinoid spines, barnacles, pelecypods,
gastropods, crab claws, fish scales & bones, ray & shark teeths (incl. Megalodon charcarodon), mastodon teeth, giant ground sloth bones, petrified wood slabs up to 2 feet. Clays and silica likely derived from weathering of volcanic ashes originating from C.A.

Late Paleocene-Recent : Belize Formation (offshore):
reef & mud carbonates, shales.

Oligocene(?): Iguana Creek Fm: limestone-(dolomite)-chert pebble conglomerate with limey matrix,
outcrops near Clarissa Falls, Iguana Creek and Belmopan.

Early Tertiary: Doubloon Bank Fm : limestone with huge chert nodules (>3 feet in diameter).
El Cayo Group: lagoonal limestone & dolomite, marl, gypsum, chert nodules, (volcanic) bentonitic clay.

Late Cretaceous-Early Tertiary: Toledo Fm (Sepur Fm Eq.) : turbidites with sandstones, conglomerates, limestones, mudstones,
volcanics (Tu # 1) and volcaniclastics (Gld # 1). A likely sediment source was the Cuban volcanic arc migrating to the NNE

Late Cretaceous-Early Tertiary : La Cumbre carbonate megabreccias,
might be partly K-T boundary-related with a collapse of the platform paleoscarp
immediately after an asteroid impacted at Chicxulub.

K/T boundary: the presence and significance of "ballistic" sediments or impactites from the Chicxulub crater is still being debated.
note: the distinction between Upper Cretaceous and Lower Tertiary carbonates is very subtle and paleontological control is sparse.
Undif. Cretaceous: Barton Creek Fm, Campur Fm (BC/K/UK), Coban Fm: (rudist) limestone, dolomite, collapse breccias, (gypsum).
Subsurface in Northen Belize: Yalbac Formation (Late Cretaceous): Y1-Y2-Y3 : anhydrite-dolomite alternations.
Hill Bank Formation (Early Cretaceous): HB : dolomite-anhydrite, sandstones.

Jurassic (?): Margaret Creek/Todos Santos Fm: "continental red beds": shales, sandstones with lignitic plant remains, usually 50-100' thick; it represents in many cases the weathered uppermost part of the basement (paleosol).
An exception is Patchacan # 1 with a thickness of > 550' that may indicate the presence of a nearby graben or failed rift.
Jurassic marine sediments : Late Jurassic/Tithonian (to Neocomian) pelagic carbonates outcropping in hills near Punta Gorda. Note; a 400' thick salt section encountered at a depth of 1241' in the Punta Gorda # 1 well is most likely Jurassic in age.
Salt water springs are also reported in the Temash area. The age of a 100' thick salt-anhydrite section encountered within the Late Paleocene section of the Gladden # 1 well is enigmatic.

Triassic : uplift/no deposition or erosion; poss. intrusions in Hummingbird-Mullins River & Cockscomb-Sapote regions.

Pennsylvanian-Permian Santa Rosa Group (important note: includes units such as Pzc & Pzv that have recently been dated as older as Early Devonian)
Pzl: carbonates : dark (blue) limestones, often crinoidal, with bivalve fragments and sometimes both solitary and colonial corals, usually thinly bedded, locally thick (Cocoa Branch, > 1500 feet, with an associated geochemical Zinc anomaly)
Pz: argillaceous sediments : shales, phyllites, black carbonaceous argillites (pyritic/silty/cherty), turbidite sequences may include coarser units (sandstones, conglomerates)
Notes : microfolded sericite micaschists encountered in Basil Jones # 1 on Ambergris Caye.
a 150' thick section of phyllites (w. garnet) encountered in the Late Paleocene section of Gladden # 1 may represent an olistolith similar to Paleogene olistostromic units found in Cuba or a sliver of Paleozoic rocks within a thrust slice.
Pzq: arenaceous sediments : quartzites,sandstones,conglomerates

Pzv: (sub-aerial) volcanic rocks: "Bladen Member" : lava flows and pyroclastic tuffs, rhyolitic to andesitic, volcaniclastics; locally hydrothermally altered. Now assigned an Early Devonian age.
Also small outcrop of basalt north of Cabbage Haul Gap (w. chalcopyrite). Exposures of volcanic flows and tuffs in Baldy Beacon/Sibun area.

Late Silurian granitoid plutons (from Zircon U-Pb ages)
-Mountain Pine Ridge plutons: diorite-granodiorite, granodiorite, quartz monzonite, granite and muscovite granite. Aplite & dolerite dikes.
-Hummingbird-Mullins River plutons: two-mica granite, granodiorite and quartz monzonite. Greisens. Pegmatites w. quartz-feldspar-mica-tourmaline-(beryl). Dolerite dikes.
-Cockscomb pluton & Sapote stock: porphyritic biotite granite. Pegmatite with tourmaline-mica in stock (sediment source of sand for Placencia peninsula via South Stann Creek)
Note: fine-grained pink biotite granite has been encountered in the northern Belize subsurface in the following oil exploratory wells: Orange Walk # 1, Tower Hill # 1&2, London # 3, Rancho Creek # 1, Shipstern # 1, Remate # 1 & Patchacan # 1(?)

Pzc: metamorphic (contact) rocks (?): schists, slates with contact metamorphism (?) minerals: andalusite/chiastolite, tourmaline, garnet, staurolite, (kyanite).Now assigned a Pre-Silurian age instead of Pennsylvanian-Permian.

Quartz-feldspar gneisses (cataclastic (?) rocks) of unknown age outcropping in the Macal River near Mollejon (Precambrian?/Early Paleozoic?)

Seismicity ○
Belize Earthquake Epicenters (1900-1999)
with Moment Magnitude (Mw) > 3.5 (see tectonic map):
22 epicenters onshore and 40 epicenters in Belizean territorial waters, or one moderate earthquake on average every 1&1/2 years.
Belize tectonicity is also evidenced by very recent changes in river courses (Belize River recently flowing into Labouring Creek while leaving abandoned meanders), possible earthquake damage to Mayan pyramid (Xunantunich), tilted beach rocks, tilted stalactites in submerged cave (Blue Hole on Lighthouse Reef).
The Cooma Cairn fault located near the Chalillo dam is still visible despite an earlier attempt at erasing it.
The fault plane orientation parallels the present-day NNE-SSW regional maximum horizontal compressive stress axe.

Bathymetry: 15m contours in inner lagoon & 200m contours Gulf of Honduras. The deepest point on the seafloor within Belize exclusive economic zone is under more than 4200 meters (or > 14,000 feet) of water depth.
Note: historical tsunami data shows Gulf of Honduras being affected once a century.

Sea level changes: the sea level was 120 meters lower between 18,000 and 11,000 years ago and possibly 2-3 m higher relative to present sea level about 5000 years ago.
The current rate of sea level increase is 1mm per year (or 10cm/100 years). However long-term rate of sea-level rise is projected at 5mm/year (50cm/100 years).

Topography:
The quartzitic rocks of Victoria Peak reach an elevation of 1120m (3675').
A peak with no official name is located in the SW Maya Mountains near the headwaters of Rio Ceibo Grande.
It reaches 1124 m (3688').

Figure 3.3. Legend for bedrock map displayed in Figure 3.2. Reprinted from Cornec 2008.

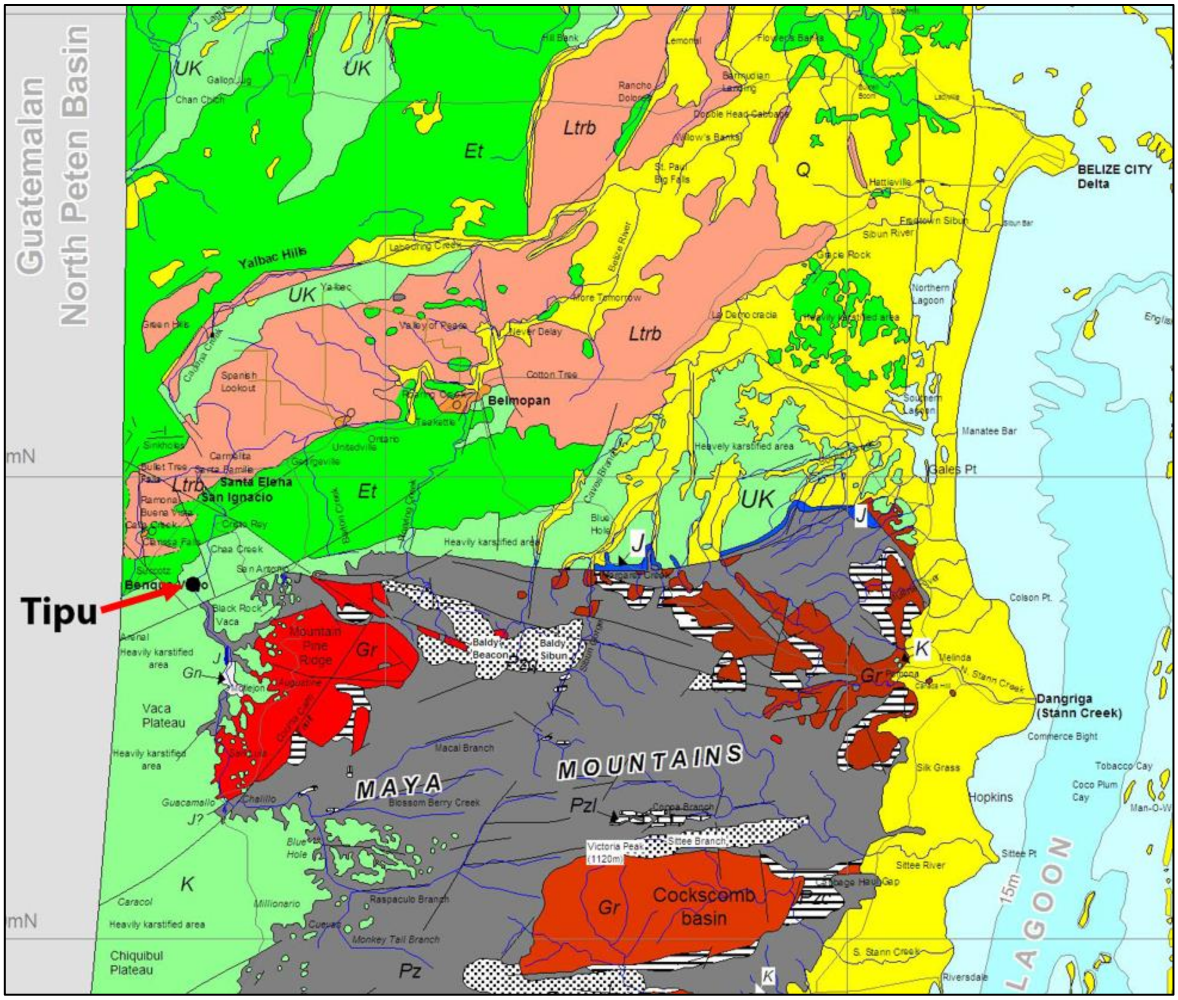


Figure 3.4. Closeup of bedrock geology of central Belize. Reprinted from Cornec 2008.

seawater strontium isotope curve, limestone deposits of this age roughly correspond to an expected strontium isotope value of around 0.7072 to 0.7077 (Veizer 1989).

There is substantial geologic variation in the region directly surrounding the site of Tipu (see Figure 3.4). Directly to the north is the Belize Valley situated on the El Cayo Group, which is largely composed of Early Tertiary lagoonal limestone dolomite, that corresponds to an expected strontium value of approximately 0.7077 to 0.7078 (Cornec

2008; Veizer 1989). To the south and southeast of Tipu are the Maya Mountains, largely composed of Paleozoic shales, sandstones, and granite (Cornec 2008; Wright et al. 1959). Upstream of Tipu, the Macal River drains a heterogenous and diverse geology. Beginning approximately 2.5 kilometers south of Tipu, the bedrock surrounding the Macal River changes into the same Pennsylvanian-Permian argillaceous sediment deposits that compose the remainder of the Maya Mountains. Two small outcroppings, one of Jurassic aged shale and sandstones and a second of quarts-feldspar gneisses of Precambrian or Early Paleozoic age, are also located along the Macal River, upstream of Tipu. The Macal River originates in the Mountain Pine Ridge region, farther south and east, which is composed of Late Silurian granitoid plutons (Cornec 2008; Wright et al. 1959).

Although no known geologic or water strontium samples have been obtained from Tipu, the lower Macal River valley, or from the region upstream of Tipu, the granitic parent materials would expect to yield strontium values much higher than expected from the limestone bedrocks. This may result in the water of the Macal River having a higher than expected strontium isotope value due to dissolved minerals from upstream, and/or the deposition of sediment originating from the erosion of upstream parent materials.

Expected Strontium Isotope Values at Tipu: Faunal Data

Strontium isotopes obtained from faunal samples are a useful tool to understand the expected values for biologically available strontium within a given area. Two previous studies have collected modern fauna samples from along the lower Macal River valley, within the scope of the Barton Creek formation of Cretacious limestone. Three of these samples are land snails (*Neocyclotus dysoni, Orthalicus sp.)* collected from the site of Tipu (Thornton 2011). These three snails have $^{87}Sr/^{86}Sr$ values of 0.7105, 0.7107, and 0.7134 (mean= 0.7116) (Thornton 2011b). Friewald also reports three additional modern samples collected from the Macal River Valley, within close proximity of Tipu (Freiwald 2011). A land snail collected approximetly 2km upstream of Tipu yielded a $^{87}Sr/^{86}Sr$ value of 0.7107. Two land snails were also collected approximately 4km downstream of Tipu near the archaeological site of Chaa Creek; these yielded $^{87}Sr/^{86}Sr$ values of 0.7089 and 0.7103. The bedrock for both of these locations is within the same geologic formation as Tipu.

The six $^{87}Sr/^{86}Sr$ values from the modern land snails are combined here to see if a more robust sample would aid in providing a better model for the human data. The combined Macal River Valley modern land snail range has a mean of 0.7108 and standard deviation of 0.00146 (observed range = 0.7089-0.7134, 2SD range = 0.7079-0.7137); the slightly lower values from the downstream site of Chaa Creek result in a slightly lower mean and tighter SD than seen with the Tipu only range. This wide range in strontium values is likely primarily due to local variations in parent materials, and thus available soils for the snails. All of the $^{87}Sr/^{86}Sr$ values for the snails are significantly higher than would be expected from the carbonate bedrock geology alone. The Macal River snail $^{87}Sr/^{86}Sr$ values are closer to those seen further south in the Maya Mountains (>0.710), and are fairly dissimilar from nearby Caracol, which has a more lowland, carbonate strontium isotope signature (faunal range = 0.7074-0.7080, Thornton 2011; human range = 0.7076 - 0.7080 +/- 0.00012, Freiwald 2011). This makes sense, as Tipu is located on a limestone bedrock floodplain with overlaying sediments that have been brought down from the Maya Mountains via the Macal

River, whereas Caracol is located on a limestone plateau directly west of the Maya Mountains (Wright, et al. 1959).

Strontium isotope values have also been obtained from large mammal bones excavated from archaeological contexts at Tipu (Thornton 2011: Table 6-4). Although strontium found within the meat itself was not likely a major source of strontium in the diet, large mammals may provide a better picture of biologically available strontium for the region surrounding Tipu. Thornton (2011) sampled bone from 11 large mammals, including species of tapir, peccary, and deer. Three obvious outliers, two deer and one collared peccary, had $^{87}Sr/^{86}Sr$ values ranging from 0.7202 to 0.7316, indicating a Maya Mountains origin. There were no discernable differences in archaeological context or species type between the animals Thornton identified as local and those identified as non-local (Thornton 2011). The remaining eight mammals have observed $^{87}Sr/^{86}Sr$ values ranging from 0.7082 to 0.7117 (mean=0.7092, ± 0.0012); seven of these were tightly clustered between 0.7082 and 0.7099, falling near the lower end of the combined modern land snail $^{87}Sr/^{86}Sr$ range for the Macal River Valley. The three outliers imply that hunting parties extended fairly far away from Tipu, up into granitic regions to the south. It is important to note that these animals have a relatively large roaming area, and the hunting range of the inhabitants of Tipu remains unknown.

The strontium isotope ratios obtained from the modern and archaeological faunal data do not appear to closely mirror expected isotope ranges based on the local carbonate geology; rather, they appear to be mixed or fall between the expected bedrock values and those expected from much higher in the Maya Mountains. For the land snails, the higher $^{87}Sr/^{86}Sr$ values (> 0.7100) are likely a result of Tipu’s location on a floodplain composed of soils and sediments washed down from the Maya Mountains. For the larger fauna, this deviation may be due to hunting ranges or sources of food (including grazing in Tipu agricultural land). Given Tipu's location on a floodplain composed of sediment eroded from Maya Mountain deposits, it is likely the local bedrock at Tipu is not an adequate representation of the locally expected values for biologically available strontium. However, the $^{87}Sr/^{86}Sr$ values of snails may be an appropriate expectation for agricultural soils within the catchment of Tipu, and therefore $^{87}Sr/^{86}Sr$ values that are biologically available to humans as dietary inputs. Tipu's position in a transitional zone between two geologic regions with very different strontium isotope signature may also be a factor in the substantial variation in biologically available strontium at Tipu.

Dietary Sources of Strontium at Tipu

Dietary sources of strontium are a major consideration when attempting to assess the strontium isotope values expected from a specific site. Although strontium is in all food and water consumed, those sources with the highest concentration of calcium, and thus strontium, will end up contributing the most to the $^{87}Sr/^{86}Sr$ value of an individual. One potential source of dietary strontium is from small partials of groundstone grit deposited in food during the grinding process. Presumably, more soluble rocks with higher calcium content (and thus higher strontium content) would have a more significant impact on consumed dietary strontium. Granite is the primary raw material type used for groundstone at Tipu (Graham, personal communication 2018). Excavations of Postclassic settlements from the nearby Belize River Valley found granite to be nearly exclusively the material used for utilitarian groundstone, with a small number of basalt groundstone items also recovered (Hoggarth 2012). There is an abundance of granitic outcrops located upstream in the Mountain Pine Ridge area (Cornec 2008; Shipley and Graham 1987); this easily accessible source of granite makes it a likely source as a raw material for groundstone at Tipu. Granite is also found in the streambeds of the Macal River which may have served as an easily accessible source for the inhabitants of Tipu (Graham personal communication 2018). Because granite is significantly less soluble than other materials like limestone, its use as groundstone is not likely to have made a major impact on the $^{87}Sr/^{86}Sr$ values of the individuals at Tipu.

Maize is an important staple food of the Maya; however, it must first be subjected to an alkaline processing when consumed at high levels. Boiling or soaking maize in an alkaline solution will change the chemical composition of maize, increasing its nutritional value (Bressani et al. 1958; Katz et al. 1974). In the Maya area, the use of burned limestone, plant ash, and burned and slaked *Pachychilus* (freshwater snail) shells to make lime has been documented (Nations 1979; Tozzer 1907; Wright 2006). Because the materials used to create the alkaline solution are much higher in calcium than maize, this process also acts to significantly increase the calcium content of the maize that is consumed, potentially accounting for a substantial portion of dietary calcium. Because of the high calcium, and thus strontium, content of limestone, ash, and shells, alkaline processing can be a significant source of strontium in the diet of cultures reliant on maize (Burton and Wright 1995; Wright 2006).

The source of lime used at Tipu is unknown, as limestone, plant ash, and *Pachychilus* were all available locally. Although Tipu is located on a limestone bedrock floodplain, it is covered by sediments brought down from the Maya Mountains. Tipu has several limestone outcrops in the general vicinity (Muhs et al. 1985), however, the quality of the limestone is unknown. Tozzer (1907) reported that the Lacandon Maya, although also located on limestone bedrock, would use *Pachychilus* shells because they had difficulty finding limestone that was suitable for maize processing. *Pachychilus* is readily available in many of the streams in the Maya area and has been documented as a source of lime for the Maya (Tozzer 1907; Nations 1979). *Pachychilus* raised in the Macal River would have $^{87}Sr/^{86}Sr$ values that are influenced by Maya Mountains geology. Although to date no known studies have strontium isotope analysis on Mopan River *Pachychilus* collected near Tipu, doing so would help clarify many issues.

Finally, the strontium content of the water may have also had a small impact on the strontium values of the Tipu population. The Macal River was likely the major water source for the people living at Tipu. As discussed previously, the river drains a very diverse geology, most of which has higher strontium values than would be expected around Tipu. Furthermore, if freshwater snail shells were used to process maize, these would have likely come from the Macal River, and thus would have a higher $^{87}Sr/^{86}Sr$ value than expected from the local limestone bedrock.

Correlating δ^{18}O Values and Migration

Stable Oxygen Isotopes in the Ecosystem

Stable oxygen isotopes are used as a proxy to infer climate change and to understand processes affecting global precipitation. Oxygen has three naturally occurring stable isotopes: ^{16}O, ^{17}O, and ^{18}O (Sharp 2007). Of them, ^{16}O is the most abundant isotope (abundance = 99.759%), followed by, ^{18}O (abundance = 0.204%), and ^{17}O (abundance = 0.037%). In geochemistry, relative differences in oxygen isotopic ratios are reported using a delta value obtained from the following equation and reported in parts thousand (‰) (McKinney et al. 1950; Sharp 2007):

$$\delta^{18}\mathrm{O} = \frac{R_{sample} - R_{standard}}{R_{standard}} \times 1000$$

The oxygen isotopic composition of the atmosphere and surface waters is driven by a series of complicated and interconnected processes in the hydrologic cycle. Understanding this cycle is essential for interpreting these values. In the hydrosphere, oxygen isotope ratios are the result of fractionation occurring during evaporation and precipitation or condensation. Evaporation is a kinetic process and can be influenced by a variety of factors. Condensation is an equilibrium-based process influenced by temperature, whereby increases in temperature result in a decrease in fractionation factors, and vice versa (Sharp 2007). This is because temperature strongly controls how much water can be held within an air mass, thus an air mass at higher, colder elevations cannot hold as much water as air at lower, warmer elevations (Sharp 2007).

The ocean represents the largest reservoir of water on earth, followed by glaciers, groundwater, surface water and atmospheric water. The oxygen isotopic composition of the ocean is largely a result of interaction between the ocean crust and the ocean water (Marshall and Fairbridge 1999). The $\delta^{18}O$ of ocean water is largely homogenous throughout the world's oceans, with variation usually limited to more shallow depths and resulting from surface evaporation, influx of freshwater from rivers and groundwater, and melting or freezing of polar ice. In the past, differences in temperature and climate have influenced the $\delta^{18}O$ values of ancient oceans (Sharp 2007).

A complex interconnected series of processes influence the $\delta^{18}O$ values of liquid surface water and water vapor in the atmosphere. Cloud masses that form by evaporation of ocean water will be depleted in ^{18}O relative to the ocean due to kinetic isotope effects during evaporation. As cloud masses move from their oceanic origin over land, the water vapor in the cloud mass will undergo chemical fractionation resulting in precipitation. During precipitation the isotopically heavier water molecules (those containing ^{18}O) will preferentially condense in the form of rain or snow. As a result of this Raleigh distillation process, as a cloud mass moves inland or rises in elevation the water vapor, and in turn rain, will have progressively lower $\delta^{18}O$ values. This process is often modeled using the Raleigh Distillation equation and is heavily influenced by temperature and original isotopic composition (Fry 2006; Sharp 2007). Similar processes may occur over large freshwater bodies of water, and evaporation of surface waters and evapotranspiration also can contribute to the vapor mass as it moves over land, as well as changing the isotope ratios of the surface reservoirs themselves.

The $\delta^{18}O$ values of meteoric water, or rain and snow that fall during condensation, are the result of precipitation of cloud masses moving over land, which is influenced by a variety of factors including temperature, distance from the ocean, latitude, elevation, relative humidity, the fraction of total water evaporated, and original isotopic composition of the cloud (Fry 2006; Gat 1996; Marshall and Fairbridge 1999; Sharp 2007). As previously stated, temperature strongly influences equilibrium fractionation in oxygen isotopes, with increased fractionation in colder areas and decreased fractionation in warmer areas. The farther cloud masses move away from the parent water source, the more Rayleigh distillation cycles of precipitation will have occurred, and in turn the more depleted the precipitation will be in ^{18}O, meaning lower $\delta^{18}O$ values. Oxygen isotopes in rain water also experience a latitude effect, where increases in latitude usually result in lower $\delta^{18}O$ values; this is the result of a decrease in atmospheric temperatures and corresponding larger equilibrium fractionation (Sharp 2007). Polar regions, especially Antarctica, experience the lowest $\delta^{18}O$ values on the planet. With increasing altitude, air masses encounter colder temperatures, resulting in greater fractionation and decline in the $\delta^{18}O$ of water vapor in cloud masses as they increase in altitude. Rapid ascents in elevation over high mountain ranges (e.g. air masses traveling from the Amazon basin over the Andes) result in a significant intensification of the Raleigh fractionation, which results in rapid rainout and rapid reduction in water vapor remaining in the air mass. Oxygen isotopes are also affected by seasonality, where differences in temperature affect precipitation throughout the year. Temporary or long term changes in source water and vapor trajectories for a region shape differences in precipitated $\delta^{18}O$ in these regions (Fry 2006; Marshall and Fairbridge 1999; Sharp 2007). Worldwide, water vapor evaporated directly from the ocean only accounts for approximately a third of total continental precipitation. The remaining precipitation is from evaporation of large lakes and rivers, and evapotranspiration of plants (Fry 2006; Sharp 2007).

Environments that experience significant amounts of evaporation, like arid and semi-arid environments, may experience extremely low $\delta^{18}O$ values that are significantly lower than the global meteoric water line (Gat 1996). Within these arid regions, ground and surface water sources that do not undergo frequent recharge may have very low $\delta^{18}O$ values. Additionally, large closed basins, like the Amazon, experience high levels of water recirculating within the closed basin environment as a result of temperature and evapotranspiration. This results in lower than expected $\delta^{18}O$ values (Gat 1996; Sharp 2007).

Groundwater $\delta^{18}O$ values generally reflect recently precipitated rainwater. For a given soil profile, groundwater $\delta^{18}O$ values decreases with depth as a result of evaporative enrichment, with seasonality and rainfall affecting groundwater recharge rates and the deviation from the $\delta^{18}O$ of local meteoric water. Underground aquifers may transport waters significant distances from the original water source, resulting in water $\delta^{18}O$ values that deviate significantly from local surface water values. Likewise, in areas with dramatic topographic changes, groundwater may reflect both local precipitation and water that precipitated at high altitude and traveled downstream (Fry 2006; Sharp 2007).

Oxygen Biogeochemistry

The use of oxygen isotopes as a tracer for migration relies on the assumption that the water that we drink is a reflection of the local climate and physical environment in some systematic way. Drinking water in lower elevations near the ocean is enriched in the heavy isotope ^{18}O (higher $\delta^{18}O$ values) compared to farther inland and higher elevation locations. Within the body, stable oxygen isotopes are fractionated as imbibed water is incorporated into body tissues. In mammals, $\delta^{18}O$ values of imbibed water are precipitated at a constant body temperature (37°C in humans) and incorporated into the structural carbonate and phosphate composing the hydroxyapatite in bones and teeth (Luz et al. 1984). While bone continuously remodels throughout life, dental enamel does not remodel once enamel formation is complete. Thus, the $\delta^{18}O$ of dental enamel reflects the $\delta^{18}O$ values of the imbibed environmental water consumed during the development of the tooth (Longinelli 1984; Luz et al. 1984; Luz and Kolodny 1985), making dental enamel apatite very useful for identifying the region where an individual lived as a child (Price et al. 2007; Schwarcz et al. 1991; Wright et al. 2010).

Environmental, cultural, and taphonomic factors may act to confound oxygen isotope data and influence the $\delta^{18}O$ values obtained from human samples. There are several specific environmental situations where the drinking water may not accurately reflect the meteoric water. In areas of extreme environmental variability and diverse environmental zones, like the Andes, the transportation of surface water (rivers, streams, etc.) is complex and water may be transported over large distances and to significantly lower elevations, thus further confounding the interpretation of oxygen isotope data (Knudson et al. 2009). Environments that experience significant amounts of evaporation, like arid and semi-arid environments, may experience extremely low $\delta^{18}O$ values that significantly deviate from the global meteoric water line. In these arid regions, drinking water sources that do not undergo frequent recharge will be evaporatively enriched and have very high $\delta^{18}O$ values (Gat 1996). As previously mentioned, large closed geographic basins experience high levels of water recirculating within the closed basin environment, resulting in lower than expected $\delta^{18}O$ values (Gat 1996).

The $\delta^{18}O$ of imbibed water may also be influenced by several biologically and culturally mediated behaviors. When using oxygen isotopes, it is important to take into account the trophic shift that occurs during breastfeeding. Because body water and thus breast-milk is enriched in ^{18}O relative to drinking water, enamel that is deposited by infants who are breastfeeding will have higher $\delta^{18}O$ values than expected from the local drinking water (Roberts et al. 1988; Wright and Schwarcz 1998). As a result, this may confound attempts to interpret mobility when using enamel that may have formed while an infant was still breastfeeding. The ages of dental development for both the tooth sampled and the comparative data should be taken into consideration to minimize or account for the impact of breastfeeding. Water that is stored in natural or man-made catchment basins or reservoirs is susceptible to evaporation and, dependent on the evaporation/recharge ratio of the basin, may have a lower $\delta^{18}O$ value than the local meteoric rain water $\delta^{18}O$ values (e.g. Scheuer, et al. 2015). Furthermore, cultural practices such as consuming boiling water (resulting in evaporation of some lighter ^{16}O) and other storage techniques may also influence the $\delta^{18}O$ of body water in humans. Despite these factors, broad patterning in $\delta^{18}O$ values is observed in Mesoamerica (Wright 2012), making $\delta^{18}O$ a useful tool to aid in the identification of migrants to a region when used in conjunction with other isotopes like strontium.

Oxygen Isotope Studies in the Maya Area

Broad baseline oxygen isotopic studies in the Maya region are limited to the analysis of river water samples. Figure 3.5 shows the patterning of oxygen isotope ratios of surface water samples from across Belize and Guatemala (Lachniet and Patterson 2009). The region typically experiences distinct dry and rainy seasons; from February to September the prevailing winds are the southeast trade winds originating in the Pacific, while from October to January the winds usually come from the north or northeast Pacific (Wright et al. 1959). During the height of the rainy season, May through July, the region experiences occasional revolving tropical storms that originate in the Caribbean (Wright et al. 1959). As would be expected based on the basic principles of oxygen isotope rainout, the Maya region shows an overall pattern whereby values from the lower elevation eastern coast are much heavier than that seen in the western Guatemalan mountainous region is observed. In the northern Maya Mountains $\delta^{18}O$ values from water samples fall within the -3 to -2‰ (SMOW) range. Research using oxygen isotopes obtained from sediment cores, cave stalactite and drip water samples have established climatic data for specific localities for the past several thousand years (Hodell et al. 1995; Kennett et al. 2012). Long term fluctuations in the $\delta^{18}O$ of meteoric water may result in temporal variation in isotope values. Scherer et al. (2015) collected meteoric, surface and cave water from a variety of localities in modern Guatemala over the course of several years. Although they found little variability in samples taken from flowing river and stream sources, evapotranspiration caused substantial variability in the $\delta^{18}O$ values for the Petén region lakes and aguadas (Scherer et al. 2015).

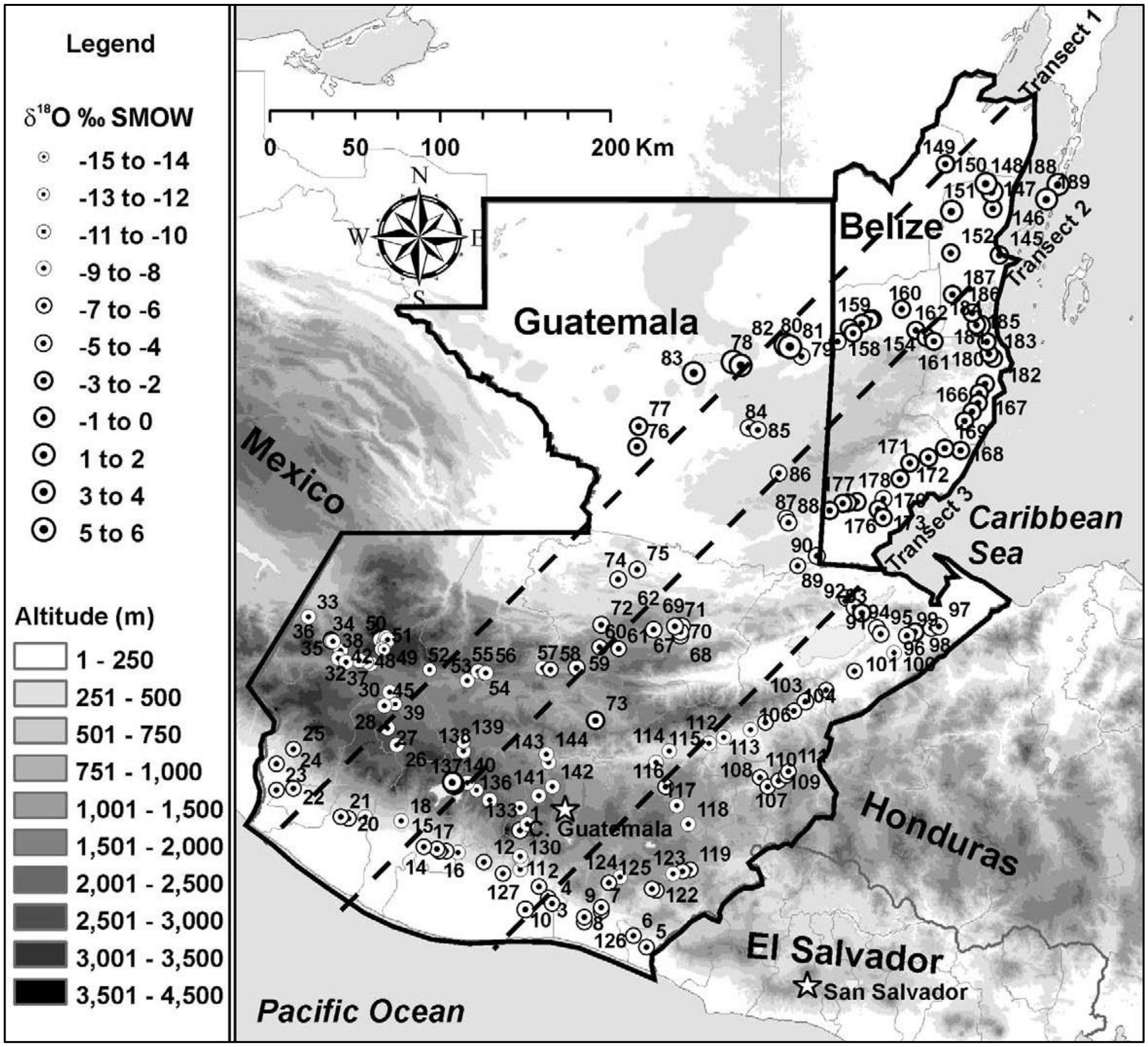


Figure 3.5. Map of oxygen isotope values from surface water collected in Belize and Guatemala. Reprinted from Lachniet and Patterson 2009: Figure 1.

Studies of human populations from numerous archaeological sites throughout the region have developed expected local oxygen isotope ranges that compliment modern records and document broad patterning in ^{18}O values over large geographic areas (Price et al. 2007; Price et al. 2010; Price et al. 2012b; Spence et al. 2004; Trask et al. 2012; White et al. 1998; White et al. 2000; White et al. 2002; White et al. 2004; White et al. 2007; Wright and Schwarcz 1998; Wright and Schwarcz 1999; Wright 2006; Wright et al. 2010; Wright 2012). Figure 3.6 shows some human $\delta^{18}O$ values from across Mesoamerica measured on both carbonate and phosphate data. Although the two data sources are not directly comparable, there is a broad trend of higher, more enriched values near the Caribbean coast, with lower, more depleted values as they travel inland and increase in elevation. Thus, when used in conjunction with other isotopes like strontium, stable oxygen isotopes are a useful tool to aid in identifying migrants in Mesoamerica.

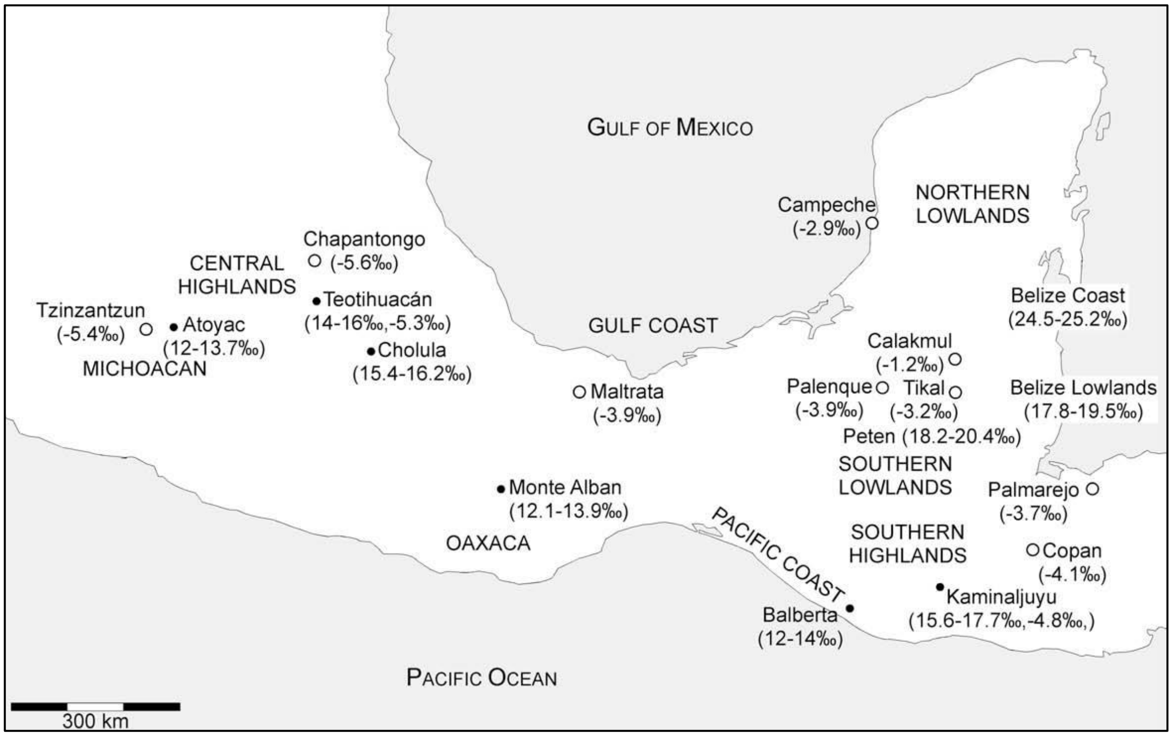


Figure 3.6. Phosphate and carbonate oxygen isotope ratios of human bone and enamel from Mesoamerica. Reprinted from Price, et al. 2010: Fig. 8. Phosphate data (black circles) are from White, et al. (2004, 2000, 1998). Carbonate data (open circles) are from Wright and Schwarcz (1999), Buikstra et al. (2004), Price, et al. (2007), and unpublished.

Estimating Oxygen Isotope Values at Tipu

Little work on oxygen isotopes has been done in the Tipu region. Oxygen isotope values from water and those from humans are not directly comparable, but similar broad trends in $\delta^{18}O$ values should exist (Bentley and Knipper 2005). Lachniet and Patterson's (2009) survey of water in Belize and Guatemala found that water samples from the northern Belize River Valley yielded $\delta^{18}O$ values within the -5 to -4‰ (SMOW) range. Table 3.1 lists $\delta^{18}O_{SMOW}$ values from water samples obtained in areas pertinent to the present work. Samples collected from an unknown location on the Macal River had an average $\delta^{18}O_{SMOW}$ of -6.83‰. Mountain Pine Ridge, located in the northern Maya Mountains, had a slightly higher value of -3.38‰ $\delta^{18}O_{SMOW}$; this is as expected given the higher elevation and generally colder temperatures of this region (Wright et al. 1959). Although water from the Macal River and Belize River Valley should have very similar $\delta^{18}O$ values, the Belize River Valley sample also had higher $\delta^{18}O$ than the Macal River; given the large standard deviation this may be an artifact of the small sample size, water source, or, most likely, an artifact of seasonality and time of year collected. As a result, these should be used with caution.

Table 3.1. $\delta^{18}O_{SMOW}$ values of select modern water sources in the Maya area.

Location	Surface water	Groundwater	Lake water	Rain water	Source
Belize River Valley	-4.41 ± 0.4 (N=10)	-4.10 ± 0.4 (N=7)			Freiwald 2011, White and Longstaffe n.d., Marfia et al. 2004
Macal River	-6.83 ± 1.0 (N=2)				Freiwald 2011, White and Longstaffe n.d.
Mountain Pine Ridge streams	-3.34 ± 1.1 (N=4)				Freiwald 2011, White and Longstaffe n.d.
Lake Petén Itzá			2.26 ± 0.4 (N=8)		Scherer et al. 2015
Yaxha	-0.25 ± 0.2 (N=2)			-7.4 (N=1)	Scherer et al. 2015
Punta Laguna, Yucatan		-3.92 (N=3)	0.66 to 0.93 (N=15)	-3.91 (N=4)	Curtis and Hodell 1996b

Oxygen isotope values from human teeth obtained from surrounding archaeological sites provide a better idea of $\delta^{18}O$ values expected for Tipu. Table 3.2 provides $\delta^{18}O$ values from sites in the Maya region pertinent to this study. Although no previous oxygen isotope work has been done at Tipu, nearby sites provide a general idea of expected values. Individuals from Chaa Creek, a Classic period site located several kilometers downstream from Tipu, have an average $\delta^{18}O$ of -3.2‰. The Belize River Valley, several kilometers north of Chaa Creek and at a lower elevation, has an average $\delta^{18}O$ value of -2.99‰. Human $\delta^{18}O$ values from the northern Maya Mountains to the south of Tipu average -3.55‰. Although there are temperature and elevation differences between these locations, these sites show a very subtle pattern of lower, more depleted values with increasing elevation. The oxygen isotopes at Tipu can be expected to roughly fall within these ranges.

Table 3.2. Human carbonate oxygen isotope values from select sites in the Maya area.

Location	Sample type	N	Range	Min.	Max.	Mean	SD	Median	Reference
Macal River (Chaa Creek)	Incisors and M1s	16	2.41	-4.61	-2.2	-3.2	0.65	-3.18	Freiwald 2011: Table 6.7
Belize River Valley	Primarily M1s	16	3.46	-4.37	-0.91	-2.99	0.87	-3.04	Freiwald 2011: Table 6.7
Northern Maya Mountains (Mountain Pine Ridge)	M1s and M2s	8	1.57	-4.44	-2.87	-3.55	0.58	-3.32	Freiwald 2011: Table 6.7
Tikal (Local only)	Canine	77		-4.36	-1.1	-2.69	0.83	-2.69	Wright 2012: Table 3
Topoxté	M3	26		-4.41	0.77	-1.62	1.6		Wright et al. 2000: Fig. 114
San Bernabe Mission (total)		23		-4.03	0.45	-1.47	1.28	-1.23	(Freiwald et al. 2018)
San Bernabe Mission (trimmed)		21?		-3.39	0.45	-1.35	1.18	-1.18	(Freiwald et al. 2018)
Caracol	Various teeth	6	1.8	-4.35	-2.55	-3.43	0.71	-3.42	Freiwald 2011: Table 6.7
Altun Ha	Bone	24				-2.5	0.76		White et al. 2001
Campeche (Local)						-2.9			Price et al. 2010: Table 1
Calakmul						-1.2			Price et al. 2010: Table 1
Mayapan (total sample)	Bone and teeth			~-7	~-2.5				Wright 2007: Figure 2

Defining “Local” Isotope Values

Local isotopic signatures must be thoroughly understood and defined in order to identify residential relocation in the archaeological record using biogeochemical analyses. Not surprisingly, there are a variety of ways to identify local variation. Several of these will be addressed below.

Methods for Determining Strontium Baselines and "Local" Values

While regional geologic, soil, and water data are helpful to understand the broad range of strontium isotope values that may be found within a given ecosystem, faunal proxies are generally preferred, especially if there is reason to believe that the fauna consumed water from similar sources and foods obtained from the same field systems as the local human population. The strontium isotope ratios of fauna should reflect an average of all strontium consumed during formation of a specific tissue, thus averaging local variability in the biologically available strontium for a specific area (Bentley et al. 2004; Bentley 2006; Price et al. 2002).

It is not always possible or cost effective to extensively characterize local isotope ratios of a site through fauna. Statistical approaches to identifying local variation within a human sample population are a useful tool to help characterize the locally expected $^{87}Sr/^{86}Sr$ range within the data. At a basic level, researchers have used the total data set mean with a two-standard deviation range to establish a "local" expected range for the population and identify individuals that fall outside of this range (Price et al. 2002). This method is also useful to help determine if the available faunal or geologic $^{87}Sr/^{86}Sr$ data adequately models the expected human $^{87}Sr/^{86}Sr$ data (Price et al. 2002). Using a simple two-standard deviation range to estimate the local range for a human population has some downsides, and may not be totally appropriate for certain populations. Additional statistical analyses of $^{87}Sr/^{86}Sr$ data, including tests of normality, are useful tools to help examine the overall distribution of the data set and help identify outliers, or migrants, in the sample (Wright 2005a; Wright 2012). The efficacy of the two-standard deviation method is contingent on how variable isotope values are within the local environment, the proportion of migrants in the sample, and the deviation of the $^{87}Sr/^{86}Sr$ values for those migrants (Wright 2005a). Ethnohistoric records suggest that during the Colonial period the Maya at Tipu were highly mobile, with the site experiencing extensive in and out migration. The possibility of the Tipu Colonial skeletal population representing a highly mobile population, may complicate the use of strictly statistical methods to define the local value; however, the majority of the Precolonial Tipu sample is expected to be born locally and have been raised eating and drinking from local sources.

Another statistical technique is to use cluster analysis to identify underlying patterns within the data (e.g. Valentine et al. 2015). Clusters are statistically established by grouping values that are more similar to each other than they are to other groups. With this approach, the local isotope range is defined by the isotope ratios of the upper and lower bounds of the clusters with the highest likelihood values (Valentine et al. 2015). This method differs from other statistical methods to identify "local" ranges in that multiple isotopes are simultaneously used to establish the clusters, rather a range established for each individual isotope; this additional discriminatory power allows for the identification of significant groupings within the data that would otherwise not be easily identified with the use of a single isotope (Valentine et al. 2015).

Methods for Determining Oxygen Baselines and “Local” Values

Variation in isotope values introduced through fractionation in the environment and human body tissues makes determining oxygen isotope baselines for a population a little more problematic to establish than is the case with strontium isotopes. Fractionation in calcium carbonate precipitation is strongly temperature dependent, and differences in body temperature between species results in different rates of fractionation; as a result, oxygen isotope data from fauna are not a good model for humans (Longinelli 1984; Luz et al. 1984). Differences in drinking water sources, breastfeeding practices, seasonality, and individual physiological variation all may significantly impact differences between individuals in a given population, occasionally making it problematic to separate out actual migrants from other noise in the data set.

Different approaches have been used to identify locally expected ranges for oxygen isotopes. Often the values from previous studies of humans from the region are used in determining the local $\delta^{18}O$ range. Some scholars have used data from local oxygen isotope values from water sources that they converted to body tissue values as a means to estimate locally expected values. Caution should be used when converting $\delta^{18}O_{precipitation}$ to $\delta^{18}O_{bioapatite}$ as various conversion equations have been shown to produce different results (Pollard et al. 2011; Pryor et al. 2014). A more rigorous method uses various statistical methods to examine the distribution of the total sample and identify outliers (Wright 2012). This method is ideal for larger samples and may allow one to detect temporal differences and better model changes in migration or water sources (Wright 2012). Given the lack of reliable oxygen isotope data for drinking water sources available to the area immediately surrounding Tipu, this latter method will be utilized.

Caveats for the Application of Isotopes to the Study of Human Migration

Biogeochemical analyses do have several limitations that should first be taken into consideration when detecting migrants in a population. Strontium and oxygen isotopes are only useful for determining migrations within the first generation. Subsequent generations will show local values. Moreover, there must be sufficient geologic and climatic differences between the two locations. High intake of non-local food and/or water with high strontium concentrations may also further confound results (Fenner and Wright 2014; Trask et al. 2012; Wright 2005a). Finally, archaeological bones and teeth are susceptible to post-depositional chemical alteration from the surrounding burial environment (Hedges 2002; Kohn et al. 1999; Lee–Thorp 2002; Sillen et al. 1989). The inorganic matrix of bones and teeth, hydroxyapatite, is more resilient than collagen and thus is often used as a measure of diet in archaeological and partially fossilized samples (Lee–Thorp 2002). Both enamel and bone are susceptible to postdepositional alteration of the hydroxyapatite matrix, although enamel is much more crystalline and stable than bone, which allows it to be much more resilient to diagenetic alteration (Lee–Thorp 2002). Postdepositional chemical alteration of the mineral phase of bone and enamel apatite typically occurs via the interaction of carbonates from the local soils and groundwater, wherein the groundwater carbonates exchange with the biogenic structural carbonates and result in progressive recrystallization of the apatite matrix through time, or fossilization (Lee-Thorp et al. 1989; Lee-Thorp and van der Merwe 1991; Lee-Thorp and Sponheimer 2003; Lee–Thorp 2002; Tuross et al. 1989). A number of studies have proposed methods to both identify the presence of diagenesis in bone and enamel apatite, and techniques and chemical methods to remove secondary mineral contaminants. These methods typically utilize a combination of treatment with dilute sodium hypochlorite or hydrogen peroxide to oxidize organic matter, followed by dilute or buffered acetic acid to dissolve diagenetic crystalline deposits (Koch et al. 1997; Lee-Thorp and van der Merwe 1991; Lee-Thorp and Sponheimer 2003; Lee–Thorp 2002; Sillen et al. 1989; Wright and Schwarcz 1998) and return the samples to as close to their original biogenic form as possible prior to obtaining carbon and oxygen isotope values. The employment of such methods ensures the isotope ratios being measured actually reflect the diet of the individual.

CHAPTER IV

MATERIALS AND METHODS

Tipu Skeletal Sample

Over 600 individuals were buried in the church nave or in the surrounding churchyard at Tipu (Cohen et al. 1997; O'Connor 1995) (Figure 4.1). The cemetery shows intensive use during the early Colonial period (1521 AD through the early 1700s). Graves from underneath the church floor are especially crowded; burials were located at different vertical depths, with some bodies buried directly on top of one another (e.g. MT-66 and MT-78). Many older burials were subjected to varying degrees of disturbance by later, intrusive interments (Cohen et al. 1997). Of the approximately 600 individuals, 270 skeletons are complete articulated primary burials, 253 of which are believed to date to the Colonial period based on archaeological evidence. An additional 106 individuals were articulated but have been disturbed in some way by a later burial event; the remaining individuals were either redeposited primary burials or comingled burials (Cohen et al. 1997). There was no clear evidence of a mass burial such as might be expected in the event of an epidemic disease (O'Connor 1995).

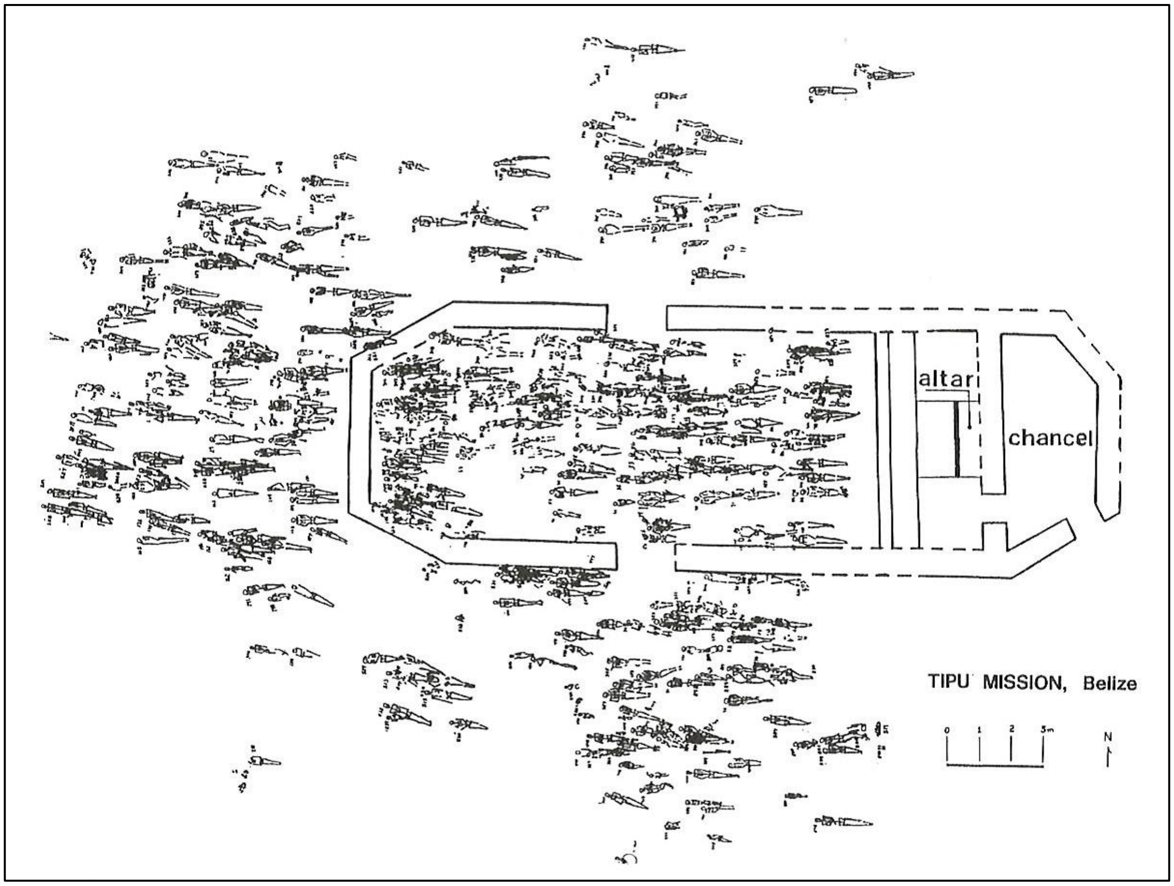


Figure 4.1. Map of the Cemetery at Tipu. Reprinted from O'Connor 1995: Figure 11; Jacobi 1996: Figure 2-3.

An additional 19 burials are believed to date to the Postclassic period (~900 AD to 1521 AD) based on burial location or other mortuary data. Many of these were associated with Postclassic house structures. Several burials believed to be Postclassic were either flexed or seated, with Postclassic burial goods, and buried outside the church, primarily on the fringes of the historic burial area (Cohen et al. 1997).

The Colonial period burials mostly conform to a standard Christian pattern, laid in a supine position, with the head oriented to the west, and the hands folded over the abdomen or pelvis. Most individuals from the Colonial period had bone or metal pins on them, indicating that they had been buried in a shroud; however, several individuals appear to have been buried without shrouds, in coffins (Cohen et al. 1997). The oldest individual in the Colonial sample, an old adult male (MT-78), was buried in a coffin under the floor of the church, in the front center near the altar. Two female individuals were buried directly next to one another and were believed to have been holding hands (MT-169 and MT-171). A young adult female (MT-96) was interred under the floor of the church near the altar and was buried holding a European-style thurible or censer believed to be of Maya manufacture (Graham 2011). Jacobi's analysis of the Tipu dental morphology identified potential clusters of individuals with rare or unusual dental traits within the cemetery, which he suggested may indicate the use of family plots (Jacobi 1996).

Overall, the skeletal remains are in a good state of preservation. The initial sex and age assessment of the Tipu skeletal collection was undertaken while the collection was housed at the State University of New York at Plattsburgh shortly after excavation, with analyses primarily performed by Mark Cohen, Sharon Bennett, Carol Armstrong, and Marie Danforth (Danforth 1989). Juvenile age was estimated using patterns of tooth calcification and eruption (Ubelaker 1978), length of long bone diaphysis (Merchant and Ubelaker 1977; Stewart 1957), and patterns of epiphyseal fusion (Krogman 1962; Modi 1957). Adult age was estimated through ectocranial suture closure (Meindl and Lovejoy 1985), auricular surface morphology (Lovejoy et al. 1985), cementum annulation (Wright 1989), and dental attrition (Kelley and Simmons 1984). O'Connor (1995) further refined the dental attrition age estimates using a series of regression analyses.

The sex of adult skeletal material was primarily estimated using sexually dimorphic traits of the skull (brow ridge and mastoid development) and pelvis (shape of the greater sciatic notch), as well as long bone robusticity (Danforth 1989). Definitive sex estimation was typically only assigned when a skull or pelvis was present (Danforth 1989). The Tipu skeletal collection was moved to the University of Southern Mississippi in 2013 and is currently under the control of Marie Danforth. Ongoing efforts are working to further sort out commingled assemblages and refine MNI, age, and sex estimations on the population. For the purpose of the present study the original age estimations were used.

Of the over 600 individuals excavated from Tipu, basic demographic information was obtained from approximately 585 individuals dating to the early Colonial period (Jacobi 2000). Of these, approximately 176 are estimated to be male or possible males, 119 are estimated to be female or possible female, 41 individuals are of indeterminate sex, and 249 individuals are juvenile (Jacobi 1996, 2000). The individuals range in age from fetal through old adult (O'Connor 1995). Of these Colonial period skeletons, 518 had some form of dental remains (Jacobi 2000).

Methods

Sample Selection

I obtained enamel samples from 195 individuals across Postclassic (N=17) and Colonial (N=178) contexts. All samples were recovered from the area immediately underneath or surrounding the church, with the exception of nine individuals who were recovered from under a Postclassic residential structure, G13-13. Table 4.1 summarizes the distribution of these samples by age and sex relative to their location at the site. The probable males and probable females will be combined with the male and female categories in statistical analyses for this project.

Table 4.1. Distribution of individuals in study sample by cemetery area.

		Location						**Total**
		G-13-13	**Inside back**	**Inside front**	**Outside north**	**Outside south**	**Outside west**	
Postclassic	Female	1	0	1	0	0	2	4
	Male	4	0	0	0	0	0	4
	Indeterminate	3	0	0	0	0	0	3
	Juvenile	1	0	0	1	2	2	6
	Total Postclassic	9	0	1	1	2	4	17
Colonial	Female	0	8	18	9	8	27	70
	Male	0	26	23	10	15	27	101
	Indeterminate	0	2	4	0	0	0	6
	Juvenile	0	0	0	0	0	1	1
	Total Colonial	0	35	45	19	23	55	178

I selected a sample of Colonial period individuals from each of the five cemetery areas defined by Jacobi (1996) to sample for isotope analysis: inside the church front, inside the church back, outside the church to the north, outside the church to the south, and outside the church to the west (Figure 4.2). I gave preference to more complete and adult individuals, particularly those with more complete biological profiles or demographic information. I chose to exclude Colonial period juveniles so that I might obtain a larger sample of adult individuals from across the cemetery, and because juveniles would (presumably) be moving with their parents. I aimed to evenly select individuals from each of the cemetery areas;

however, this was not always possible. Given the degree of commingling observed in the skeletal collection, I ensured the tooth sampled belonged to a specific individual so that the same individual was not accidently sampled twice; this was done by refitting loose teeth into the maxilla or mandible, or through pair matching and reconstruction of the dental arcade. By design, this sampling strategy avoids many, but not all, of the most disturbed and commingled assemblages, particularly those within the church. My exclusion of juveniles and many of the disturbed and comingled burials within the church does ignore a potentially important segment of the burial population; hopefully a future study may address these individuals further.

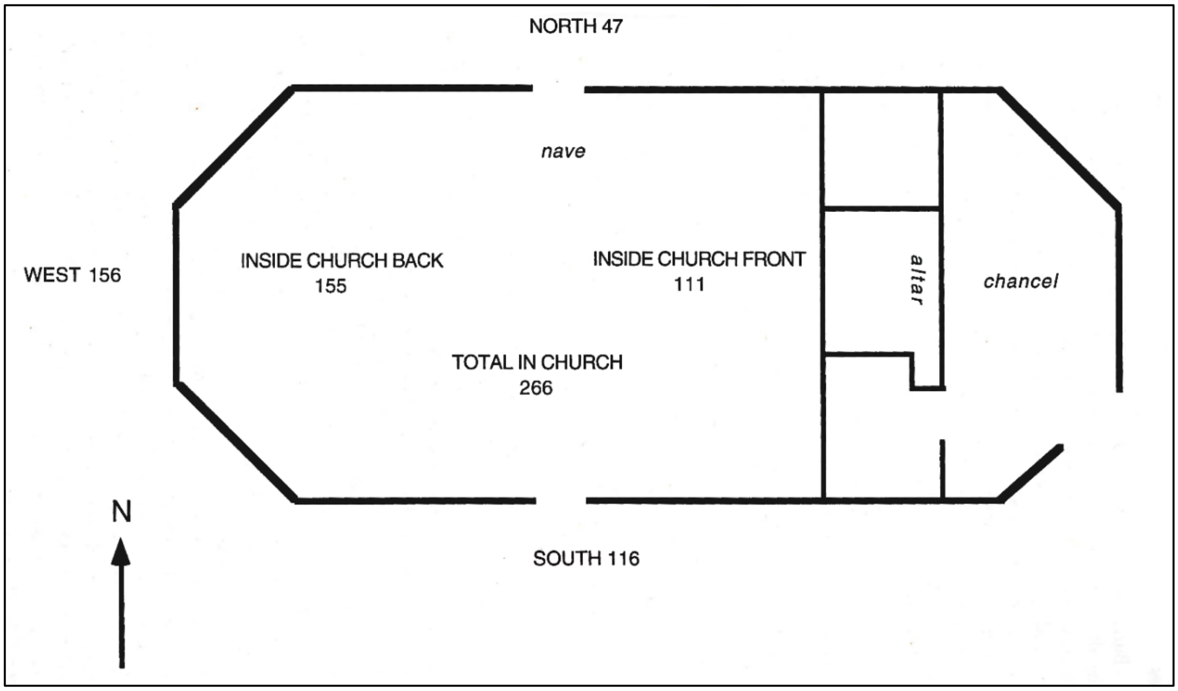


Figure 4.2. Tipu cemetery areas used in this study. Reprinted from Jacobi 2000: Figure 7.1. Numbers represent total numbers of burials in skeletal sample recovered from each cemetery area.

Isotope values obtained from 17 Postclassic individuals provide an idea of the range of isotope values at Tipu prior to the arrival of the Spanish, affording context for better interpretation of the Colonial period data. Nine individuals were buried in the Postclassic residential structure G13-13, and the remaining eight individuals were buried in the area that would later become the church cemetery. The project archaeologists identified these individuals as Postclassic through the presence of Postclassic grave goods or burial positioning (Cohen et al. 1997; Jacobi 1996); however preliminary radiocarbon dating results indicate at least one individual may be from the Classic period (Hoggarth, personal communication, 2017). Although there is a possibility that one or more of the individuals from presumed Postclassic contexts actually lived prior to the Postclassic, for the purposes of my current research I group these individuals into one “Postclassic” sample. In order to maximize the sample of Postclassic individuals, I selected all individuals with fully formed dentitions.

I primarily obtained enamel samples from maxillary and mandibular canines, which reflect the first few years of life (Alqahtani et al. 2010; Smith 1991; Ubelaker 1978). Canines have a longer mineralization phase than other teeth, typically beginning enamel mineralization by about 6 months (±3 months) and completing crown development by around 5-6 years (Alqahtani et al. 2010; Smith 1991; Ubelaker 1978). To minimize the destructive impact on the collection, I selected canines, which allowed me to reuse 95 teeth previously sectioned by Danforth (1989). Although the long time for enamel mineralization in canines can represent the period of breastfeeding and onto a solid diet, selection of canines was considered optimal to minimize any unnecessary destruction of dentition. In cases where a previously sectioned tooth was not available to sample, I selected a canine from the maxilla or mandible. In a few cases where canines were not available, other teeth were selected. The Postclassic dental material was more poorly preserved, experiencing higher rates of antemortem and postmortem loss, and greater wear than the Colonial material. To maximize the size of the Postclassic sample I also sampled one incisor, one premolar, one molar, one deciduous incisor, one deciduous canine, and one deciduous 1st molar. Care was taken to avoid sampling teeth with pathology, unusual antemortem wear, cultural modification, or other unique, identifying characteristics.

Strontium and oxygen sampling protocol

Strontium and oxygen isotopes require that small samples of enamel be removed from the tooth. In most cases, I was able to utilize teeth that were previously sectioned by Danforth (1989) for her study on enamel microstructures. For these instances, I used a Dremel drill and with carbide or diamond tipped Brasseler dental drill bits to remove the embedded tooth or partial crown from the epoxy that Danforth used to set the teeth. The surface of the tooth was then mechanically abraded to remove adhering surface debris, dentin, or epoxy. For teeth that were not utilized by Danforth (1989), I made every effort to thoroughly document the teeth prior to destructive analysis. I took high resolution macro photographs of the teeth and made molds of the individual teeth using Presidents Jet polysiloxane impression material (Coltene-Whaledent, Inc.). Using these molds, I made high resolution epoxy casts of the teeth. The casts, molds, and portions of unsampled teeth were sent back to the University of Southern Mississippi for placement with the skeletal remains. I removed any calculus deposits on the sampled teeth and curated them for future studies.

I first sonicated the teeth for 15 minutes in deionized (DI) water to remove adhering surface debris and let them dry overnight. Several teeth had large chunks of crown break off, and required minor reconstruction with a water based Elmers glue so that they could be fully documented, photographed, and the entire tooth could be cast prior to cutting (MT-538, MT-469, MT-1, MT-217, MT-308, MT-218, MT390, MT-271); once documentation was complete the glue was removed by soaking in DI water for 15 minutes to 1 hour. I removed an approximately 2 to 3mm section wide section of enamel spanning from the cemento-enamel junction (CEJ) to cusp using a Brasseler diamond coated dental wheel saw and carbide dental drill. By removing a CEJ to cusp section, I aimed to obtain a representative sample of residency during the entire span of enamel development for all individuals, and hopefully minimize the expression of age-based differences in diet. The enamel section was then mechanically abraded to remove adhering surface debris, pulp, and dentin. The enamel chunk was subsequently divided longitudinally, with 5-10 mg of enamel set aside for strontium isotope ratio measurement, and 20-30 mg of enamel reserved for oxygen isotopes.

Strontium Isotope Analysis

For strontium isotopes, I processed the enamel samples based on accepted protocol outlined in Price et al. (1994), Knudson (2004), Bentley (2003), in at the R. Ken Williams Radiogenic Isotope Geosciences Laboratory at Texas A&M University, a class 100 ultra-clean laboratory. After weighing the sampled enamel chunks, I transferred them to acid-cleaned centrifuge tubes. To treat for diagenetic contaminants, I first ultrasonically cleaned the enamel samples by sonicating them for 30 minutes in 1mL 1M acetic acid (optima), then again in a second aliquot of 1mL acetic acid (optima) for 15 minutes, then rinsed three times with Milli-Q water. I then dissolved the samples in 750 µl of 3N HNO_3 or 5N HNO_3. Once the samples were fully dissolved (after at least 48 hours), I transferred them to acid-cleaned Savillex PFA vials and let them evaporate on a hot-plate. I then redissolved the dried-down samples in 500µl of 3M HNO3, after which I purified through cation ion exchange columns filled with new Sr-exchange resin. Sr resin was not reused. Once the purified samples were dried on a hot-plate, they were redissolved in 1 µl of 0.1M H3PO4 and 1 µl of TaCl5, and loaded on to degassed Rhenium filaments for analysis. Finally, I ran my samples using a Thermo Scientific Triton thermal ionization mass spectrometer (TIMS) located at the Williams Radiogenic Isotope Geosciences Laboratory at Texas A&M University.

Several samples did not yield sufficient strontium the first time and had to be rerun. For these, I used powder leftover after running the carbon and oxygen isotopes; once these samples were weighed and transferred to acid-cleaned centrifuge tubes they were cleaned by sonicating for 25 minutes in 1mL 1M acetic acid (optima), sonicated again for 5 minutes in a second aliquot 1mL 1M acetic acid (optima), rinsed three times with Milli-Q water, and then processed according to the remainder of the strontium protocol outlined above.

Oxygen Isotope Analysis

I prepped all oxygen and carbon isotope apatite samples in Dr. Lori Wright's lab in the Texas A&M University Department of Anthropology using protocol outlined by (Wright

2013). For oxygen and carbon isotopes, I ultrasonically cleaned the enamel chunks in distilled water for 30 minutes. I then let them sit in 1mL 0.25M HCl for one minute, and then added 1mL DI water, and then removed the liquid and rinsed three times with DI water, after which I let sit overnight to dry. Once dried, each sample was finely ground with an agate mortar and pestle until the powder could pass through a 50µm copper sieve. To treat for possible organic contaminants, each sample was soaked for 48 hours in a ~1.5% sodium hypochlorite solution and then rinsed three times with DI water. To treat for diagenesis, each sample was soaked for 15 minutes in an acetic acid solution buffered to 4.5 pH with NaOH and then rinsed three times with DI water. The Texas A&M University Stable Isotope Geosciences Facility ran all oxygen and carbon isotope samples using the Thermo Scientific Kiel IV Automated Carbonate Device coupled to a Thermo Scientific MAT 253 isotope ratio mass spectrometer (IRMS).

CHAPTER V

RESULTS

Strontium and oxygen isotopes are the two primary lines of evidence used to identify local and non-local individuals in the Tipu early Colonial Period population. The previous chapters have outlined the basis for strontium and oxygen isotopes and demonstrate the utility in using isotopes to answer questions about within-life migrations of individuals from past populations. The combination of both strontium and oxygen isotopes allows me to consider geological variation in location of birth, as well as variation in drinking water sources; this multi-isotope approach helps tease out a more complex isotopic signature that would otherwise be invisible if only a single isotope were used.

In this chapter, I present the results of my strontium and oxygen isotope data collection. First, I address potential issues for contamination of the teeth previously embedded in resin. Second, I individually introduce the descriptive statistics for the $\delta^{18}O$ and $^{87}Sr/^{86}Sr$ datasets. During which, I examine the distributions of the total pooled sample (combined Postclassic and Colonial samples), Postclassic sample, and Colonial samples, and statistically test whether they represent normal distributions. Third, I compare how the $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ values from the Postclassic and Colonial period datasets compare to expected isotope values for the region from previous studies. Incorporating the results of the statistical analyses of the isotope distributions, and the comparison of the Postclassic and Colonial ranges to previous isotope data, I define the range I will use to represent the locally expected strontium and oxygen isotope range for Tipu. All subsequent analyses will primarily focus on the Colonial period isotope data in order answer the hypothesis presented in Chapter 1.

Once the Tipu local range is defined, I use a cluster analysis on the Colonial period sample to identify potential groups of individuals with similar isotope values, and investigate potential meanings of the clusters. I also use the statistically defined isotope clusters to look for evidence of spatial patterning in location of burial within the cemetery, based on geographical place of origin. Then, I use isotope data from several comparative sites and regions in an effort to estimate potential homelands of the migrants buried at Tipu. Afterward, I divide the Colonial period sample into locals and non-locals, based on where their isotope values fall in relation to the previously defined local isotope range. I use the groups of locals and non-local individuals to explore potential spatial and demographic differences between the local and non-local Tipu Colonial populations. Finally, I use the isotope data to briefly address several specific burials with unique mortuary contexts.

Potential Resin Contamination of Strontium Isotope Ratios

As discussed in Chapter 4, ninety-five of the enamel samples came from teeth that were previously embedded in resin and sectioned for mounting onto microscope slides. Using these teeth allows me to utilize teeth that had previously been cut (therefore minimalizing further damage to the Tipu skeletal collection), but introduces a potential for chemical contamination of the enamel from the resin. To assess if the resin chemically contaminated or altered the enamel $^{87}Sr/^{86}Sr$ values of the enamel, I compare the $^{87}Sr/^{86}Sr$

values of teeth embedded in resin to their antimeres. To do this, I took an enamel sample of a tooth that had been embedded in resin and an enamel sample from its resin-free antimere from four individuals. These eight samples were processed following the criteria outlined in Chapter 4 for strontium isotopes. Table 5.1 contains the results of this comparison.

Table 5.1. Strontium isotope ratios for samples obtained from resin and a previously unprocessed antimere.

	$^{87}Sr/^{86}Sr$		**Standard error (abs.)**	
Burial ID	Control	Resin	Control	Resin
MT-11	0.70828	0.70831	0.0000042	0.0000046
MT-16	0.70856	0.70858	0.0000047	0.0000059
MT-19	0.70852	0.70849	0.0000048	0.0006792
MT-83	0.70817	0.70817	0.0000051	0.0000042

For all four individuals, the values for the resin and control samples are very similar. For all four individuals, the measured difference lies in the 5th decimal place; human $^{87}Sr/^{86}Sr$ data is usually only reported to the 3rd or 4th decimal place due to lack of instrument precision and repeatability of measurements. Although the sample size is too small to use statistical tests to produce any meaningful results, the fact that there was no difference between the $^{87}Sr/^{86}Sr$ values of the control and resin samples when rounded to the 4th decimal place indicates the resin did not significantly alter the $^{87}Sr/^{86}Sr$ values for the Tipu teeth embedded in resin. Therefore, the teeth embedded in resin and those that were not embedded in resin were not treated differently for the remainder of the analysis.

Descriptive Statistics: Strontium

Table 5.2 contains the statistics for the total pooled sample of 195 individuals, as well as the Postclassic and Colonial time periods individually. The total data set has a mean $^{87}Sr/^{86}Sr$ of 0.70863, a high standard deviation (0.00073) and a wide range of values extending from 0.70763 to 0.71265. The skewness statistic is many times larger than the standard error, indicating that these data to not represent a normal distribution. The large, positive kurtosis statistic indicates this is a leptokurtic distribution, with the kurtosis more concentrated around the mean than would be expected from a normal distribution; this is probably due to the outlier. A Shapiro-Wilk test for normality confirms that these data do not represent a normal distribution (statistic= 0.770, df=195, p=0.000). Figure 5.1 shows a Q-Q plot that was used to examine the data by quantiles to the expected normal curve. This plot highlights the extremes of the dataset, particularly the group of outliers above 0.7090; the removal of the highest outlier does not help the data better conform to a normal distribution. The above results indicate that the total pooled dataset for strontium does not represent a normal distribution, and thus warrants further examination.

Table 5.2. Descriptive statistics for $^{87}Sr/^{86}Sr$ ratios measured on the Tipu sample, by time period.

		Pooled sample $^{87}Sr/^{86}Sr$	**Postclassic $^{87}Sr/^{86}Sr$**	**Colonial $^{87}Sr/^{86}Sr$**
N	Statistic	195	17	178
Mean	Statistic	0.70863	0.70891	0.7086
	Standard Error	0.00005	0.00014	0.00006
Median	Statistic	0.70847	0.70866	0.70845
Std. Deviation	Statistic	0.00073	0.00056	0.00074
Variance	Statistic	5.36E-07	3.32E-07	5.48E-07
Range	Statistic	0.00502	0.00182	0.00502
Minimum	Statistic	0.70763	0.70828	0.70763
Maximum	Statistic	0.71265	0.71009	0.71265
Skewness	Statistic	2.27683	0.76631	2.42504
	Standard Error	0.17408	0.54975	0.18207
Kurtosis	Statistic	6.53157	-0.81873	7.18907
	Standard Error	0.34646	1.0632	0.3622

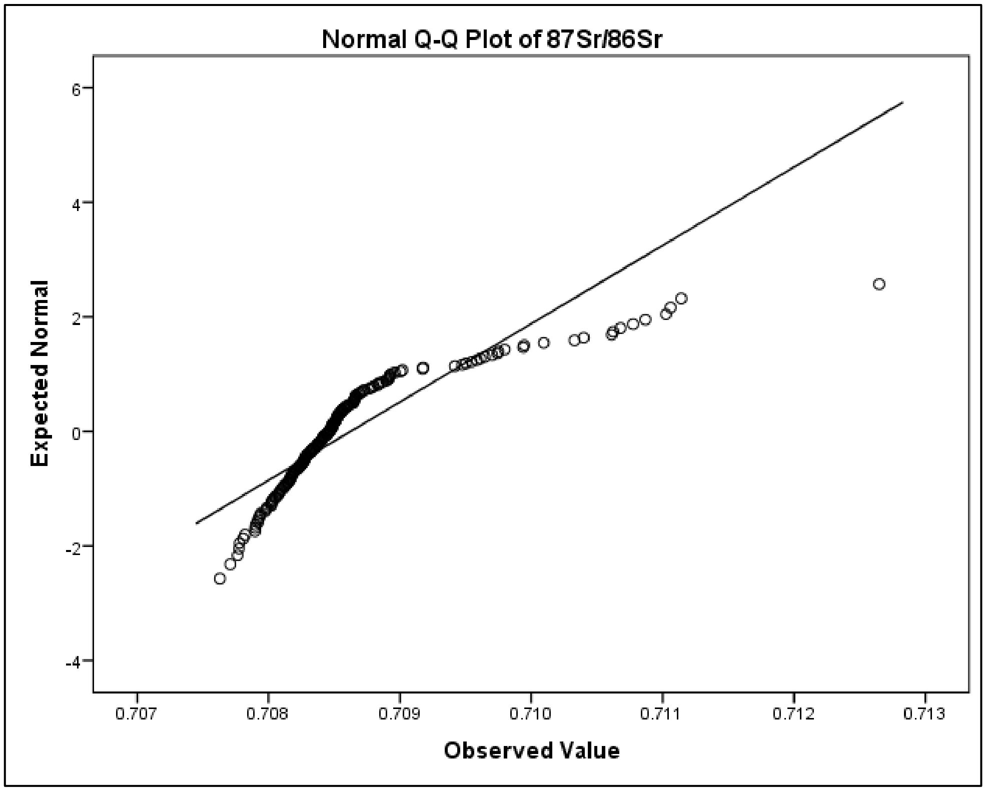


Figure 5.1. Q-Q probability plot for $^{87}Sr/^{86}Sr$ for the total pooled sample.

In addition, Table 5.2 (above) further breaks down the descriptive statistics for strontium data by time period, with the Postclassic data presented separately from the Colonial period data. The Postclassic sample has a mean $^{87}Sr/^{86}Sr$ value of 0.70891, a much lower standard deviation of 0.00058, and a narrower range than the total pooled Tipu population (Postclassic $^{87}Sr/^{86}Sr$ range = 0.70828 – 0.71009). The Postclassic sample is also far less skewed compared to the total Tipu sample, with the skewness statistic being very similar to the standard error. A Shapiro-Wilk test for normalcy (statistic= 0.870, df=17, p= 0.022) indicates that this sample is not normally distributed. A Q-Q plot was used to examine the data by quantiles to the expected normal curve (Figure 5.2); this plot shows the data has some deviations from the normal curve, but there are no real outliers in the data. The distribution appears to be slightly platykurtic, with the lower tail of the distribution having the largest impact on the sample statistics. This may be a sign of a multimodal distribution; the histogram also suggests the Postclassic data may be a multimodal distribution, although the sample size is small and the value falls within the standard error.

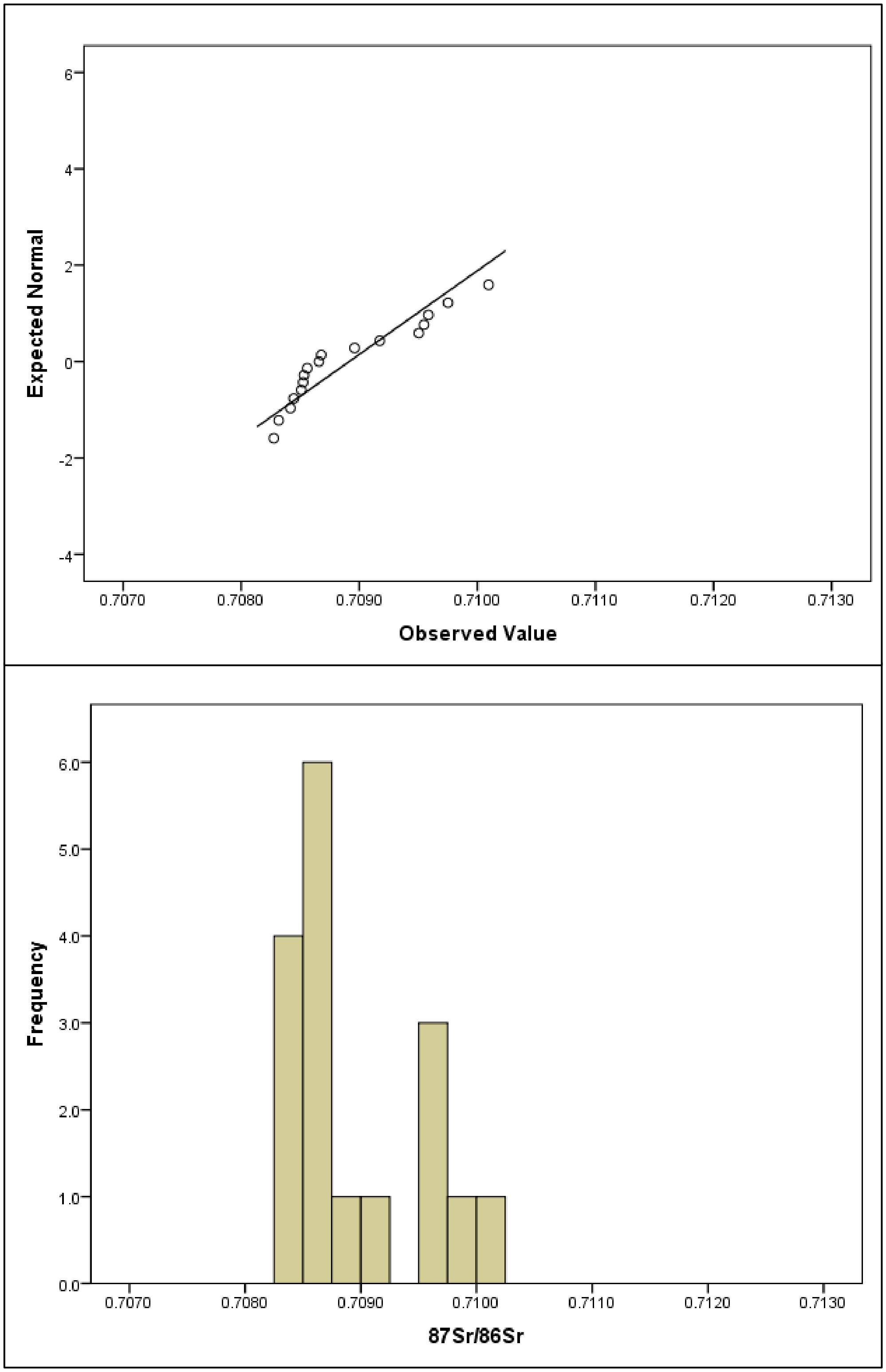


Figure 5.2. Q-Q probability plot (top) and histogram (bottom) for ^{87}Sr/^{86}Sr for the Postclassic sample.

The descriptive statistics for the Colonial period $^{87}Sr/^{86}Sr$ data are also presented in Table 5.2 (above). There is a clear difference between the Postclassic and Colonial strontium data sets. The Colonial mean of 0.70860 is almost the same as the total pooled Tipu sample mean, while the standard deviation of the Colonial sample is slightly higher at 0.00074. In contrast to the Postclassic $^{87}Sr/^{86}Sr$ range, the Colonial sample range is very broad (Colonial period $^{87}Sr/^{86}Sr$ range = 0.70763 – 0.71265). The sample is skewed towards the lower end of the range, and the skewness standard error is several times larger than the skewness statistic, indicating a non-normal distribution. The large positive kurtosis value indicates this is a leptokurtic distribution, meaning more individuals are in the tails than would be expected in a normal distribution; this is likely influenced by the presence of the outlier. For the Colonial sample, most of the individuals are located in the lower range of the distribution, and Figure 5.3 shows that the majority of individuals have $^{87}Sr/^{86}Sr$ values less than 0.7090. A Shapiro-Wilk test for normality confirms these data do not represent a normal distribution (statistic= 0.745, df=178, p=0.000). A Q-Q plot is used to examine the data by quantiles to the expected normal curve (see Figure 5.3); in addition to highlighting the extremes of the dataset and dense clustering of lower strontium values, the plot also highlights the large group of outliers above 0.7090. These results indicate that the Colonial strontium data do not represent a normal distribution. Skewed and non-normal distributions such as this one would be expected from a highly migratory population.

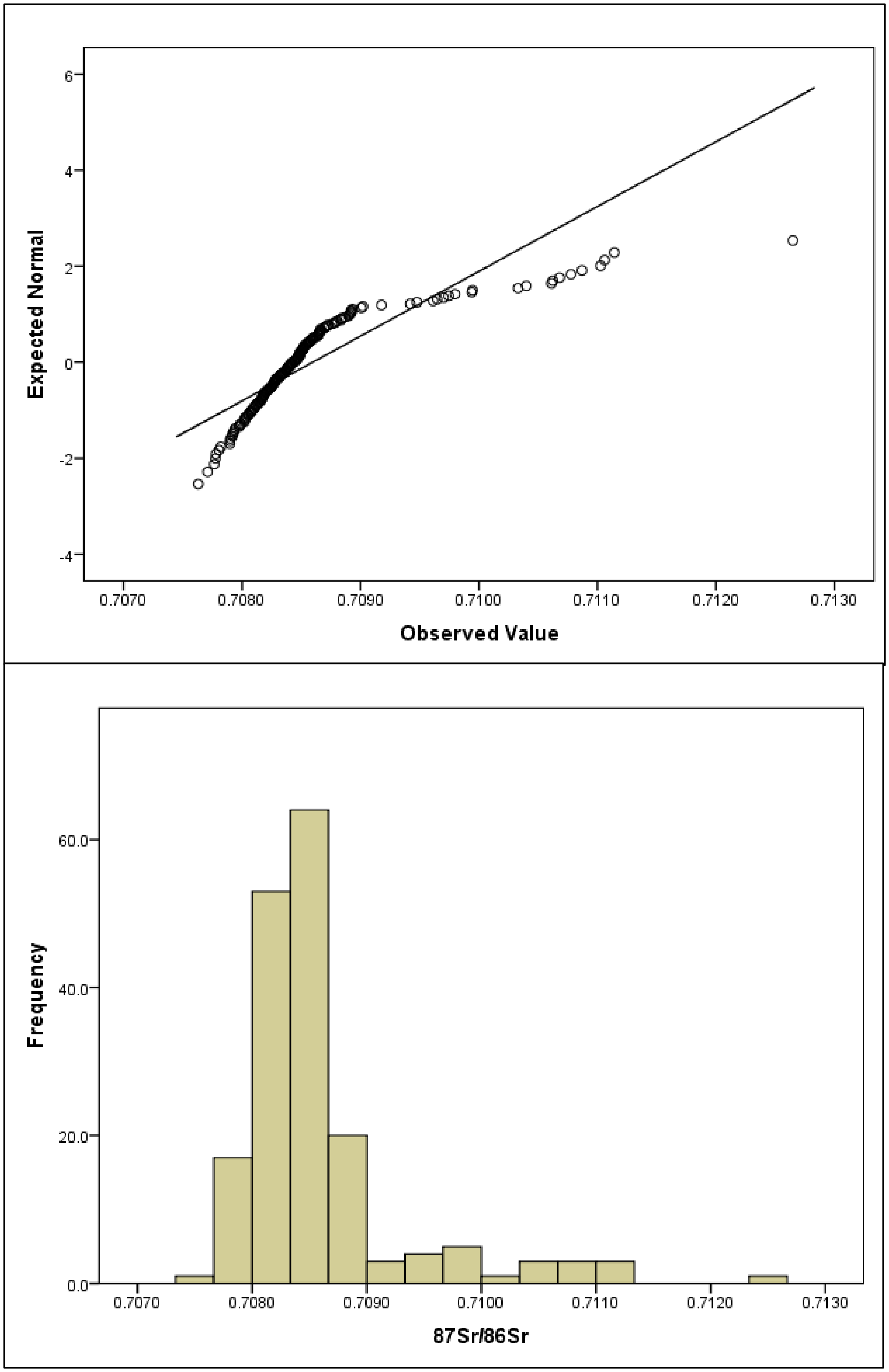


Figure 5.3. Q-Q probability plot (top) and histogram (bottom) for $^{87}Sr/^{86}Sr$ for the Colonial sample.

The extreme skewness observed in the Colonial period sample may be the result of multiple, overlapping distributions or populations. Both graphical representations of the Colonial $^{87}Sr/^{86}Sr$ data (see Figure 5.3 above) depict what may be a large cluster of individuals with lower $^{87}Sr/^{86}Sr$ values, and a second cluster of individuals with higher $^{87}Sr/^{86}Sr$ values. Figure 5.4 presents a histogram highlighting these two groups. This suggests the Colonial data may actually be a bimodal distribution, which would account for the leptokurtic appearance of the distribution for the values below 0.7090, and the platykurtic distribution of the values above 0.7090. To further investigate the presence of a multimodal distribution, two test groups are created by splitting the Colonial $^{87}Sr/^{86}Sr$ data at 0.7090 and removing the high $^{87}Sr/^{86}Sr$ outlier; the resulting two distributions are plotted in Figure 5.5a-b. Figure 5.5a shows the Q-Q probability plot for Colonial period individuals with values below 0.7090, while Figure 5.5b shows the Q-Q probability plot for the Colonial period individuals with $^{87}Sr/^{86}Sr$ values above 0.7090. Both distributions cluster around the expected normal line, suggesting they are consistent with normal distributions. For the $^{87}Sr/^{86}Sr < 0.7090$ group, a Shapiro-Wilk test for normality indicates it is consistent with a normal distribution (statistic=0.990, df=155, p=0.333). Similarly, for the $^{87}Sr/^{86}Sr > 0.7090$ group, a Shapiro-Wilk test for normality indicates it also is consistent with a normal distribution (statistic=0.939, df=22, p= 0.186). The possibility of the Colonial period strontium isotope data representing a multimodal distribution will be discussed in further detail later in this chapter.

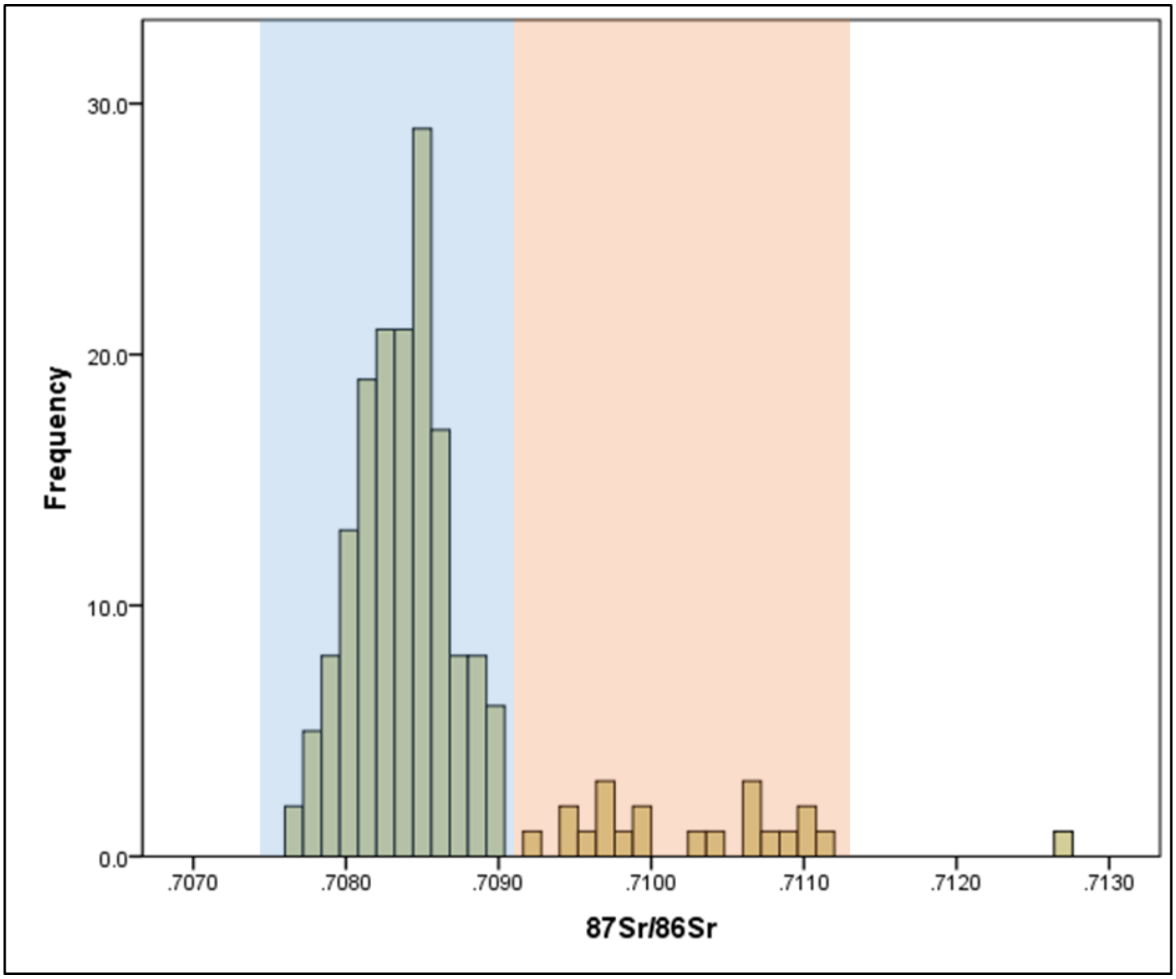


Figure 5.4. Possible multimodal distribution in the Tipu Colonial ^{87}Sr/^{86}Sr data.

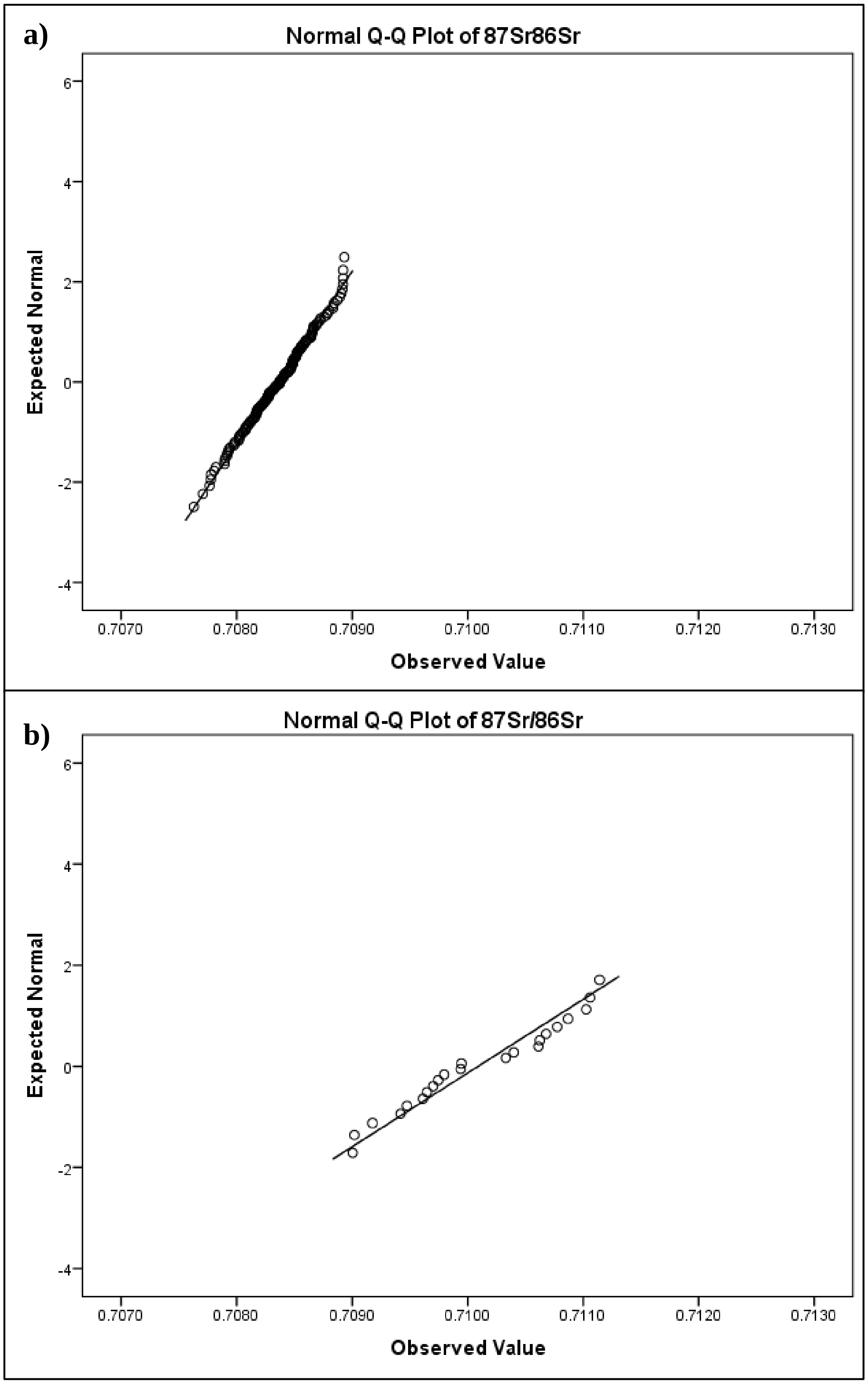


Figure 5.5. Q-Q probability plots for the divided Colonial sample. The plot above (a) shows only individuals with ^{87}Sr/^{86}Sr values that fall below 0.7090. The plot below (b) shows only individuals with ^{87}Sr/^{86}Sr values that fall above 0.7090 (excluding the one ^{87}Sr/^{86}Sr outlier).

Although both the above groups appear to follow a normal distribution, the < 0.7090 group contains many individuals that are classified as non-local through oxygen isotopes, as will be addressed later in the chapter; the removal of these individuals significantly reduces the appearance of a normal distribution for the < 0.7090 group. The > 0.7090 group has no individuals that classify as migrants only through oxygen isotopes. Furthermore, the total Postclassic $^{87}Sr/^{86}Sr$ range (0.70828-0.71009) nearly evenly straddles the high end of the < 0.7090 distribution and the low end of the > 0.7090 distribution, failing to characterize either of these groups.

In summary, the statistical analysis of the both the total pooled sample and Colonial samples found them to be consistent with non-normal distributions, displaying a wide range of variation in strontium isotopes, and with values skewed toward the lower end of the distribution. The Postclassic sample has a much tighter range of strontium values than the total pooled and Colonial groups. There is what appears to be a break in the Colonial distribution around $^{87}Sr/^{86}Sr=0.7090$, which may be an artifact of a bimodal distribution. Although splitting the Colonial sample at 0.7090 does create two groups with distributions that cluster around the normal line, neither of the split groups have range endpoints that are similar to those of the Postclassic range. Next, I discuss how the Tipu human strontium isotope data relate to expected strontium values for Tipu based on faunal and geologic data.

Expected Strontium Isotope Ratios for Tipu

The above section details a wide range of variation in strontium isotope values for the Tipu total pooled sample and Tipu Colonial period sample; the Tipu Postclassic sample has a much smaller range of variation. Therefore, it is useful to consider expected strontium values for the local area from faunal and geological samples when reconstructing locally expected ranges.

Chapter 3 provides an in-depth discussion of the underlying geology for Tipu and the broader Maya region, discusses expected strontium isotope ranges based on this information. As discussed in Chapter 3, the expected strontium values from the bedrock geology of Tipu is significantly different from all faunal and human samples, suggesting it is not an accurate estimator of biologically available strontium. Tipu's location in a transitional strontium zone may contribute to this deviation; although the underlying bedrock is limestone, sediment runoff and dissolved particulates originating in the Maya Mountains (located several kilometers upstream of Tipu) may be influencing the Tipu local range.

Figure 5.6 compares the $^{87}Sr/^{86}Sr$ values obtained from the 17 Tipu Postclassic individuals with the combined Macal River Valley land snails and the large mammals excavated from Tipu; these data show that there is considerable overlap in strontium values between the Postclassic individuals and the lower ranges for the snails and large mammals. Combined, the Tipu faunal and Postclassic human $^{87}Sr/^{86}Sr$ data span three of Hodell et al. (2004) strontium clusters, and include values found throughout most of the northern and central Maya lowlands. If all outliers with $^{87}Sr/^{86}Sr$ values of greater than 0.7110 are removed, all the faunal data and the Postclassic human data fall nicely between 0.7082 and 0.7110. This range can be further tightened to 0.7082-0.7100 with the removal of the land snails falling above the concentration of human and faunal values.

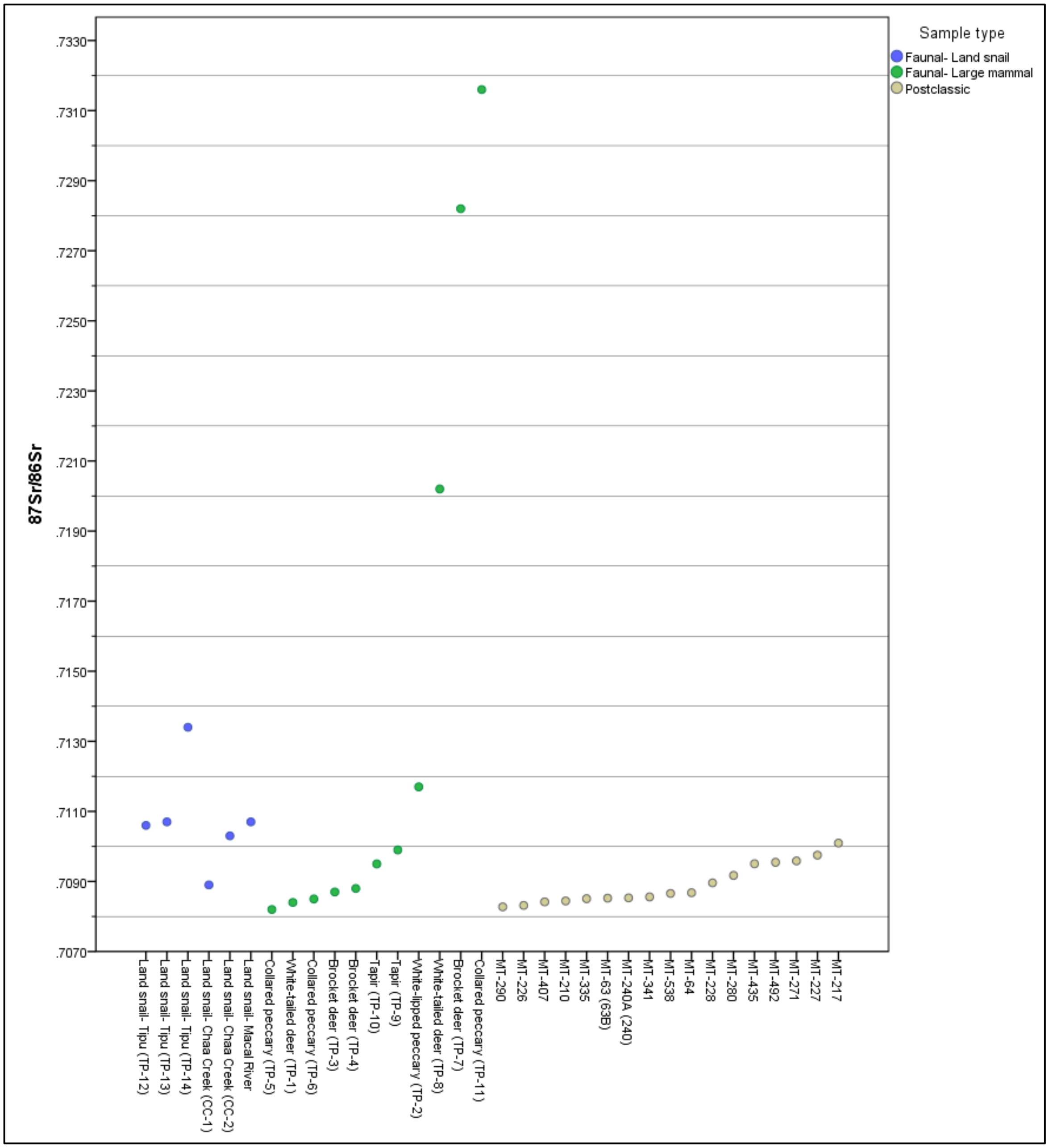


Figure 5.6. Comparison of strontium data obtained from modern land snails (Thornton 2011; Freiwald 2011) with archaeological large mammals (Thornton 2011) and Tipu Postclassic humans (present study).

The boxplots in Figure 5.7 compare the distributions of the $^{87}Sr/^{86}Sr$ values from the faunal data with the Tipu Postclassic and Colonial human samples. To facilitate comparisons with the human data, the land snail and large mammal data are presented in two different ways: as complete data sets, and trimmed data sets, with the highest outliers removed (see Figure 5.7). The Postclassic sample has a slightly lower range than the combined modern land snails, and a much more tightly clustered range than the overall large mammal samples. Trimming the large mammal range by removing the four highest outliers significantly tightens the range to 0.7082 to 0.7099; this trimmed range very closely matches the Postclassic human data, suggesting this is a good representation of the locally expected $^{87}Sr/^{86}Sr$ range. Trimming the modern land snail data by removing the highest value has little impact on the distribution. The very similar interquartile ranges observed for the Postclassic and faunal data indicate that, while the trimmed large mammal and Postclassic human $^{87}Sr/^{86}Sr$ data closely resemble one another, neither of the complete or trimmed faunal data sets appear to be a useful model for the Colonial human $^{87}Sr/^{86}Sr$ data.

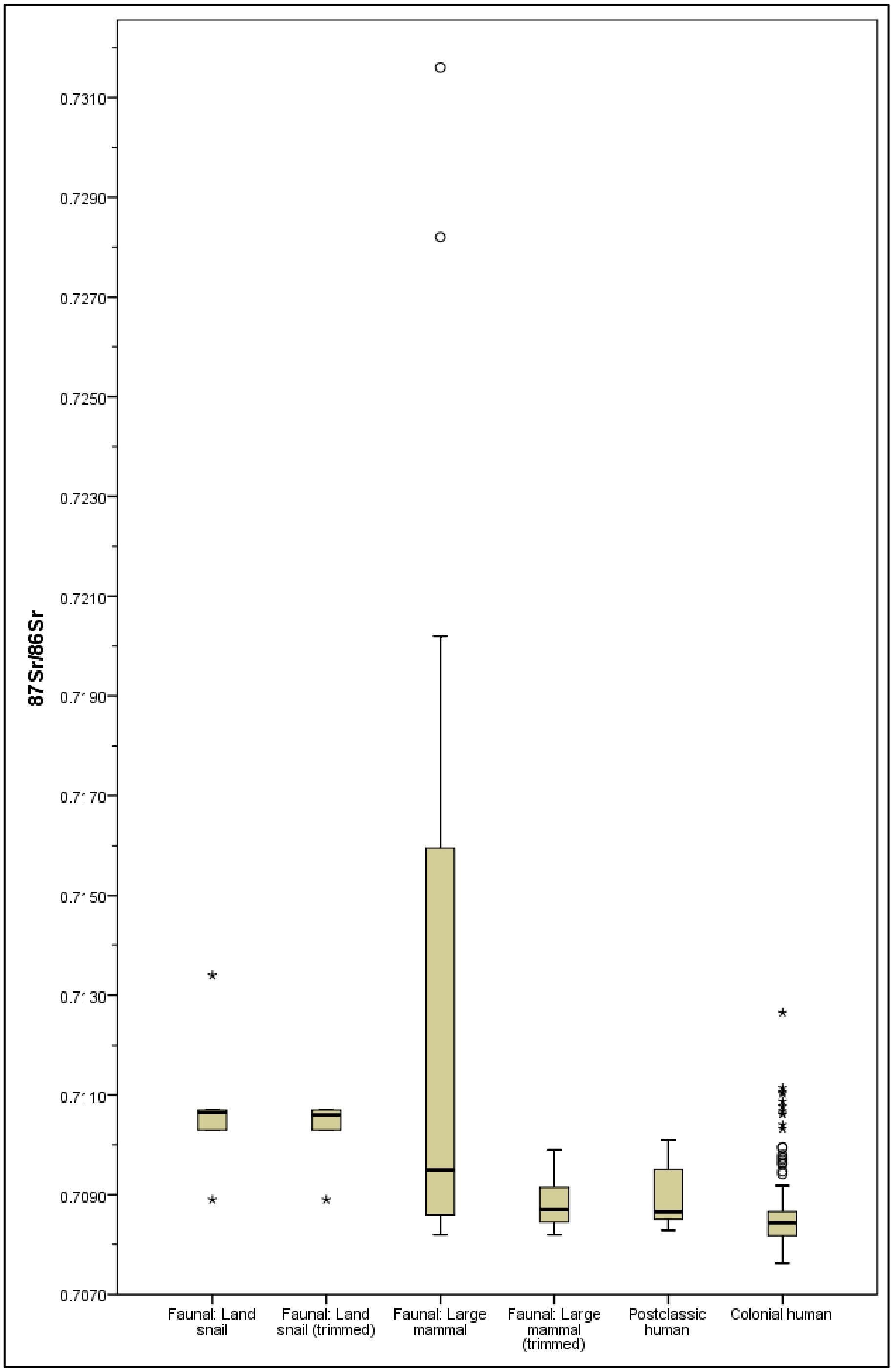


Figure 5.7. Boxplot of ^{87}Sr/^{86}Sr values of modern land snails collected near the Macal River (Freiwald 2011; Thornton 2011b), large mammals from archaeological contexts at Tipu (Thornton 2011b), Tipu Postclassic humans, and Tipu Colonial humans. The land snails are presented as a pooled sample (far left) and with the highest value trimmed (second from the left). The large mammals are presented as a pooled sample (third from the left) and with the highest four outliers trimmed (third from the right).

Descriptive Statistics: Oxygen

Basic descriptive statistics for the oxygen isotopes from the total sample, as well as the separated Postclassic and Colonial samples are presented in Table 5.3. The total pooled sample has a mean of -2.28‰$_{PDB}$ and a standard deviation of 0.73‰. The skewness statistic is several times larger than the standard error, indicating the distribution is not normal. The large, positive kurtosis statistic indicates the distribution is leptokurtic, meaning more individuals in the distribution have values in the tails than would be expected in a normal distribution. A Shapiro-Wilk test for normality confirms that these data do not represent a normal distribution (statistic=0.916, df=195, p=0.000). A Q-Q plot was used to examine the data by quantiles to the expected normal curve (Figure 5.8); in addition to highlighting the extremes of the dataset and dense clustering of lower oxygen values, the plot also highlights the large group of outliers above around -1.0‰$_{PDB}$.

Table 5.3. Descriptive statistics for δ^{18}O values measured on the Tipu sample, by time period. All δ^{18}O values below are reported in per mil (‰).

		Pooled sample δ^{18}O (PDB)	**Postclassic δ^{18}O (PDB)**	**Colonial δ^{18}O (PDB)**
N	Statistic	195	17	178
Mean	Statistic	-2.28‰	-2.77‰	-2.23‰
	Standard Error	0.052	0.102	0.055
Median	Statistic	-2.44‰	-2.82‰	-2.41‰
Standard Deviation	Statistic	0.73‰	0.42‰	0.74‰
Range	Statistic	3.8	1.6	3.8
Minimum	Statistic	-3.45‰	-3.38‰	-3.45‰
Maximum	Statistic	0.35‰	-1.78‰	0.35‰
Variance	Statistic	0.533	0.176	0.542
Skewness	Statistic	1.225	0.699	1.193
	Standard Error	0.174	0.55	0.182
Kurtosis	Statistic	1.884	0.435	1.741
	Standard Error	0.346	1.063	0.362

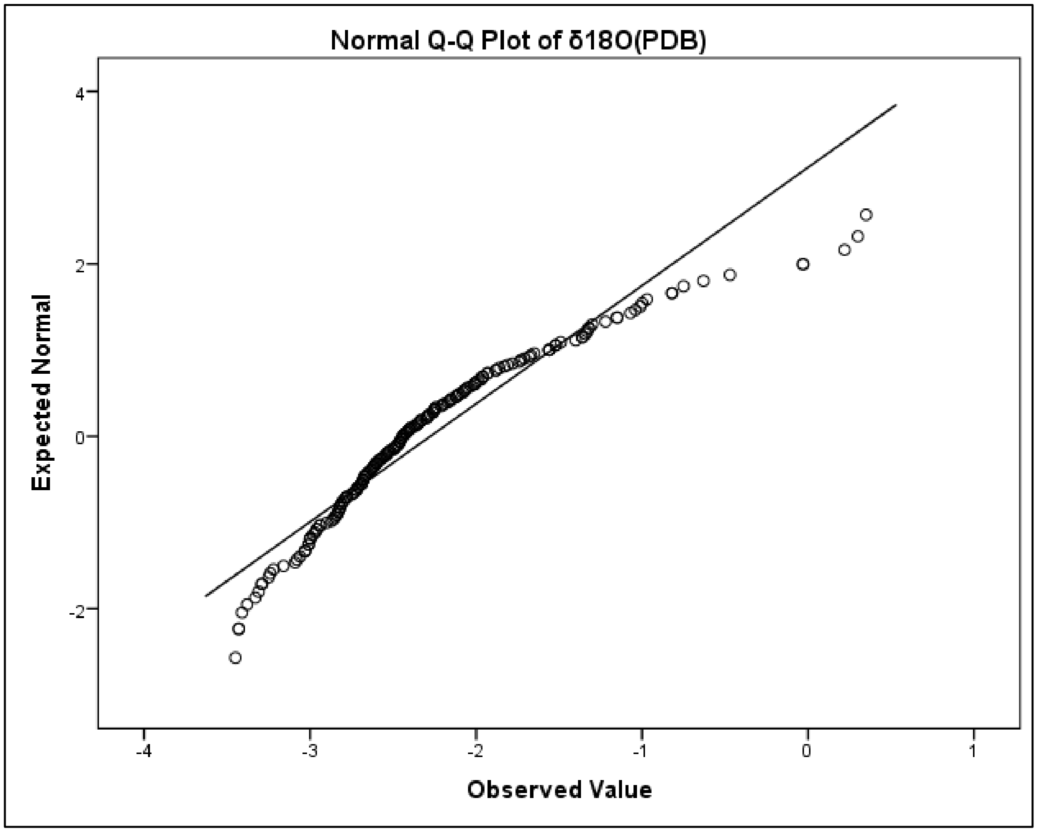


Figure 5.8. Q-Q probability plot for δ^{18}O for the total pooled Tipu sample.

Table 5.3 (above) also contains the oxygen isotope descriptive statistics for the Postclassic sample. The mean is -2.77‰$_{PDB}$ and the standard deviation is 0.42‰, much smaller than the standard deviation for the complete sample (0.73‰). The distribution does not appear to be skewed. A Shapiro-Wilk test for normality (statistic=0.959, df=17, p=0.611) indicates that this sample is normally distributed. A Q-Q plot was used to examine the data by quantiles to the expected normal curve (Figure 5.9); this plot shows the data tightly conform to the expected normal curve, with only one obvious outlier. The single outlier, MT-538, is a sample obtained from the deciduous maxillary canine of a juvenile buried outside and south of the church. Deciduous canines develop during the late stages of gestation and first year of life (Alqahtani et al. 2010; Ubelaker 1978) while children are breastfeeding. Because breastmilk is more enriched in ^{18}O than water, the oxygen isotope values of deciduous teeth and early developing permanent teeth can also be expected to be enriched (Wright and Schwarcz 1998). Overall, these data indicate that, although the Postclassic is only represented by a small data set, it appears to be normally distributed, implying that these individuals came from a homogeneous hydrological regime.

Table 5.3 (above) also contains the oxygen isotope descriptive statistics for the Colonial period sample. The mean is -2.23‰$_{PDB}$ and the standard deviation is 0.74‰, which is much larger than the standard deviation for the Postclassic period sample, and slightly larger than the standard deviation for the total pooled sample. The skewness statistic is several times larger than its standard error, indicating that the distribution is not normal. The large, positive kurtosis statistic indicates the distribution is leptokurtic, indicating that there are more individuals in the tails than would be expected in a normal distribution. A Shapiro-Wilk test for normality confirmed that these data do not represent a normal distribution (statistic= 0.918, df=178, p=0.000). A Q-Q plot was used to examine the data by quantiles to the expected normal curve (Figure 5.10); in addition to highlighting the extremes of the dataset and dense clustering of lower oxygen values, the plot also highlights the group of outliers above -1.0‰.

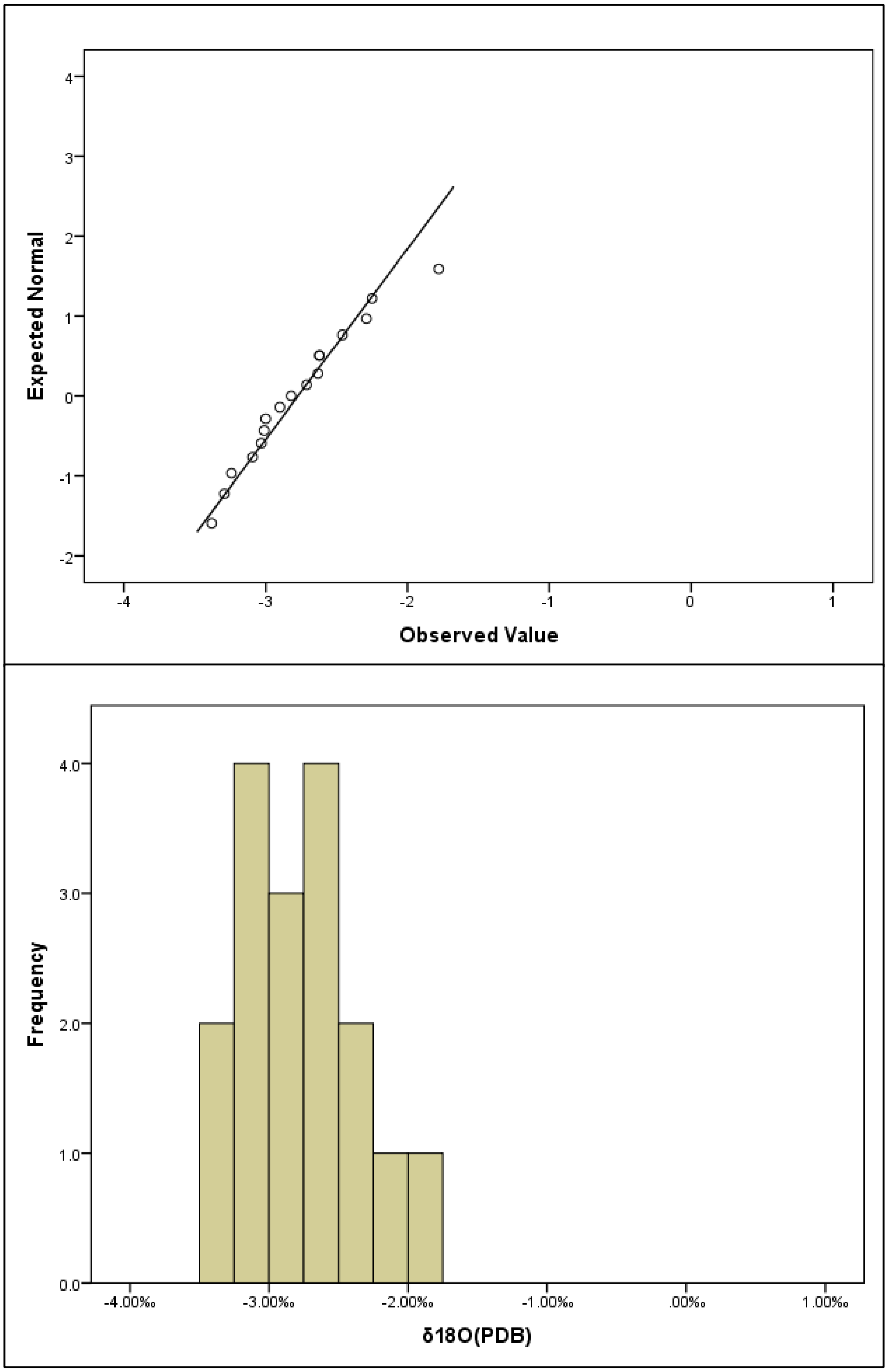


Figure 5.9. Q-Q probability plot (top) and histogram (bottom) for δ^{18}O for the Postclassic Tipu sample.

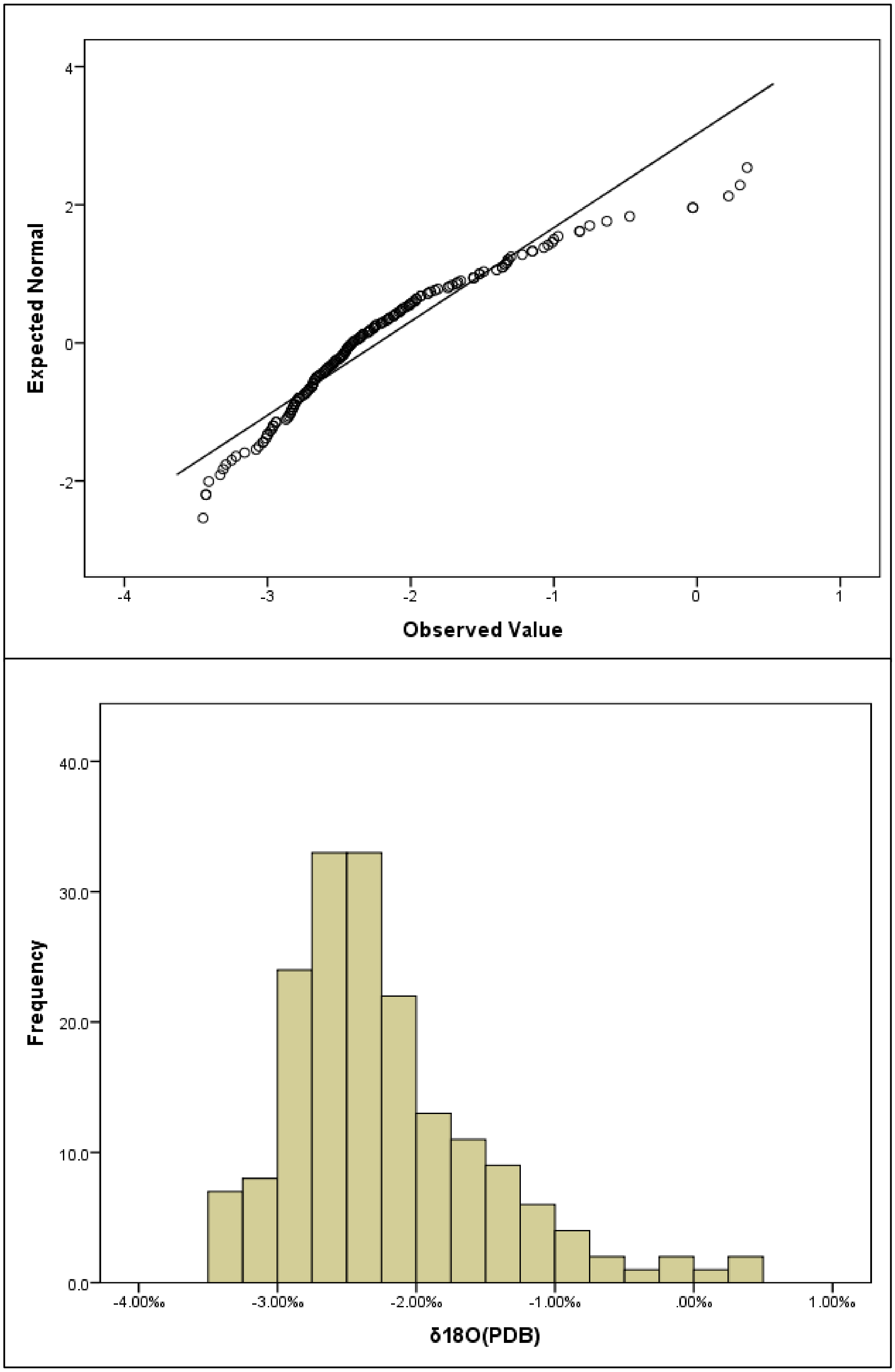


Figure 5.10. Q-Q probability plot (top) and histogram (bottom) for $\delta^{18}O$ for the Colonial Tipu sample.

In summary, the statistical analysis of the both the total pooled sample and Colonial samples found them to be non-normal distributions, displaying a wide range of variation in oxygen isotopes, with values skewed toward the lower end of the distribution. The Postclassic sample has a much tighter range of oxygen isotope values than the total pooled and Colonial groups, and is consistent with a normal distribution. The ranges for the Postclassic and Colonial samples are not consistent. Even with the removal of the Colonial period outliers (estimated to be the individuals with $\delta^{18}O$ ratios above -1.0‰ in Figure 5.10, above), the distribution of $\delta^{18}O$ ratios for the Colonial period sample is broader, with more individuals with enriched values, than is seen in the fairly tight total Postclassic range ($\delta^{18}O$ = -3.38‰ – -2.25‰). In the following section, I will compare the Tipu human oxygen isotope data to expected oxygen isotope ratios for Tipu.

Expected Oxygen Isotope Ratios for Tipu

The above section details a wide range of variation in oxygen isotope values for the Tipu total pooled sample and Tipu Colonial period sample; the Tipu Postclassic sample has a much smaller range of variation. A detailed discussion of the distribution of oxygen isotopes within the Maya area and expectations for Tipu based on published literature is provided in Chapter 3. Even though the sample sizes for many of these sites or groups of sites are quite small, and some groups of sites, like the Belize Valley, have watersheds that are quite large, nearby sites are still very useful for helping to provide a very broad, general idea of expected values for the areas around Tipu. Average human enamel $\delta^{18}O$ ratios for sites near Tipu range from -2.9‰ (Belize Valley) to -3.6‰ (Mountain Pine Ridge) and show a subtle trend of lower, more depleted values with increases in elevation. These values from nearby sites are all lower than the mean $\delta^{18}O$ values for the Tipu total pooled sample (-2.28‰), Tipu Postclassic sample (-2.77‰), and Tipu Colonial sample (-2.23‰). The mean $\delta^{18}O$ value for the Tipu Postclassic sample is the closest to the nearby comparative sites.

Figure 5.11 compares boxplots for the Tipu Postclassic and Colonial samples with each other, and with three comparative sites or groups of sites located relatively close to Tipu: the Belize Valley (located in a lower elevation with sites ranging from 10-30 kilometers north of Tipu), Chaa Creek (located in the foothills several kilometers downstream of Tipu), and Mountain Pine Ridge (located in a higher elevation approximately 15-20 kilometers upstream of Tipu in the northern Maya Mountains) (comparative data from Freiwald 2011). For the Postclassic and Colonial samples, there are significant differences in the distribution of the oxygen isotope values between the two time periods. When compared to the Colonial Period sample the Postclassic distribution has a much tighter overall $\delta^{18}O$ range, lower median $\delta^{18}O$ ratio, and the overall interquartile range has slightly lower $\delta^{18}O$ values. The lack of similarities between the two groups suggest these populations are not from similar distributions, and thus the range for the Colonial period sample is not a sufficient tool to estimate the local Tipu range.

The Tipu Postclassic range also deviates significantly from the isotope values for the comparative sites. Although it is most similar to the Belize Valley sample, this sample contains several migrants with enriched isotope values; removing these migrants significantly decreases the Belize Valley IQR and whisker size and shifts the Belize Valley sample $\delta^{18}O$ range lower. The Tipu Postclassic $\delta^{18}O$ median value and IQR are more similar to the $\delta^{18}O$ values from other nearby comparative sites than the Tipu Colonial Sample, although it is slightly higher than expected based on its location three kilometers upstream of Chaa Creek.

As discussed previously, the Postclassic dataset has a clear outlier, a sample obtained from the deciduous canine from an individual estimated to be around 2 years of age at death. The offset of the $\delta^{18}O$ value for this individual from the remainder of the Postclassic sample is consistent with the expected offset from breastfeeding (Wright and Schwarcz 1998); this suggests the $\delta^{18}O$ value for this individual was elevated by nursing, and should not be used for estimating the locally expected $\delta^{18}O$ range. When MT-538 is removed, the Postclassic $\delta^{18}O$ mean lowers to -2.83‰ with a much tighter standard deviation of 0.34‰. Removing the oxygen outlier also acts to narrow the Postclassic IQR, and it becomes closer to the other comparative $\delta^{18}O$ samples. Overall, the Tipu Postclassic sample is more consistent with the expected $\delta^{18}O$ values for Tipu based on other data from nearby sites, indicating it is a more reliable indicator for estimating the local range.

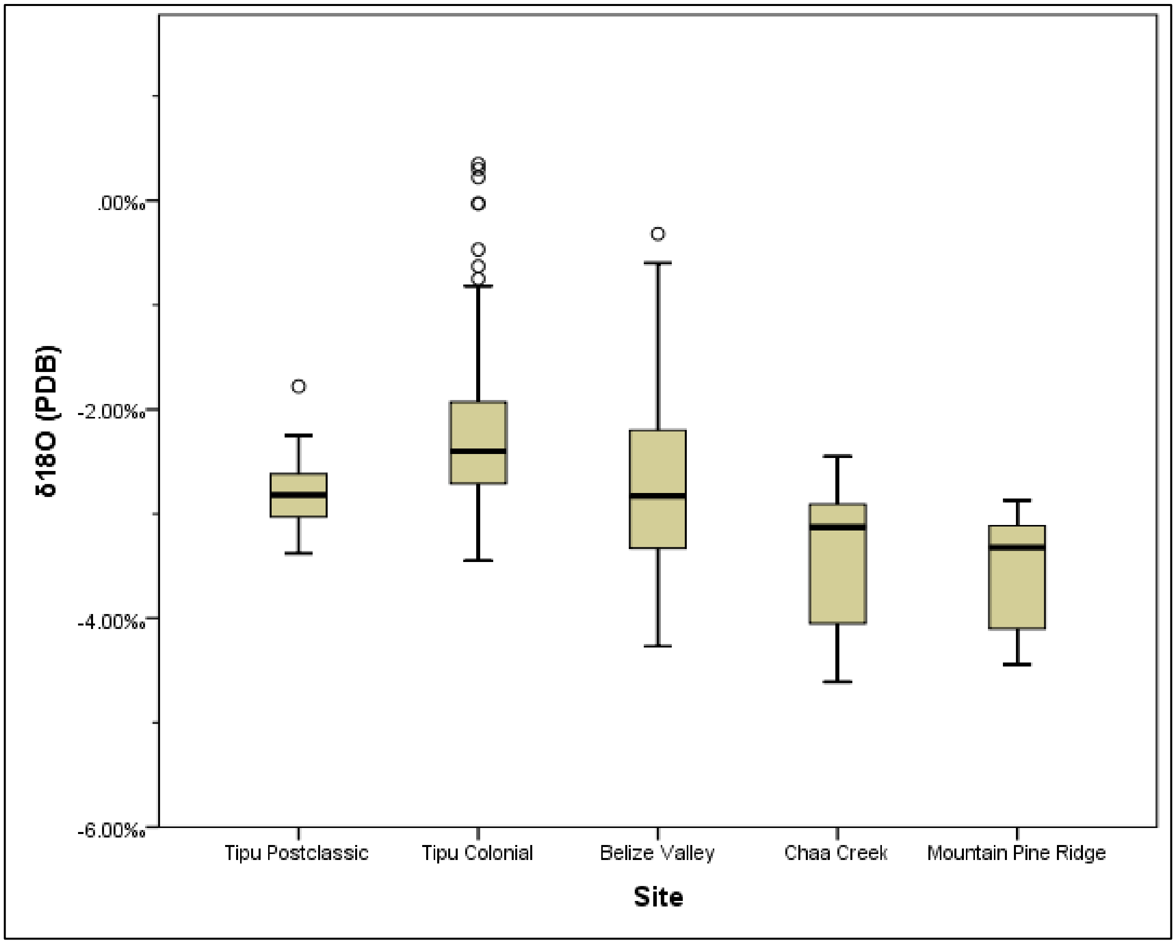


Figure 5.11. Boxplot comparing distribution of $\delta^{18}O$ ratios for Postclassic and Colonial period individuals. Data for Belize Valley (N=28), Chaa Creek (N=12), and Mountain Pine Ridge (N=8) is from Freiwald 2011: Appendix C. The Belize River Valley and Mountain Pine Ridge sites represented pooled samples from multiple sites.

Defining the Local Isotope Ranges for Tipu

Defining the Tipu local range for strontium and oxygen isotopes is essential for providing an answer to the hypotheses outlined in Chapter 1. As detailed in the above sections, the range of values observed in the strontium and oxygen total pooled datasets are far too broad to be used to define a local Tipu range. Much of the variation observed is likely the result of the presence of many migrants in the populations. Available ethnohistoric records for the Maya lowlands detail extensive evidence of long and short distance population movements and migrations of Maya peoples during the early Colonial Period, including to remote sites like Tipu. Historical records also suggest Tipu experienced dramatic fluctuations in population size throughout the early Classic period. Long distance migration in the Maya Lowlands is known to have also occurred during the Postclassic, most specifically the migration of the elite Itzá from the Postclassic city of Chich'en Itzá in the Northern Yucatán to Lake Petén Itzá, located in the Petén Lakes region of northern Guatemala (Rice and Rice 2005); there is also evidence for a great deal of continuity in occupation of smaller settlements, especially for sites like Tipu that were peripheral to much of the action seen elsewhere during the Terminal Classic and Postclassic. The nature of migration certainly changed between the Postclassic and early Colonial time periods; the driving forces impacting migration during the Colonial Period resulted in a rapid and widespread population change that exceeded anything previously seen in the Maya area. With consideration to the purported high frequency of Colonial period migration, the strontium and isotope data presented above will be further explored in order to identify a local Tipu isotope range for use in the remainder of this study.

An earlier section compared the Tipu human strontium isotope data to the geologic and faunal data, and identified several issues that complicate assessment of the local strontium range from geological and faunal comparative samples. For strontium isotopes, I found the trimmed large mammal faunal dataset overlaps well with the Postclassic human dataset, without having to remove any individuals from the human sample. The Colonial period $^{87}Sr/^{86}Sr$ dataset showed a wide range of variability, and could not be modeled well by any of the comparative faunal samples or by the Postclassic human dataset. The expected $^{87}Sr/^{86}Sr$ values of the local bedrock is not consistent with any of the human or faunal samples. Therefore, Price et al.'s (2002) method to estimate ranges of biologically available strontium using locally obtained faunal data does not work for the Colonial period sample. Conversely, the faunal and Postclassic human strontium data ranges are very similar, indicating the Postclassic sample is a good model for estimating local strontium isotopes. It should be noted that the faunal $^{87}Sr/^{86}Sr$ dataset used above is less than ideal. The sample size for mammals is fairly small, and the limited mobility and diet of land snails makes them a somewhat poor proxy for the estimation of biologically available strontium. Small mammals, like rodents, and freshwater snails may be better controls to estimate biologically available strontium within a given area.

For oxygen isotopes, the Postclassic and Colonial samples showed significant differences in the distribution of the oxygen isotope values between the two time periods. I compared the mean $\delta^{18}O$ ratios from the Tipu Postclassic and Colonial samples to published mean human enamel $\delta^{18}O$ ratios from several nearby sites. The Tipu Postclassic sample was closest to the expected $\delta^{18}O$ values from the nearby comparative sites.

The statistical analyses of the distributions of the Colonial period strontium and oxygen isotope data identified a wide range of variability in the datasets, much of which is likely the result of migration. The Colonial $^{87}Sr/^{86}Sr$ data had a much wider range of variation than was observed in the Postclassic sample, the tail was significantly skewed towards the right, and potentially may represent a bimodal distribution. Efforts to identify a local $^{87}Sr/^{86}Sr$ range by trimming the Colonial $^{87}Sr/^{86}Sr$ dataset (following Wright 2005a) were largely unsuccessful. Although, splitting the Colonial $^{87}Sr/^{86}Sr$ dataset at 0.7090 provided two datasets that both appeared to follow normal distributions, neither of these datasets accurately model the faunal or Postclassic human ranges; both the Postclassic human and trimmed large mammal $^{87}Sr/^{86}Sr$ ranges have mean values near 0.7090 split point. Additionally, the total Postclassic $^{87}Sr/^{86}Sr$ range (0.70828-0.71009) nearly evenly straddles the high end of the < 0.709 distribution and the low end of the >0.709 distribution, failing to characterize either of the split Colonial distributions. Furthermore, the <0.7090 group contains many individuals that are classified as non-local through oxygen isotopes. The removal of these individuals significantly reduces the appearance of a normal distribution for the <0.7090 group; there are no individuals in the >0.7090 group that are identified as migrants through oxygen isotopes. This could be indicative of the presence of more than two modes in the Colonial strontium sample, or may be that the Postclassic sample is also bimodal for strontium but not oxygen. Regarding the latter, a possible bimodal distribution can be observed in the Postclassic $^{87}Sr/^{86}Sr$ histogram (see Figure 5.2), although the sample size is too small to say for sure. In summary, all efforts to eliminate $^{87}Sr/^{86}Sr$ outliers from the Colonial population did not result in range endpoints that are in any way comparable to the Postclassic or faunal range endpoints.

Similar to the statistical analysis of the $^{87}Sr/^{86}Sr$ data, the Colonial $\delta^{18}O$ dataset had a much wider range of variation than observed in the Postclassic sample, was somewhat skewed, and significantly deviated from a normal distribution. The Postclassic $\delta^{18}O$ dataset was normally distributed. Even with outliers in the Colonial sample removed, the upper range value for the Colonial range deviated substantially from the upper Postclassic range, indicating the distribution seen in the Colonial sample likely includes several migrants. The lack of similarities between the oxygen isotope values for the Postclassic and Colonial groups suggest these populations are not from similar distributions, and thus the oxygen isotope range for the Colonial period sample is not a sufficient tool to estimate the local Tipu range.

The difficulties encountered when trying to determine a local range from the Colonial strontium and oxygen values can be explained by the Colonial sample consisting of a highly migratory population. This makes defining the local range based on statistical methods problematic. For highly mobile populations, defining local ranges based solely on the distribution of isotope values of the test population has the potential to be highly circular, and may in turn significantly bias all additional results and interpretations. As such, any definition of local based off the distributions identified within the Colonial period dataset may lead to bias in the results. Other potential factors, like Tipu's position on a transitional strontium zone, may an additional confounding factor in defining the Tipu local range. Fortunately, other methods to define the Tipu local range, like the Postclassic sample, are available.

Based on the above analysis, and with consideration given for the high migration and large population fluctuations reported for Colonial Tipu, the observed strontium and oxygen isotope ranges for the Postclassic sample are considered to be the most parsimonious model available to define the Tipu local strontium and oxygen isotope ranges. Furthermore, although it is probable the Postclassic sample contains migrants, there is insufficient strontium baseline isotope data available to identify these; thus, no individuals will be excluded from the Postclassic strontium dataset used to define the local range. One Postclassic individual, a young juvenile with an oxygen isotope value believed to be influenced by breastfeeding, will be eliminated from the Postclassic strontium dataset prior to defining the local range. Using the Postclassic observed range to define local for strontium and oxygen isotopes, Tables 5.4 and 5.5 provide the descriptive statistics for the Postclassic and Colonial total samples, as well as the Colonial "local" isotope sample. The $^{87}Sr/^{86}Sr$ range for the total Postclassic sample (0.70828 – 0.71009) is consistent with what is known about Tipu's location in a transitional or mixed geological area between the southern Maya Lowlands and Maya Mountains, as well as the available data on biologically available strontium. The trimmed $\delta^{18}O$ range for the Postclassic sample (-2.25‰ – -3.38‰) is consistent with the human $\delta^{18}O$ ratios from other nearby sites (discussed in Chapter 3), and is consistent with the bulk of $\delta^{18}O$ values for Colonial individuals. Using the Postclassic sample as a proxy to define the local range also allows for a base level of isotope variability expected from the Tipu population immediately prior to the arrival of the Spanish.

The issues identified with the Colonial period isotope data sets, in conjunction with the available ethnohistoric data and comparisons between the faunal data and Colonial sample, suggest using the Colonial sample to define a local Tipu range would be inappropriate and create a potential for bias. Therefore, I will use the strontium and oxygen isotope data from the Postclassic sample to define the Tipu local range. The Tipu local range for $^{87}Sr/^{86}Sr$ is defined as 0.70828 – 0.71009, and the Tipu local range for $\delta^{18}O$ is defined as $-2.25‰_{PDB}$ – $-3.38‰_{PDB}$. Although this is a wide, conservative range which likely encompass individuals born elsewhere, it does reflect the total range of variation for migrant and local $\delta^{18}O$ and $^{87}Sr/^{86}Sr$ values, and by extension, Tipu's interaction sphere, immediately prior to the arrival of the Spanish.

Table 5.4. Descriptive statistics for $\delta^{18}O$ for Tipu human enamel, for the Postclassic complete and trimmed data set, and the Colonial complete and local data set. All $\delta^{18}O$ values below are reported in per mil (‰).

	Postclassic $\delta^{18}O$		**Colonial $\delta^{18}O$**	
Statistic	**Complete**	**Trimmed**[1]	**Complete**	**Local**
N	17	16	178	66
Mean	-2.77	-2.83	-2.23	-2.63
Std. Error of Mean	0.10	0.09	0.06	0.03
Median	-2.82	-2.86	-2.41	-2.60
Std. Deviation	0.42	0.34	0.74	0.25
Variance	0.176	0.118	0.542	0.063
Skewness	0.699	0.155	1.193	-0.488
Std. Error of Skewness	0.550	0.564	0.182	0.295
Kurtosis	0.435	-0.851	1.741	-0.462
Std. Error of Kurtosis	1.063	1.091	0.362	0.582
Range	1.60	1.13	3.80	1.04
Minimum	-3.38	-3.38	-3.45	-3.29
Maximum	-1.78	-2.25	0.35	-2.25
25th Percentile	-3.06	-3.08	-2.71	-2.81
50th Percentile	-2.82	-2.86	-2.41	-2.60
75th Percentile	-2.54	-2.62	-1.93	-2.42

[1] Trimmed Postclassic data set only excludes MT-538, a sample taken from a deciduous canine. The $\delta^{18}O$ value is probably enriched by breastfeeding and so excluded.

Table 5.5. Descriptive statistics for $^{87}Sr/^{86}Sr$ from Tipu human enamel, for the Postclassic complete and local data set, and the Colonial complete and local data set.

	Postclassic $^{87}Sr/^{86}Sr$		**Colonial $^{87}Sr/^{86}Sr$**	
Statistic	**Complete**	**Local**	**Complete**	**Local**
N	17	17	178	66
Mean	0.70891	0.70891	0.70858	0.70872
Std. Error of Mean	0.00014	0.00014	0.00006	0.00005
Median	0.70866	0.70866	0.70843	0.70853
Std. Deviation	0.00057	0.00057	0.00074	0.00044
Variance	3.32E-07	3.32E-07	5.48E-07	1.95E-07
Skewness	0.766	0.766	2.45	1.505
Std. Error of Skewness	0.550	0.550	0.182	0.295
Kurtosis	-0.819	-0.819	7.189	1.380
Std. Error of Kurtosis	1.063	1.063	0.362	0.582
Range	0.00182	0.00182	0.00502	0.00166
Minimum	0.70828	0.70828	0.70763	0.70828
Maximum	0.71009	0.71009	0.71265	0.70995
25th Percentile	0.70848	0.70848	0.70818	0.70842
50th Percentile	0.70866	0.70866	0.70843	0.70852
75th Percentile	0.70953	0.70953	0.70866	0.70888

Cluster Analysis of Colonial Period Human $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ Data

Cluster analysis is a useful tool for identifying cluster or groups of individuals within a sample population based on isotope data. I carried out a hierarchical cluster analysis for the Colonial period skeletons using strontium and oxygen isotope data. The Postclassic individuals are excluded from the cluster analysis to simplify the identification of isotope clusters within the Colonial sample, and to eliminate a potentially confounding variable. By itself, the Postclassic sample is too small for any meaningful cluster analysis to be performed. The hierarchical cluster analysis was conducted in IBM SPSS Version 23 using average-linkage between groups and squared Euclidian distance. Additionally, to allow for the two very different types of data to be used together I transformed the variable values by standardizing them with z-scores. The resulting hierarchical clusters are depicted in the dendrogram shown in Figure 5.12.

Using the dendrogram created with the hierarchical cluster analysis of the strontium and oxygen isotope data (see Figure 5.12), I chose to define the groups at the second hierarchical level. This resulted in the identification of eight distinct groups of individuals, which I named clusters 1-8 (Figure 5.13). I chose the second hierarchical level instead of the third (which would have resulted in two fewer groups) in an attempt to maximize my ability to separate out the individuals in the large cluster represented by clusters 1 and 2 and avoid obscuring potential pertinent separations of the data. Clusters 1 and 2 cover a quite large range and include a significant portion of the sample; it is possible the large sample size in those two clusters is influencing the cluster analysis.

Most of the Colonial period individuals classify into clusters 1 and 3; they contain individuals with strontium values ranging from the high 0.707's to ~0.709 (see Figure 5.13). Cluster 1 is composed of individuals with δ^{18}O values below ~ -1.8‰, while cluster 3 is composed of individuals with values above ~ -1.8‰. Cluster 2 has a slightly lower and tighter overall δ^{18}O range than cluster 1 (with considerable overlap); however, these individuals show a slightly higher ^{87}Sr/^{86}Sr range. Clusters 4, 5, 6, and 8 all have similar oxygen ranges as cluster 2, but with progressively higher ^{87}Sr/^{86}Sr ranges. Clusters 7 and 8 are clear outliers. Cluster 7 is composed of five individuals with extremely enriched oxygen values (0.0‰ and higher), while Cluster 8 is comprised of a single individual with a ^{87}Sr/^{86}Sr ratio much higher than all other individuals (^{87}Sr/^{86}Sr=0.7126).

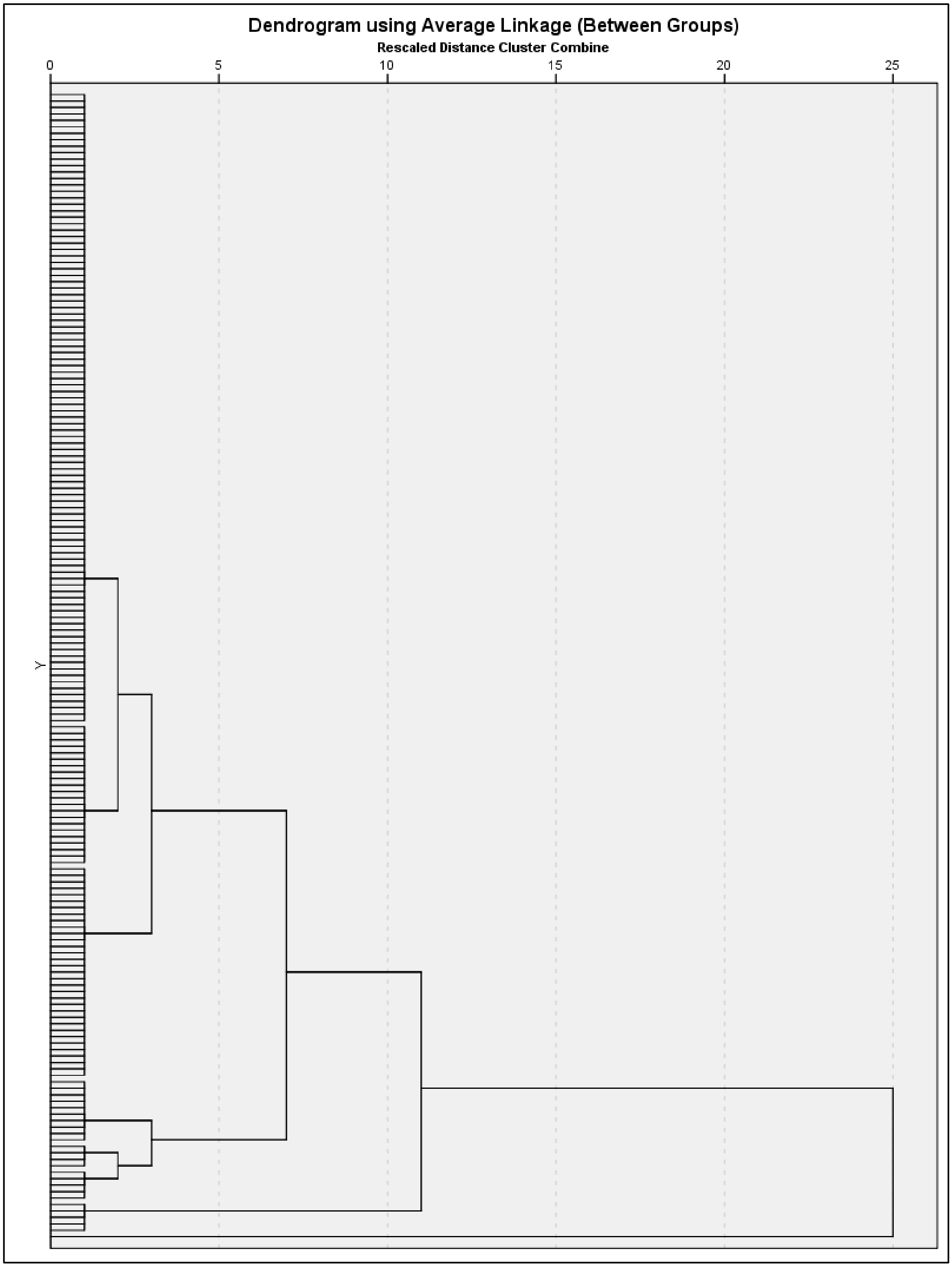


Figure 5.12. Dendrogram of hierarchical cluster analysis.

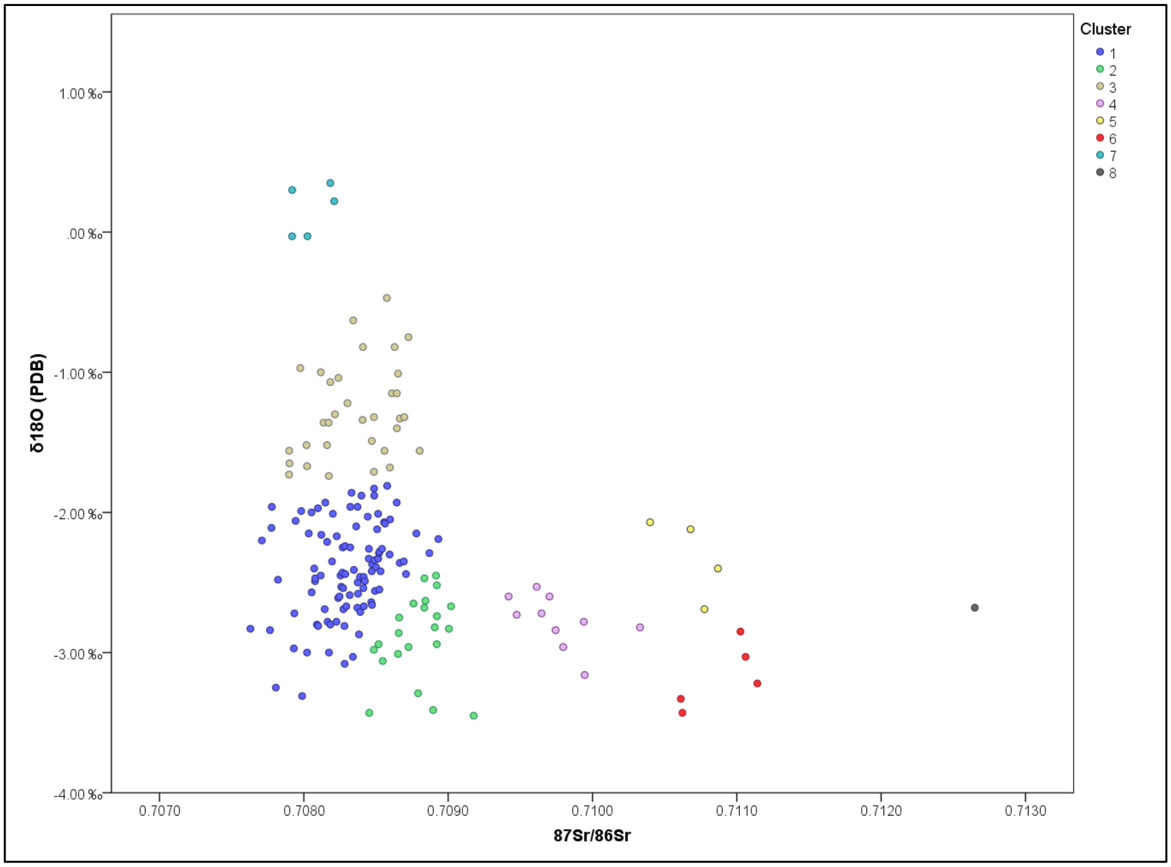


Figure 5.13. Plot of hierarchical clusters obtained from the Colonial Period strontium and oxygen isotope data.

To assess how well the clusters identified using the Colonial sample isotope data reflect actual isotope groupings based on common birth origin, Figure 5.14 shows the Postclassic data overlaid onto the Colonial isotope clusters. The Postclassic data do not appear to readily fit into a single cluster modeled from the Colonial data. The plotted strontium and oxygen isotope values for the Postclassic individuals fall within the upper range of strontium values for cluster 1 and extend over most of the cluster 2 and 4 ranges. Furthermore, with the exception of the oxygen outlier, the Postclassic δ^{18}O values roughly are in the same range as clusters 2, 4, 5, 6, and 8. Although there is significant overlap between the Colonial period cluster 1 and the Postclassic data, the isotope clusters of Colonial individuals that overlap with the Postclassic data also extend to lower $^{87}Sr/^{86}Sr$ and higher $\delta^{18}O$ values than shown in the Postclassic sample.

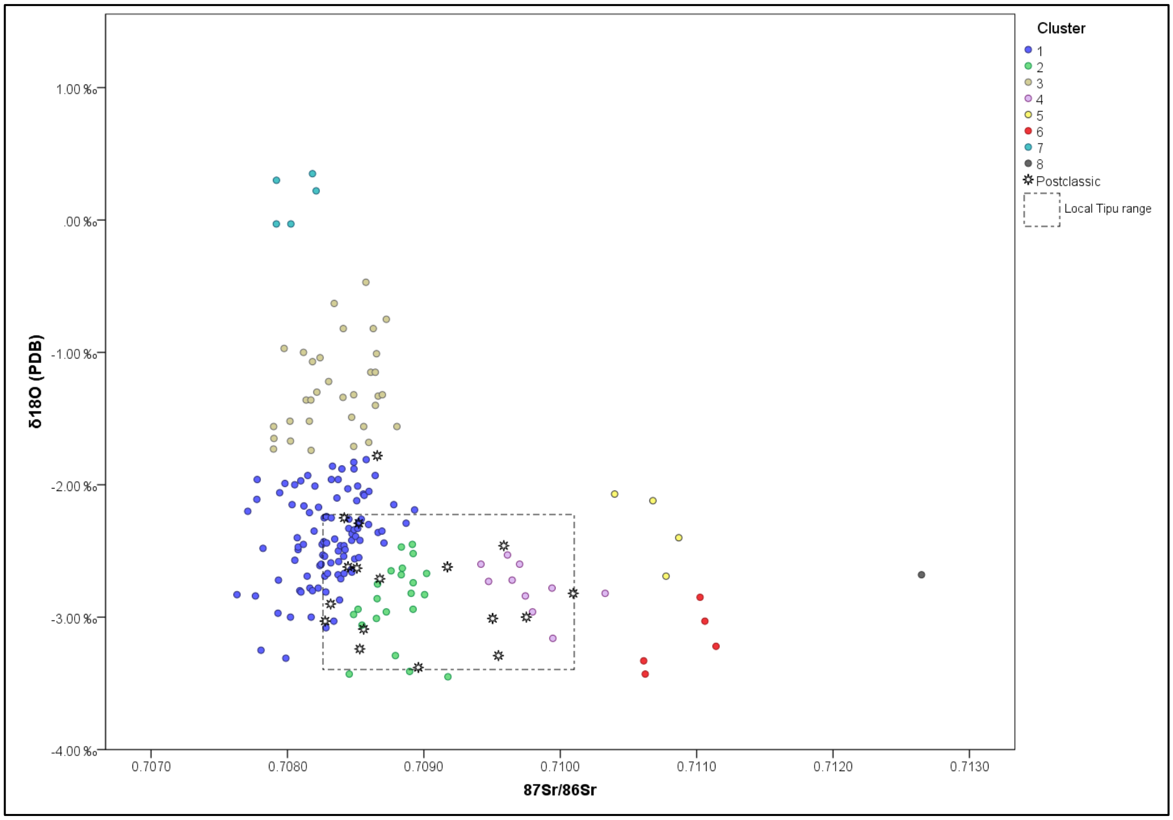


Figure 5.14. Plot of hierarchical clusters obtained from the Colonial Period strontium and oxygen isotope data, with an overlay of the Postclassic individuals (starbursts) to give an idea of Postclassic isotopic variability. The Tipu local range is indicated by a dashed line.

There is a dramatic difference in the observed ranges of $\delta^{18}O$ and $^{87}Sr/^{86}Sr$ values between the Postclassic and Colonial samples. Although there was certainly some degree of population movement occurring prior to the arrival of the Spanish, the data show a dramatic expansion of Tipu's interaction sphere during the Colonial period; there is an increase in the number people migrating to Tipu, as well as a much broader range of origins.

Finally, the combined strontium and oxygen isotope data support a possible bimodal distribution within the Tipu local range. A clear separation between clusters 2 and 4 is present, right around $^{87}Sr/^{86}Sr$= 0.7090-0.7093 (see Figures 5.13 and 5.14, above). In the Postclassic sample this divide appears to still be present, but is much less distinct. The observation of a similar hiatus in strontium isotope values in both the Postclassic and Colonial samples has several possible interpretations. First, the hiatus may reflect the utilization of two distinct areas or sources of biologically available strontium by different sub-groups within the Tipu population; differential access to two distinct sources of strontium, whether a result of behavior or just residence in geologically distinct areas around Tipu, could explain the bimodal distribution. For the Postclassic sample, this may also indicate that there are two populations represented within the Postclassic sample (one local, one migrant); if so, this may indicate that the location-specific migration continued into the Colonial period. Finally, it is possible that there are just insufficient data in that range. Additional sampling may help elucidate this issue.

Possible Homelands of Colonial Tipu Migrants

To approximate potential homelands for the possible migrant individuals buried at Tipu, the strontium and oxygen values obtained from the Tipu Colonial Period individuals are compared to existing isotopic data from the wider Maya lowlands. In the following sections, the Colonial period data will be compared to the expected $^{87}Sr/^{86}Sr$ ranges for different geographical regions throughout the Maya area, as well as $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ ranges for several comparative sites. As stated previously, isotopes are most useful as an exclusionary tool for identifying birthplaces of migrants. This allows me to identify one or more regions that are consistent with the Tipu Colonial migrants, as well as to better understand where Tipu fits in within the range of isotope variability of the Yucatán Peninsula.

Potential Homelands: $^{87}Sr/^{86}Sr$ Data

The $^{87}Sr/^{86}Sr$ ratios from the Colonial period Tipu population are first compared to estimated $^{87}Sr/^{86}Sr$ ranges for five broad geographic and geologic zones in the Maya area. The ranges used for these zones are chiefly based on the zones that Hodell et al. (2004) identified via bedrock, water, and plant samples, but have been further refined through several subsequent large metadata analyses of $^{87}Sr/^{86}Sr$ isotope ratios obtained from faunal studies and human populations (Price et al. 2008; Price et al. 2010). Several significant deviations from Hodell et al.'s original 2004 characterization should be noted. First, Hodell et al. (2004) defined the Northern Lowland zone as 0.7083-0.7099; local values obtained from human and faunal data from the Northern Lowlands shows that sites in the northern Yucatán Peninsula do not exceed 0.7090 (Price et al. 2008; Price et al. 2010). Second, variation in the ratios provided for the lower range for the Maya Mountains has also been noted, with the lower bound extending from 0.7102 (Miller 2014) to 0.7120 (Hodell et al. 2004); for the present study lower range of 0.7100 will be used (Price et al. 2008; Price et al. 2010).

Figure 5.15 shows that most of the Colonial Period Tipu individuals (~73%, N=129) fall within the range typically associated with the Northern Maya lowlands (0.7080 – 0.7090). Although some of these individuals may be from the Northern Lowlands, it is highly unlikely that such a large portion of the population originated there. Several Central Lowland sites in the Belize River Valley and northern Belize have $^{87}Sr/^{86}Sr$ values that also fall within this range. Human $^{87}Sr/^{86}Sr$ data from the western portion of the Central Lowlands (specifically Belize, north of the Maya Mountains) typically falls within the range of the Northern Lowlands, ~0.7080 to ~0.7090. Freiwald’s 2011 study of strontium variability in the nearby Belize River Valley identified a local $^{87}Sr/^{86}Sr$ range of 0.7080-0.7091 based on a two-standard deviation range for the human data. Given the Belize River Valley’s proximity to Tipu, and that the Macal River drains into the Belize valley, the Belize River Valley is likely source for several of the migrants at Tipu.

Sites in Northern Belize also have $^{87}Sr/^{86}Sr$ values that fall within the Northern Lowlands’ range. Nojol Nah is a small Classic Period Maya site near the Hondo River, and is located in near the estimated southern boundary of the La Pimienta region during the early Colonial Period (Jones 1989); all individuals at Nojol Nah have strontium ratios between 0.7080 and 0.7087 (Das Neves 2011). Although it is a site dating from the Early Classic to the Terminal Classic, it is within the geographical scope of the La Pimienta area and so is a good proxy for expected values in the region. Similar strontium ranges are seen at other sites in northern Belize/ the northern central lowland have similar values (e.g. Colha=0.7082

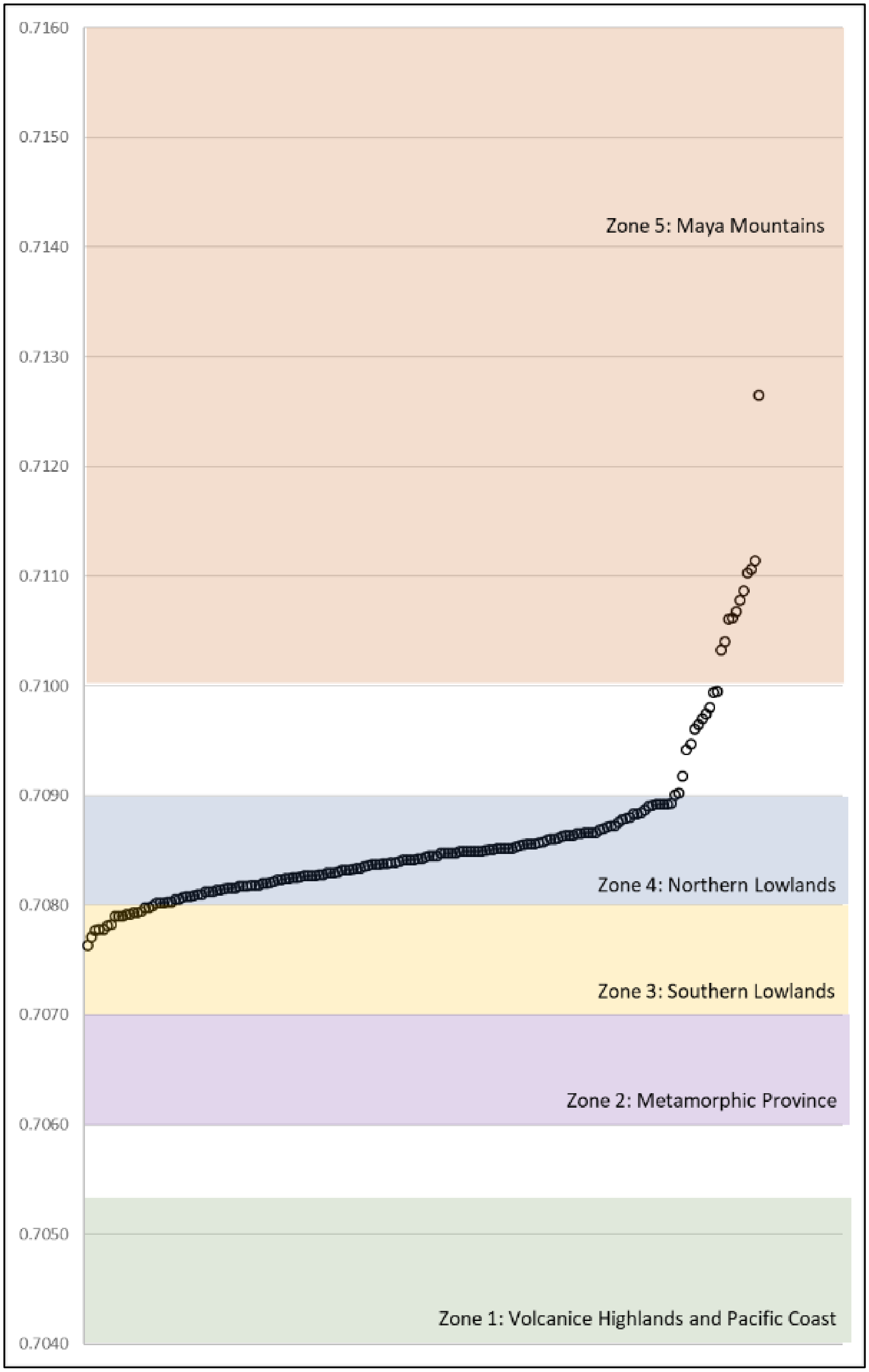


Figure 5.15. Overlay of Tipu Colonial strontium isotope ratios on geologic strontium zones in Maya area. Strontium zone ranges based on ranges and data provided in Hodell et al. (2004); Price et al. (2008); Price et al. (2010); Wright (2005a).

(Price et al. 2010); Nohmol=0.7085 (Price et al. 2012a)), as do sites in the southern Quintana Roo district of Mexico (Becan $^{87}Sr/^{86}Sr$= 0.7082 (Price, 2010 #24)). Most of the mean $^{87}Sr/^{86}Sr$ data from northern Belize fall into the lower 0.7080's range, while the Belize River Valley local range extends from 0.7080 to 0.7091. The above combined data show that many sites in the western portion of the Central Lowlands have values that extend into the Northern Lowland zone; this suggests there is a need to further revise these zones, potentially expanding the definition of the Northern Lowland zone to include the northern Belize area.

Nineteen of the Colonial period Tipu individuals (~11%) fall within the upper half of the Southern Lowland strontium zone (observed $^{87}Sr/^{86}Sr$ range= 0.70763 – 0.70799; see Figure 5.15 above). Many sites in the Petén region of Guatemala (directly west of Tipu) have average values falling within this range, as does Caracol, which is located directly south of Tipu (Freiwald 2011; Freiwald and Pugh 2017; Freiwald et al. 2018; Price et al. 2008; Price et al. 2010; Wright 2005a).

Thirty individuals from the Colonial Tipu sample (~17%) have $^{87}Sr/^{86}Sr$ values that are above 0.7090 (see Figure 5.15); ten of these individuals are above 0.7100, with the highest $^{87}Sr/^{86}Sr$ value at Tipu being 0.71265. Strontium isotope values above 0.7100 clearly fall within the Maya Mountain range, a region clearly distinctive from elsewhere in the Maya region. The reminder of these individuals have $^{87}Sr/^{86}Sr$ values that fall into a somewhat uncharacterized zone between the expected range for the Maya Mountains and the expected range for the Northern Lowlands and Northern Belize. Freiwald (2011) found that most of the individuals from Chaa Creek, a small site located several kilometers downstream from Tipu, fell within this range. Furthermore, several individuals recovered from Belize Valley sites also have $^{87}Sr/^{86}Sr$ values within this range (Freiwald 2011). The presence of $^{87}Sr/^{86}Sr$

values between 0.7090 and 0.7100 at multiple sites in the Maya Mountains foothills may suggest that the northern Maya Mountain foothills are a transitional or mixed isotopic zone, where values can be expected to fall between those expected for the Maya Mountains and those expected for northern Belize. This may be the result of sediment deposits and/ or water originating in the Maya Mountains creating a mixed signal. Alternatively, this may also be a consequence of data from previously isotopically unknown regions allowing us to have a more complete picture of $^{87}Sr/^{86}Sr$ variability in the Maya area.

Figure 5.16 shows a boxplot comparison of the Tipu Colonial and Postclassic $^{87}Sr/^{86}Sr$ data with $^{87}Sr/^{86}Sr$ data from several comparative sites and regions (Das Neves 2011; Freiwald 2011; Freiwald and Pugh 2017; Hodell et al. 2004; Wright 2012); many of these regions have been identified in the ethnohistorical literature as potential origins for the migrants at Tipu. The interquartile ranges (IQR) for the Macal River sample and the Tipu Postclassic sample both show substantial overlap in ranges; this overlap is not unexpected given that Chaa Creek, the site composing the Macal River sample, is located in the foothills several kilometers downstream of Tipu. Furthermore, the overlap between the Macal River and Tipu Postclassic samples provide ancillary evidence that the Tipu Postclassic range is suitable for the approximation of a local Tipu $^{87}Sr/^{86}Sr$ range. The IQR for the Mountain Pine Ridge sample, which is used to represent the northern Maya Mountains, is significantly higher than the remainder of the comparative samples, and with the highest outlier values from the Tipu Colonial sample falling within the range. The interquartile ranges for the Caracol and Petén Lakes samples are both less than 0.7080 and are consistent with the lower bound of the Colonial Tipu whisker. Nojol Nah, a site in northern Belize in the general region of the purported location of La Pimienta, has an IQR that falls a little below the Tipu

Postclassic IQR (~0.7080 to ~0.7083); this indicates that the region of northern Belize surrounding Nojol Nah may be a potential location for many of the Tipu migrants. Xunantunich, although located within the Belize Valley, has a number of migrants from other regions, and so is separated from the remainder of the Belize Valley sample; this acted to significantly narrow the Belize Valley IQR range. The Belize Valley IQR is very similar to the Tipu Colonial range, and has a similar median value as the Tipu Postclassic range. Given its close proximity to Tipu, there very likely was population movement between the Belize Valley and Tipu.

Overall, the above results show that many of the Colonial Tipu migrants may have been born in the nearby Central Lowland sites (like Caracol and the Petén), the nearby Belize Valley, the northern Maya Lowlands (including much of the Yucatan peninsula and northern Belize), as well as the Maya Mountains. The oxygen isotope data may assist in further segregating these groups.

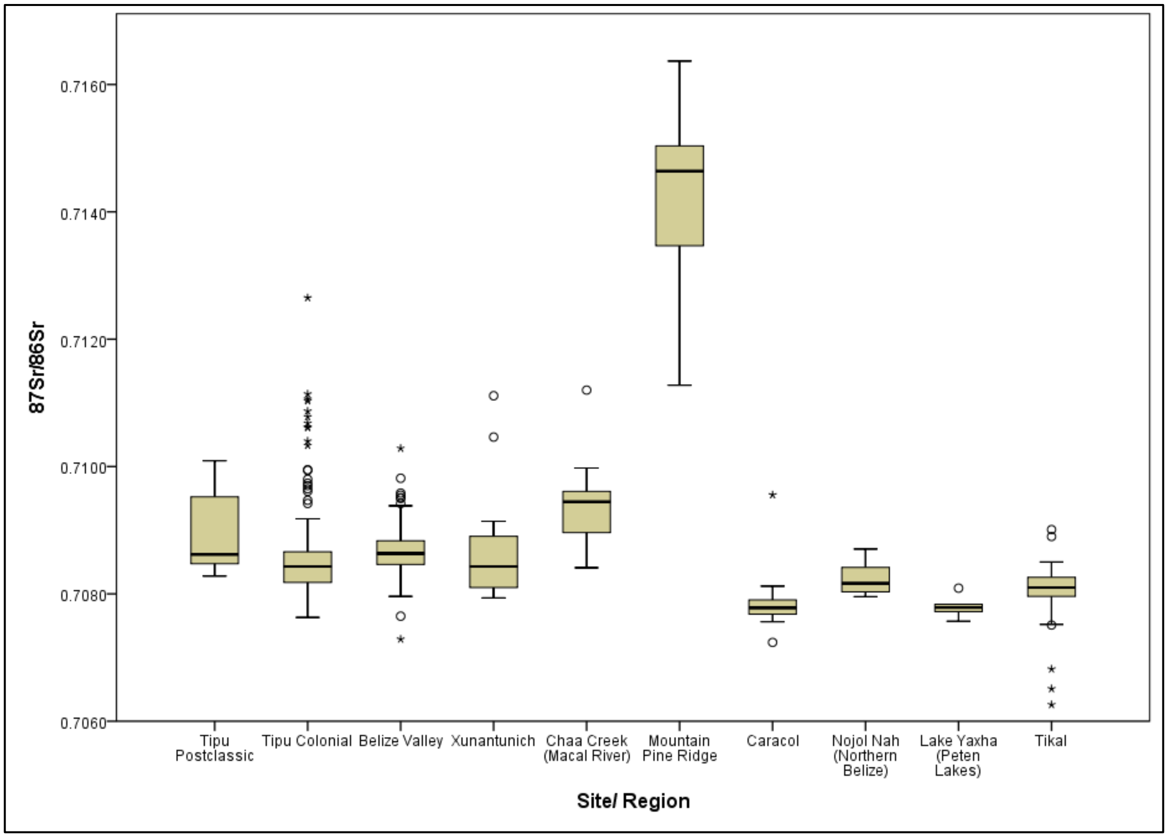


Figure 5.16. Boxplots of $^{87}Sr/^{86}Sr$ values for the Tipu Postclassic and Colonial samples, and several comparative sites. Comparative data sample size and sources are as follows: Belize River Valley (N=104; Freiwald 2011), Xunantunich (N=19; Freiwald 2011), Chaa Creek (N=12; Freiwald 2011), Mountain Pine Ridge (N=11; Freiwald 2011), Caracol (N=11; Freiwald 2011), Lake Yaxha (N=6; Freiwald and Pugh 2017; Hodell et al. 2004), Nojol Nah (N=14; Das Neves 2011), Tikal (N=94; Wright 2012).

Potential Homelands: $\delta^{18}O$ Data

Figure 5.17 compares the Postclassic and Colonial Tipu $\delta^{18}O$ values to the same comparative sites and regions used above (Das Neves 2011; Freiwald 2011; Freiwald and Pugh 2017; Wright et al. 2000; Wright 2012). The Macal River, Belize Valley (excluding Xunantunich), Mountain Pine Ridge (used to represent the northern Maya Mountains), and

Caracol samples all have $\delta^{18}O$ interquartile ranges that overlap with the lower portion of the Tipu Postclassic IQR, and fall within the Tipu Colonial lower whisker. Both Topoxté, a site in the Petén Lakes region, and Nojol Nah, a site in northern Belize, have IQR values that are consistent with the more enriched $\delta^{18}O$ values from the Tipu Colonial Period sample (greater than -2.25‰); of these, only Topoxté has positive $\delta^{18}O$ values. The ^{18}O range for Topoxté is similar to the San Bernabé Mission sample (local $\delta^{18}O$ range = -3.39‰ – 0.45‰), a Colonial period site located on nearby Lake Petén Itzá (Freiwald et al. 2018). This suggests that migrants from the Tipu population with more enriched $\delta^{18}O$ values may have been born in areas that utilize evaporative bodies of water for drinking water sources (like the Petén Lakes) or northern Belize. Xunantunich $\delta^{18}O$ sample has a very broad range; this is likely a result of the dataset containing several obvious migrant outliers.

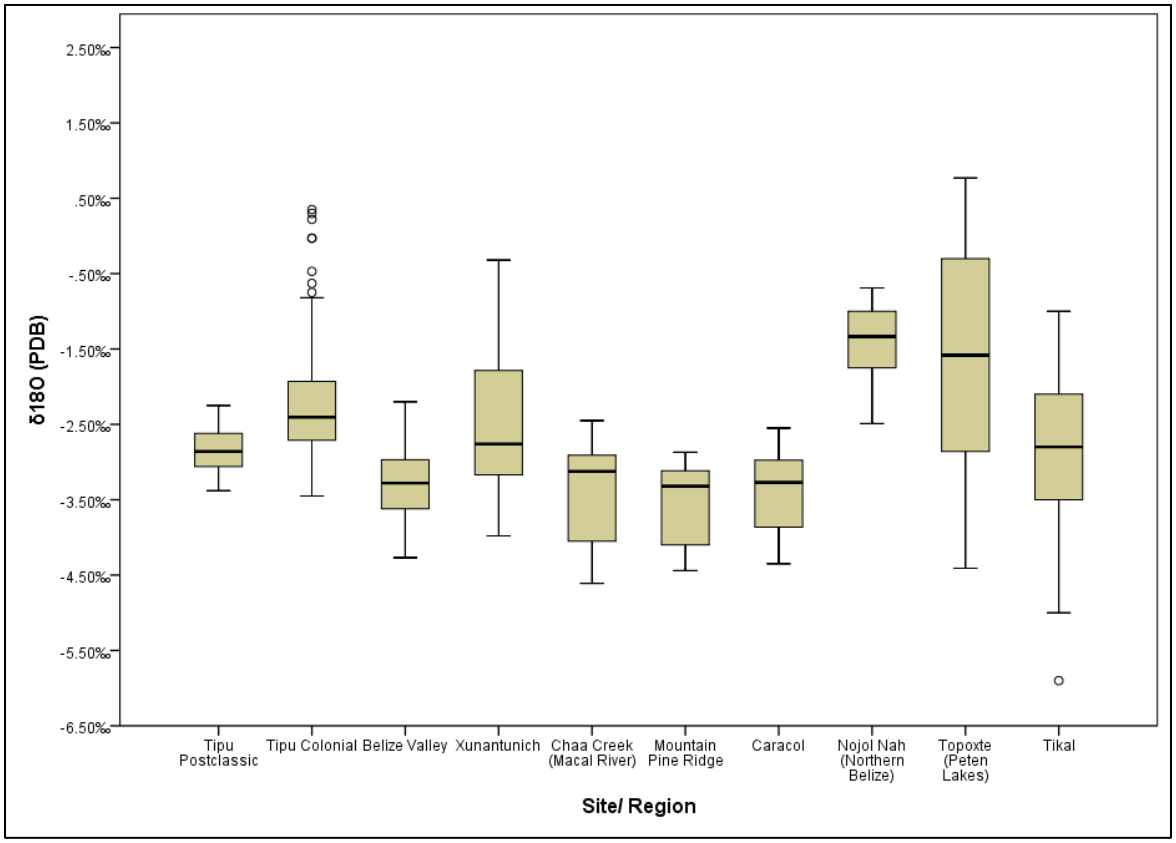


Figure 5.17. Distribution of Oxygen isotopes for Tipu and several comparative sites. Comparative data sample size and sources are as follows: Belize River Valley (N=7; Freiwald 2011), Xunantunich (N=19; Freiwald 2011), Macal River (N=12; Freiwald 2011), Mountain Pine Ridge (N=8; Freiwald 2011), Caracol (N=7; Freiwald 2011), Topoxté (N=26; Wright et al. 2000), Nojol Nah (N=14; Das Neves 2011), Tikal (N=90; Wright 2012).

Potential Homelands: Combined ^{87}Sr/^{86}Sr and δ^{18}O Data

The Tipu Colonial period data are also compared to strontium and oxygen isotope values obtained from several comparative datasets from throughout the Maya Northern and Central Lowlands. Sites are selected based on their likelihood of being a potential source of migrants based on ethnohistoric records, with focus given to sites in the Central Lowlands near Tipu, the Petén region of northern Guatemala, northern Belize, and the northern Lowlands. The lack of availability of complete raw datasets in the published literature, or the availability of only strontium or oxygen data for certain sites, hampered efforts to undertake a larger, more comprehensive metadata analyses.

Figure 5.18 shows a scatterplot of the $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ isotope values for the Colonial Tipu sample, with an overlay of the observed ranges for the Tipu Postclassic sample and the previously discussed comparative sites. All of the comparative samples used have previously been addressed in some fashion, with the exception of three new samples, which are discussed below. The Campeche sample represents expected values for the northern Yucatán; local ranges are based on the observed range of local $^{87}Sr/^{86}Sr$ values for the site, and the $\delta^{18}O$ range is from the range of values found within the "Native" sample (Price et al. 2012a). Kaminaljuyu is used to show isotope values expected from the Maya highlands (Wright et al. 2010), while Copan shows expected ranges from the Motagua Valley of Northern Honduras (Miller 2014; Price et al. 2010).

There is substantial overlap in the oxygen isotope ranges of the Belize River Valley, Macal River Valley, Campeche, Tikal, Nojol Nah, and Tipu Postclassic samples. The degree of overlap in "local" ranges for so many sites suggests that the exact homelands for many individuals within this area cannot be distinguished with the available data; however, the most parsimonious explanation is that many of the individuals comprising the densest cluster of Tipu individuals are most likely to have been born in areas that are a short distance away (e.g. Belize Valley), rather than a trip that could take a month or more (e.g. Campeche).

The Macal River range also has some overlap with the Tipu Postclassic range, but it has slightly higher $^{87}Sr/^{86}Sr$ values and slightly lower $\delta^{18}O$ values. Given the close proximity of Tipu and Chaa Creek, many of the individuals within the $^{87}Sr/^{86}Sr$ range of 0.7090-0.7100 may be from anywhere on the lower Macal River, including Tipu or Chaa Creek. Individuals with $\delta^{18}O$ values above ~-2‰ appear consistent with $^{87}Sr/^{86}Sr$ values for northern Belize and southern Yucatán, while the extremely enriched $\delta^{18}O$ values fall within the $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ ranges for Topoxté and the Petén Lakes. Individuals with lower $^{87}Sr/^{86}Sr$ values (0.7076-0.7083) and lower $\delta^{18}O$ values (less than ~-3‰), are consistent with isotope values from the Petén Lakes region or Caracol.

The highest Colonial Tipu $^{87}Sr/^{86}Sr$ value falls within the Mountain Pine Ridge $^{87}Sr/^{86}Sr$ range and slightly above the Mountain Pine Ridge $\delta^{18}O$ range, indicating this individual likely originated somewhere in the Maya Mountains. Variability in strontium and oxygen isotopes across the Maya Mountains is poorly understood, complicating attempts to further narrow potential homelands. Many of the individuals that have $^{87}Sr/^{86}Sr$ values that fall between the upper bound of the Chaa Creek range (~0.7100) and the lower bound of the Mountain Pine Ridge range (~0.7110) are interpreted as originating somewhere in the Maya Mountains, although it is possible these values may also represent a yet uncharacterized transitional isotope zone.

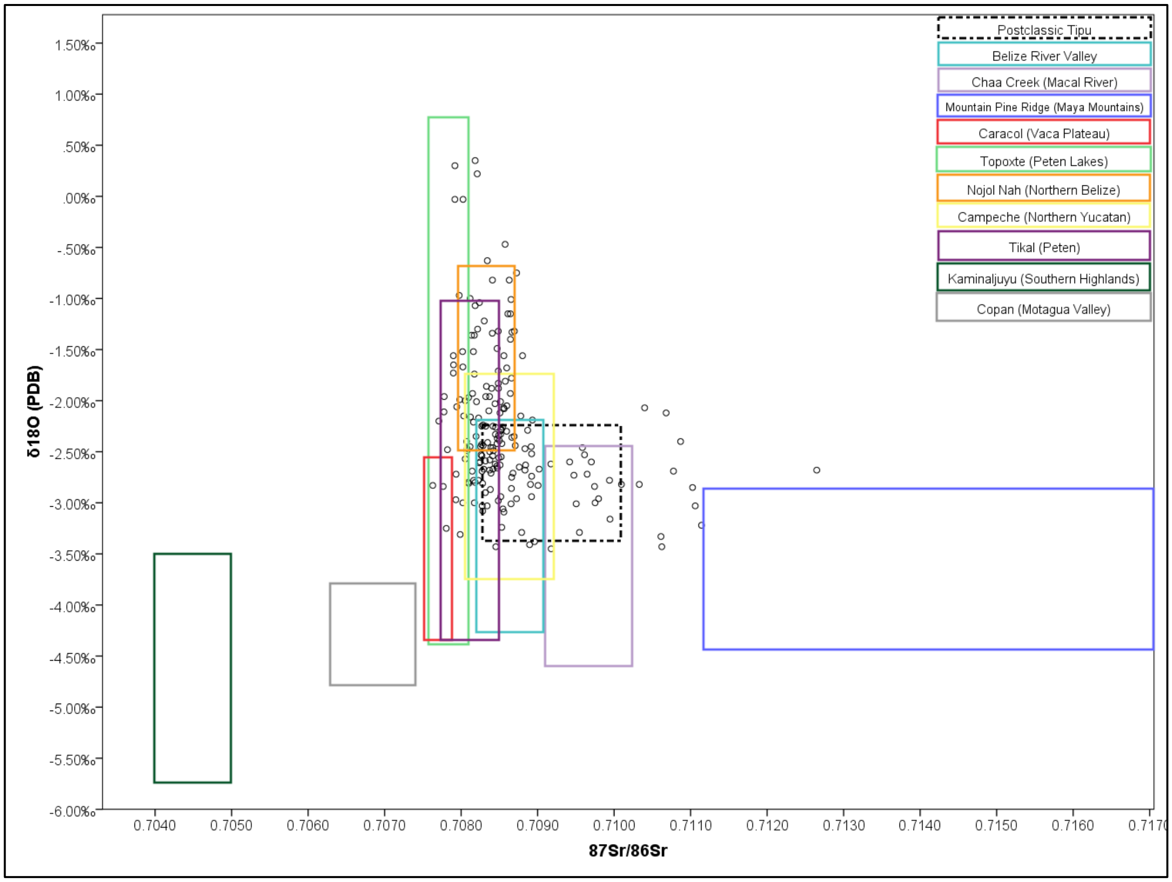


Figure 5.18. Comparison of $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ isotope values from the Tipu Colonial Sample (open circles), with overlay of Postclassic Tipu sample (dashed line) and previously published data from the following comparative sites or regions in the greater Maya area (colored rectangles): Belize River Valley (Freiwald 2011), Macal River (Freiwald 2011), Maya Mountains (Freiwald 2011), Caracol (Freiwald 2011), Topoxté (Lake Yaxha) (Wright et al. 2000; Hodell et al. 2004; Freiwald and Pugh 2017), Nojol Nah (Das Neves 2011), Campeche (Price et al. 2012), Tikal (Wright 2012), Kaminaljuyu (Wright et al. 2010), Copan (Price et al. 2010; Miller 2014).

I also use bidirectional interquartile ranges to compare the Colonial isotope data to several comparative sites ranges. The bidirectional interquartile ranges are created by combining the IQRs calculated for both $^{87}Sr/^{86}Sr$ and $\delta^{18}O$, and are useful for making comparisons because they provide a median and 50% interquartile range for both isotopes. Bidirectional interquartile ranges don’t indicate estimated local ranges, like in the above plots, but rather provide an idea of the highest frequency of isotope values for each site or group of sites. The use of interquartile ranges help eliminate some noise from outlying values that may be included in other methods. The downside to this IQR comparisons is that only studies with published complete $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ datasets, or published interquartile ranges can be utilized.

Figure 5.19 shows a scatterplot of the Tipu Colonial isotope data with an overlay of bidirectional strontium and oxygen interquartile ranges for several of the following sites or regions: Belize Valley, Chaa Creek, Mountain Pine Ridge, Caracol, Tikal, Nojol Nah and Topoxté. The bidirectional IQRs for Topoxté (Petén lakes) and Nojol Nah (northern Belize) show that many of the individuals with $\delta^{18}O$ ratios between ~-2‰ and ~-1‰ and $^{87}Sr/^{86}Sr$ values between ~0.7080 and ~0.7090 fall closer to northern Belize isotope values than they do to the Petén. Most of the extremely enriched oxygen isotope values within the ~0.7075 to ~0.7085 $^{87}Sr/^{86}Sr$ range are closest to Topoxté, the Petén lakes sample. Interestingly, the Belize Valley $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ IQRs significantly overlap with the <0.7090 Tipu local range, while the Macal River (Chaa Creek) $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ IQRs overlap with parts of the >0.7090 Tipu local range; the significance this overlap may have to the possible bimodal distribution within the Tipu local range is unknown. Several of the individuals with $^{87}Sr/^{86}Sr$ values above 0.7100 (within the Maya Mountain geologic range) have oxygen isotope values above the IQRs for both Chaa Creek (in the foothills downstream of Tipu) and Mountain Pine Ridge (upstream of Tipu in the Maya Mountains). The deviation in Colonial $\delta^{18}O$ values from the $\delta^{18}O$ upper quartile for the comparative Maya Mountain sample may be a result of origin from a yet uncharacterized Maya Mountains location with more enriched $\delta^{18}O$ values, potentially on the eastern flank of the mountains, or a consequence of insufficient strontium and oxygen isotopic characterization of Maya Mountains isotopic diversity. The Mountain Pine Ridge area lies in the rain shadow of the Maya Mountains, and experiences less precipitation than the remainder of the Maya Mountains (Lachniet and Patterson 2009; Wright et al. 1959); this may explain the difference in $\delta^{18}O$ ratios between the northern Maya Mountains comparative sample and the individuals from the Tipu Colonial sample.

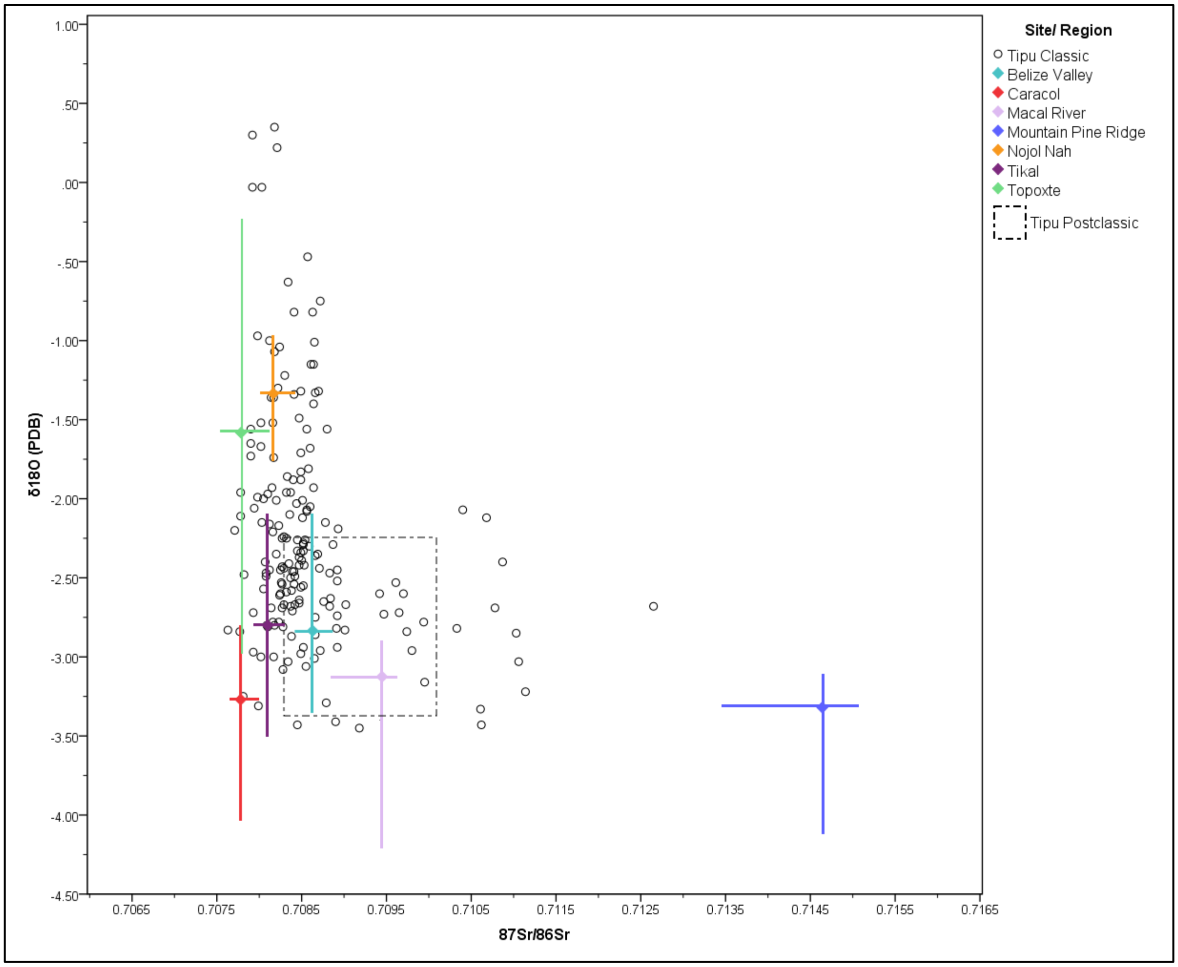


Figure 5.19. Comparison of Colonial Period individuals with other sites in the Maya Lowlands. Whiskers indicate inter-quartile ranges from total data sets for δ^{18}O and ^{87}Sr/^{86}Sr, while diamonds indicate site median values for δ^{18}O and ^{87}Sr/^{86}Sr. The dashed line indicates the Tipu local range. Comparative data obtained from the following sources: Belize River Valley (Freiwald 2011), Macal River (Freiwald 2011), Maya Mountains (Freiwald 2011), Caracol (Freiwald 2011), Topoxté (Lake Yaxha) (Wright et al. 2000; Hodell et al. 2004; Freiwald and Pugh 2017), Nojol Nah (Das Neves 2011), Tikal (Wright 2012).

Colonial Tipu Migrants and Potential Regions of Origin: Summary

Although isotopes are a useful exclusionary tool to help narrow potential homelands of migrants, they cannot be used to conclusively identify a specific birthplace, because more than one location will typically share a similar signal due to similar geology. The above analyses show that substantial homogeneity in oxygen and strontium isotope values for large areas of the Maya lowlands is a confounding factor for the identification of potential homeland regions for many of the Colonial period migrants. As a consequence, strontium and oxygen isotopes alone have insufficient discriminatory power to differentiate between areas nearby Tipu (e.g. the Belize Valley) and the northern Yucatan, where historical records suggest many of the Tipu migrants originated. Potential homelands for those individuals with more extreme isotope values can be narrowed down.

Several individuals in the Colonial sample have $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ values that are consistent with Topoxté, a site in the Petén Lakes region to the west of Tipu. Tipu played an important role as a border town on the frontier between Spanish held territories and the lands to the west held by the Itzá Maya. The heartland of the Itzá Maya territory, the Petén Lakes region, is due west of Tipu, and is where the Itzá capital city, Tah Itzá (or Tayasal), is located. Much of the trade and interaction occurring across the Maya-Spanish frontier likely would have involved sites within the Petén Lakes region on the Itzá side. To date, individuals with both extremely enriched $\delta^{18}O$ values ($\delta^{18}O$ above ~-0.5‰) and $^{87}Sr/^{86}Sr$ values in the 0.7075-0.7085 range have only been identified in Petén sites (Freiwald and Pugh 2017; Freiwald et al. 2018; Wright et al. 2000), or as clear outliers in other regions (e.g. Freiwald 2011). As a result, these individuals will be interpreted as being consistent with an origin somewhere in the Petén, probably near an evaporative drinking water source like the Petén lakes. Several of the individuals that fall into the $^{87}Sr/^{86}Sr$= ~0.7075 to ~0.7085 range may also be from the Petén, however there is no clear way to distinguish these individuals from other sites with similar isotope values.

All of the individuals with $^{87}Sr/^{86}Sr$ values above 0.7100 are consistent with an origin somewhere in the Maya Mountains. Geologically, in Mesoamerica the Maya Mountains have a unique $^{87}Sr/^{86}Sr$ signature, and is the only known region to yield very high (above 0.7100) $^{87}Sr/^{86}Sr$ values on a broad scale. To date, the only human remains from the Maya area to yield $^{87}Sr/^{86}Sr$ values above 0.7100 were either excavated from sites in the Maya Mountains (e.g. Freiwald 2011) or are clear outlier migrants recovered from other sites (e.g. Wright 2012, Miller 2014). The variability in biologically available strontium and human oxygen values across the Maya Mountains is poorly understood, and a comprehensive study of this variability needs to be undertaken to help clarify these results. There is a potential alternative interpretation of these results, which will be addressed farther below.

A cluster of individuals in the Colonial Tipu sample have isotope values consistent with either a Northern Belize or possibly a Petén origin. During the early Colonial period, much of inland northern Belize and southern Yucatán was within the realm of La Pimienta, a poorly defined Maya-held region that was believed to have a large population of refugee populations from the northern Yucatán. Maya living in the La Pimienta area would frequently lead raids of Spanish towns and would help "free" Maya who wished to leave them. Nojol Nah is a Classic Period Maya site near the Rio Hondo, in the northwest corner of modern Belize and near the southern boundary of La Pimienta estimated by Jones (1998). The individuals with $^{87}Sr/^{86}Sr$ values between roughly 0.7075 and 0.7090, and $\delta^{18}O$ ratios falling a little above the Tipu local range (~ -2.0‰) and below ~ -0.5‰, fall closest to Nojol Nah. The individuals in this cluster that fall near the lower end of the $^{87}Sr/^{86}Sr$ range (~0.7075 – ~0.7080) are close enough to the Topoxté sample to warrant its mention as a potential origin.

Finally, there are several individuals that have isotope values consistent with an origin somewhere in the southern Maya lowlands to the west or southwest of Tipu. The isotope values for these individuals plot closest to the Caracol sample (which represents the Vaca Plateau to the south west of Tipu) and Tikal sample (which represents the Petén to the west of Tipu). The future incorporation of additional isotopes may aid in further discriminating between potential homelands for the Tipu migrants.

Are There First-Generation Spanish Burials at Tipu?

Although few Spanish visited Tipu, it is important to address the potential for the presence of people who were born in Spain being buried in the Tipu mission cemetery. Several burials have previously been identified as potential candidates based on mortuary context, however, research on the Tipu skeletal assemblage has yet to identify clear evidence of Spanish ancestry for any individuals in the Colonial population. Here, I briefly summarize expected isotope values for Spain, and apply them to the Tipu Colonial sample.

The Iberian Peninsula, consisting of the modern countries of Spain and Portugal, shows substantial geologic variability. Figure 5.20 shows expected $^{87}Sr/^{86}Sr$ values from water for Europe, including the Iberian Peninsula. The western portion of the region, with one exception discussed below, is largely composed of older, Paleozoic and Precambrian metamorphic deposits, and generally tends to have water $^{87}Sr/^{86}Sr$ values that fall within the 0.7130 and 0.7200 range. The exception is a small portion of the western coast near Lisbon, which has values falling between 0.70901 and 0.7110 due to the presence of younger carbonate sediments (Voerkelius et al. 2010); these values are consistent with biologically available strontium estimates from human (0.7091 – 0.7115) and faunal (0.7055 – 0.7132) material recovered from this region (Waterman et al. 2014). Several of the migrants recovered from a site near Lisbon have $^{87}Sr/^{86}Sr$ values consistent with origin elsewhere in the western Iberian Peninsula (0.7067 – 0.7075 and 0.7144 – 0.7207) (Waterman et al. 2014). The eastern, southern, and northern portions of the peninsula are generally composed of younger, Cenozoic and Mesozoic sediments, and tend to have water $^{87}Sr/^{86}Sr$ values between 0.7070 and 0.7100 (Voerkelius et al. 2010). Pooled human $^{87}Sr/^{86}Sr$ data from several sites across northern Spain yield local values ranging from somewhere between 0.7078 and 0.7096 (Alt et al. 2016; Guede et al. 2017; Villalba-Mouco et al. 2017), while a central Iberian faunal sample has a range of 0.7091 to 0.7104 (Yravedra et al. 2016); these are roughly consistent with the $^{87}Sr/^{86}Sr$ values from water. The extreme northeastern portion of the peninsula, including the area near Barcelona, is composed of a thin band of older Middle Upper Paleozoic sediments, Mesozoic metamorphic, lower Paleozoic sediments, and Paleozoic metamorphic rocks, which have water $^{87}Sr/^{86}Sr$ values between 0.7110 and 0.7800 (Voerkelius et al. 2010). Studies of archaeological faunal material have found the $^{87}Sr/^{86}Sr$ values from sheep enamel to be fairly consistent ($^{87}Sr/^{86}Sr=0.7090 – 0.7110$) (Valenzuela-Lamas et al. 2016), and potential human migrants from this area have been identified in neighboring regions (Villalba-Mouco et al. 2017).

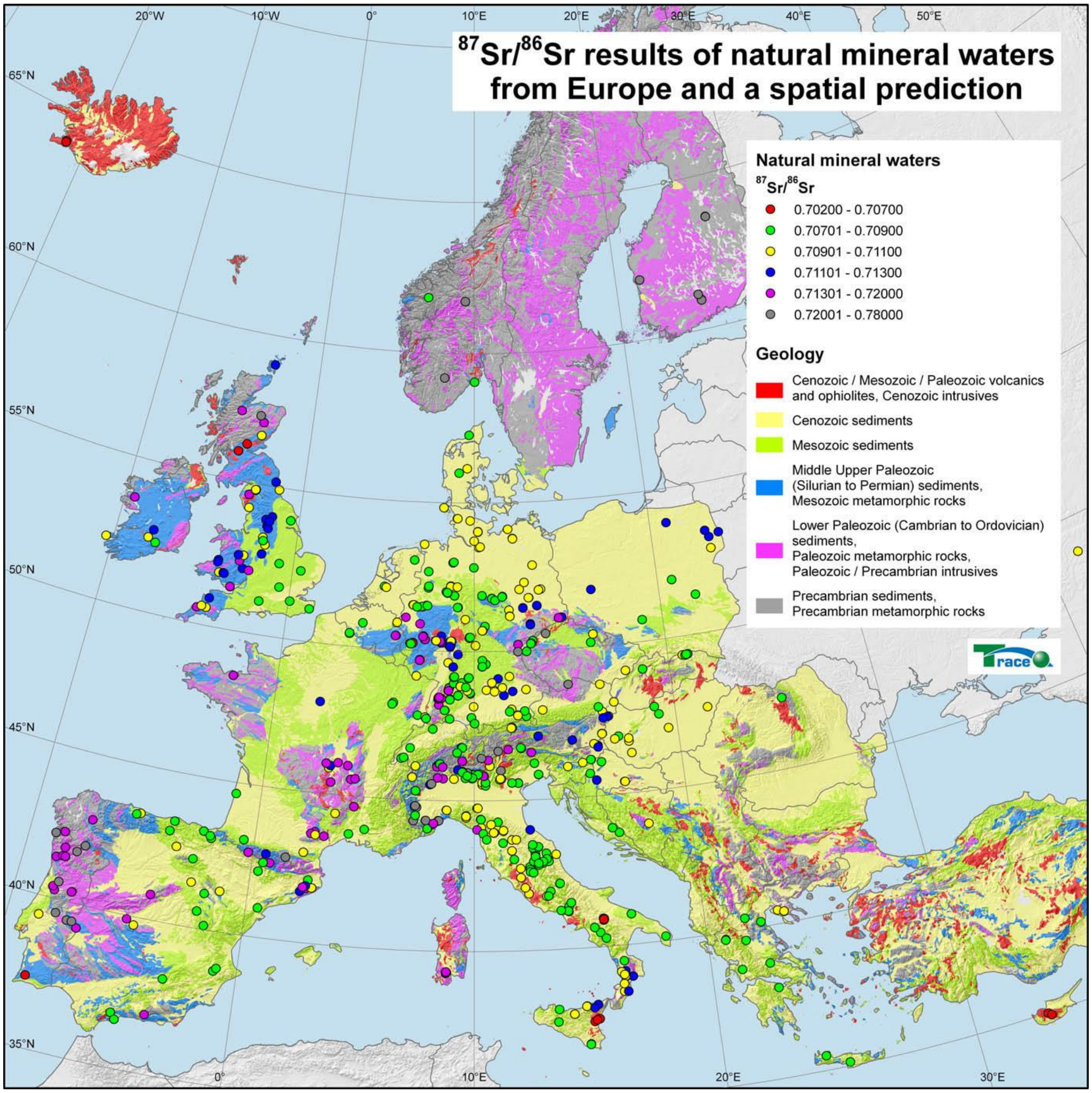


Figure 5.20. Distribution of ^{87}Sr/^{86}Sr water values across Europe. Reprinted from Voerkelius, et al. 2010: Figure 1.

Human oxygen isotope data from the Iberian Peninsula is much more limited and could only be found for sites in northeastern Spain. Studies of human enamel from this region have reported carbonate $\delta^{18}O_{PDB}$ values from enamel between -9.65‰ and -5.64‰

(Prevedorou et al. 2010) and phosphate $\delta^{18}O_{SMOW}$ ranging between 14.25‰ to 18‰ (Guede et al. 2017); a crude conversion of the later range from SMOW to PDB is ~-8‰ to ~-4‰, which permits comparison with the Tipu $\delta^{18}O_{PDB}$ carbonate values obtained from the Tipu sample.

The above data shows there is a broad range of variation in isotope values for Spain. The variation in strontium isotope data variation spans the entire length of isotope variation for the Tipu sample, preventing any specific individuals from being singled out as having a possible Spanish origin. The limited available oxygen isotope data suggest that Spanish born in northeastern Spain would have lower $\delta^{18}O$ oxygen values than are seen in the Tipu sample.

Demographic Differences in Migration to Tipu during the Early Colonial Period

As detailed above, the Postclassic observed ranges for $^{87}Sr/^{86}Sr$ (0.70828 – 0.71009) and $\delta^{18}O$ (-3.38‰$_{PDB}$ – -2.25‰$_{PDB}$) can used as a rough estimator of an expected local range for the Tipu population. Table 5.6 shows the estimated number of local and non-local individuals in the Colonial Period Tipu population. Sixty-three percent of the Colonial population is estimated to have been foreign born. Many of these are individuals with $^{87}Sr/^{86}Sr$ values that fall below the Tipu Postclassic range and/ or individuals with $\delta^{18}O$ values that are higher than the Tipu Postclassic range.

Table 5.6. Colonial period sample separated by local and non-local.

	Frequency	**Percent**
Non-local	112	62.9%
Local	66	37.1%
Total	178	100.0%

Sex-Based Differences in the Colonial Tipu Population

To explore sex-based differences in the composition of the Colonial migrant and local populations I further divide the local and non-local groups by sex category (Table 5.7). There are roughly equal numbers of non-local males and females in the Colonial population. Interestingly, there are marked differences in the distribution of sexes between local males and females. Within the local category, there are significantly fewer females that classified as local than males; only 30.3% of all individuals falling within the local range are female, while almost 67% of the local population is male. Looking within each sex category, there are slightly more males that are non-local (56.4%) compared to those of local birth (43.6%). For females, 71.4% of the female population was born non-locally, while only 28.6% lie within the local range.

Table 5.7. Distribution of local and non-local individuals in the Colonial Period, by sex.

		Sex			Total
		Female	**Male**	**Indeterminate**	
Non-local	N	50	57	5	112
	% within Non-local	44.60%	50.90%	4.50%	100.00%
	% within Sex	71.40%	56.40%	71.40%	62.90%
	% of Total	28.10%	32.00%	2.80%	62.90%
Local	N	20	44	2	66
	% within Local	30.30%	66.70%	3.00%	100.00%
	% within Sex	28.60%	43.60%	28.60%	37.10%
	% of Total	11.20%	24.70%	1.10%	37.10%
Total	N	70	101	7	178
	% within Non-local and Local	39.30%	56.70%	3.90%	100.00%
	% within Sex	100.00%	100.00%	100.00%	100.00%
	% of Total	39.30%	56.70%	3.90%	100.00%

Using a Pearson Chi-Square test, I test if differences in the frequencies of individuals in each of the following groups are significant: local females, non-local females, local males, non-local males (Table 5.8). The individuals of indeterminate sex are excluded from this analysis due to insufficient sample size. A Pearson Chi-Square value of 3.968 is obtained, df=1, with an asymptotic 2-sided significance of p=0.046 (IBM SPSS Statistics Version 23). Using an alpha of 0.05, this indicates there is a statistically significant difference between the number of male and female migrants and locals. This suggests that while there is a relatively similar distribution of local and non-local males, the majority of females at Tipu are of non-local birth.

Table 5.8. Chi-Square observed and expected counts, based on sex and local versus non-local birth.

		Sex		Total
		Female	**Male**	
Non-local	Observed	50	57	107
	Expected	43.8	63.2	107.0
Local	Observed	20	44	64
	Expected	26.2	37.8	64.0
Total	Observed	70	101	171
	Expected	70	101	171

A scatterplot of Colonial Tipu strontium and oxygen isotope values separated by sex is shown in Figure 5.21. For non-local individuals, there does not appear to be any obvious clustering of δ^{18}O and ^{87}Sr/^{86}Sr values for males or females. Within the box representing the local range for Tipu, it is interesting that there are few females in the center of the box, although there are plenty of males. This cluster of males is primary located between the ^{87}Sr/^{86}Sr range of 0.7086 and 0.7098, and the δ^{18}O range of -2.40‰ and -3.3‰; within this narrowed range there are 21 male individuals, two females (located on the periphery of the range), and one individual of indeterminate sex. This means nearly half (21 individuals) of the total number of local males (44 individuals) have isotope values that fall within a relatively narrow range that largely excludes females.

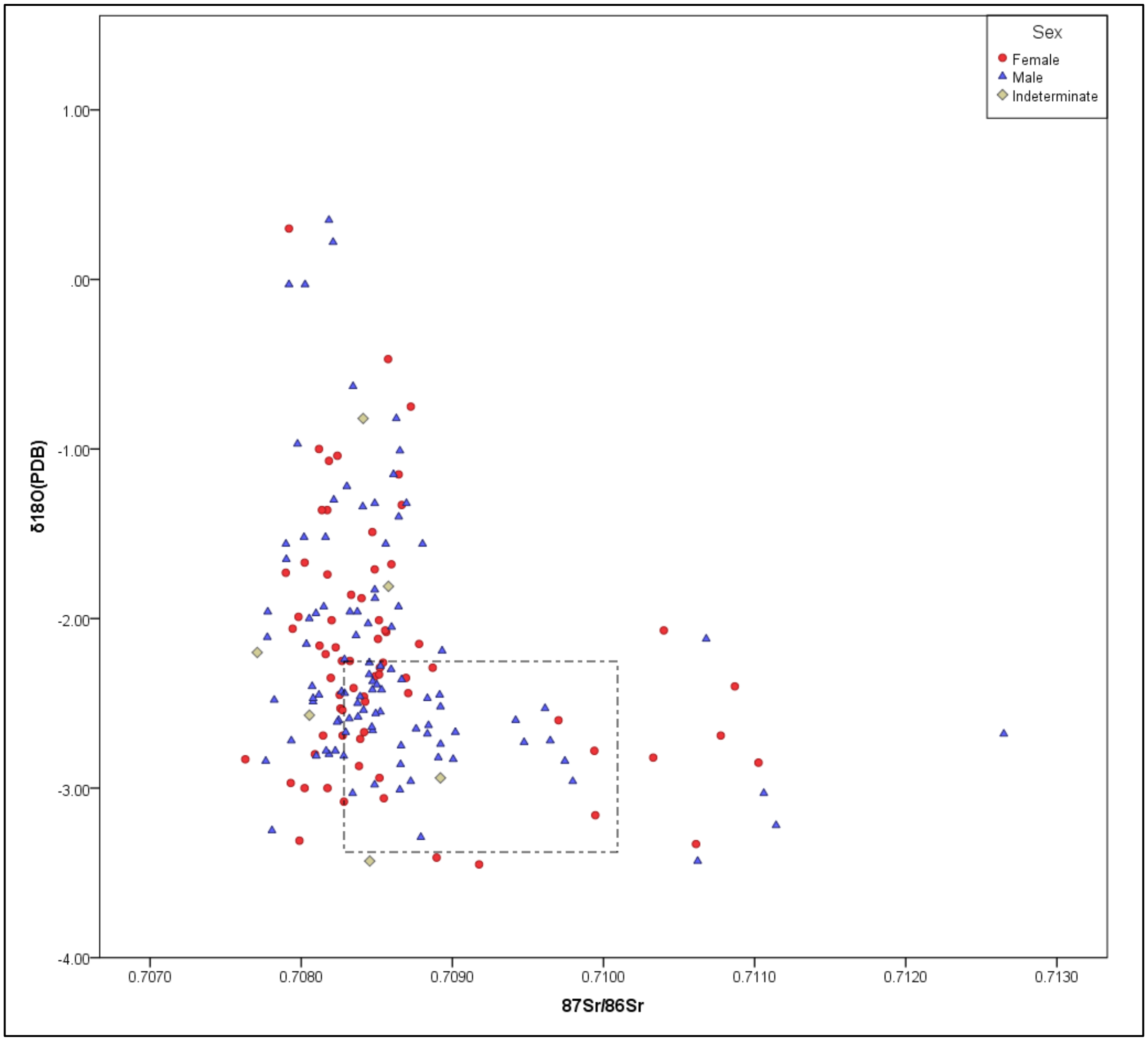


Figure 5.21. Scatterplot of δ^{18}O and ^{87}Sr/^{86}Sr values for Tipu Colonial individuals by sex. Dashed line indicates estimated local range based on observed Postclassic human data.

Differences in Burial Location for Migrants during the Early Colonial Period

To identify potential within- cemetery patterning of migrant and local burial locations, individuals are separated into five groups based on location of burial relative to the church. These five groups defined by Jacobi (2000) are outlined in Chapter 4 and briefly summarized here: inside front (inside and in front of the church), inside back (inside and in back of the church), outside north (outside and north of the church), outside south (outside and south of the church), outside west (outside and south of the church). See Chapter 4, Figure 4.2 for a map of these five cemetery areas.

The distribution of migrants and local individuals for each cemetery area is presented in Table 5.9 and shown in Figures 5.22 and 5.23. For each of the five cemetery areas, there are more individuals in the non-local category than are in the local category. The inside of the church has the highest concentration of locally born individuals for the site. The inside front of the church has nearly equal numbers of non-local (55.6%) and local (44.4%) individuals, while a little under two-thirds of the back half of the church is comprised of non-local individuals (non-local=61.1%, local = 38.9%). Outside the church, the differences between local and non-locally born individuals are much more marked than is seen inside the church. Burials in the areas north and south of the church are more sparsely placed, and do not show the density seen inside the church and to the west of the church. Although the sample sizes for the outside north and outside south areas are small, there are still markedly more non-local people buried in these two areas than local individuals (outside north =73.7% non-local, outside south = 60.9% non-local). The area west of the cemetery (outside west) composes the largest burial location group for the Colonial Period sample; 67.3% of the individuals buried outside and west of the church are not of local birth.

Table 5.9. Distribution of local and non-local individuals, by burial location.

		Burial location					Total
		Inside Back	**Inside Front**	**Outside North**	**Outside South**	**Outside West**	
Non-local	Count	22	25	13	14	38	112
	% within Migrant	19.6%	22.3%	11.6%	12.5%	33.9%	100.0%
	% within location	61.1%	55.6%	72.2%	56.0%	70.4%	62.9%
Local	Count	14	20	5	11	16	66
	% within Migrant	21.2%	30.3%	7.6%	16.7%	24.2 %	100.0%
	% within location	38.9%	44.4%	27.8%	44.0%	29.6%	37.1%
Total	Count	36	45	18	25	54	178
	% within Migrant	20.2%	25.3%	10.1%	14.0%	30.3%	100.0%
	% within location	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

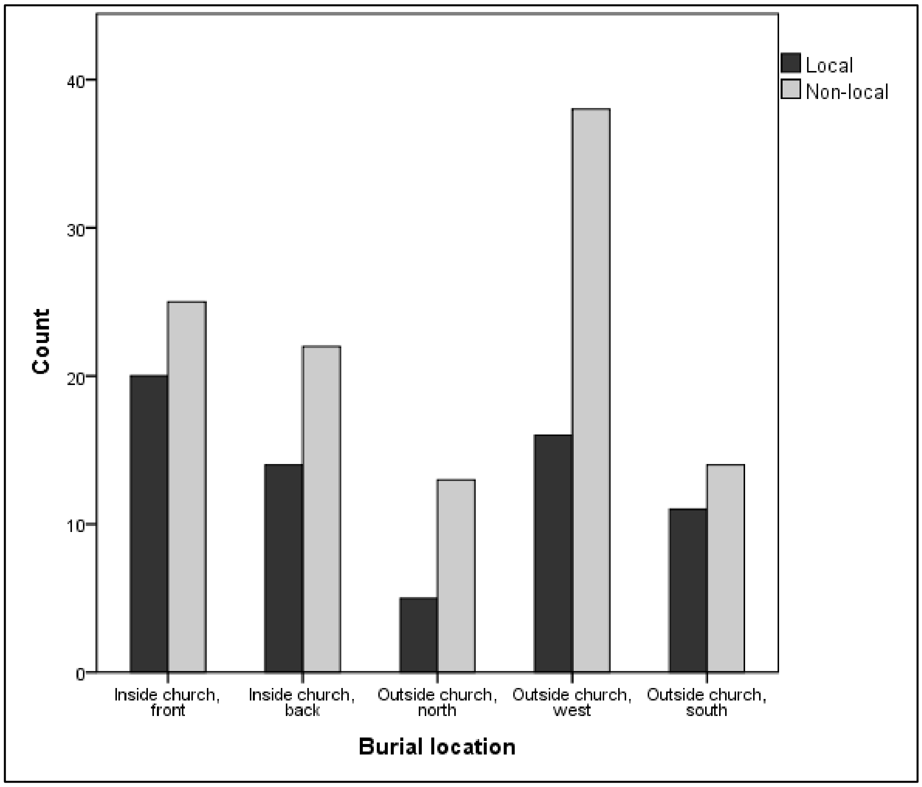


Figure 5.22. Bar chart of local and non-local individuals, by burial location.

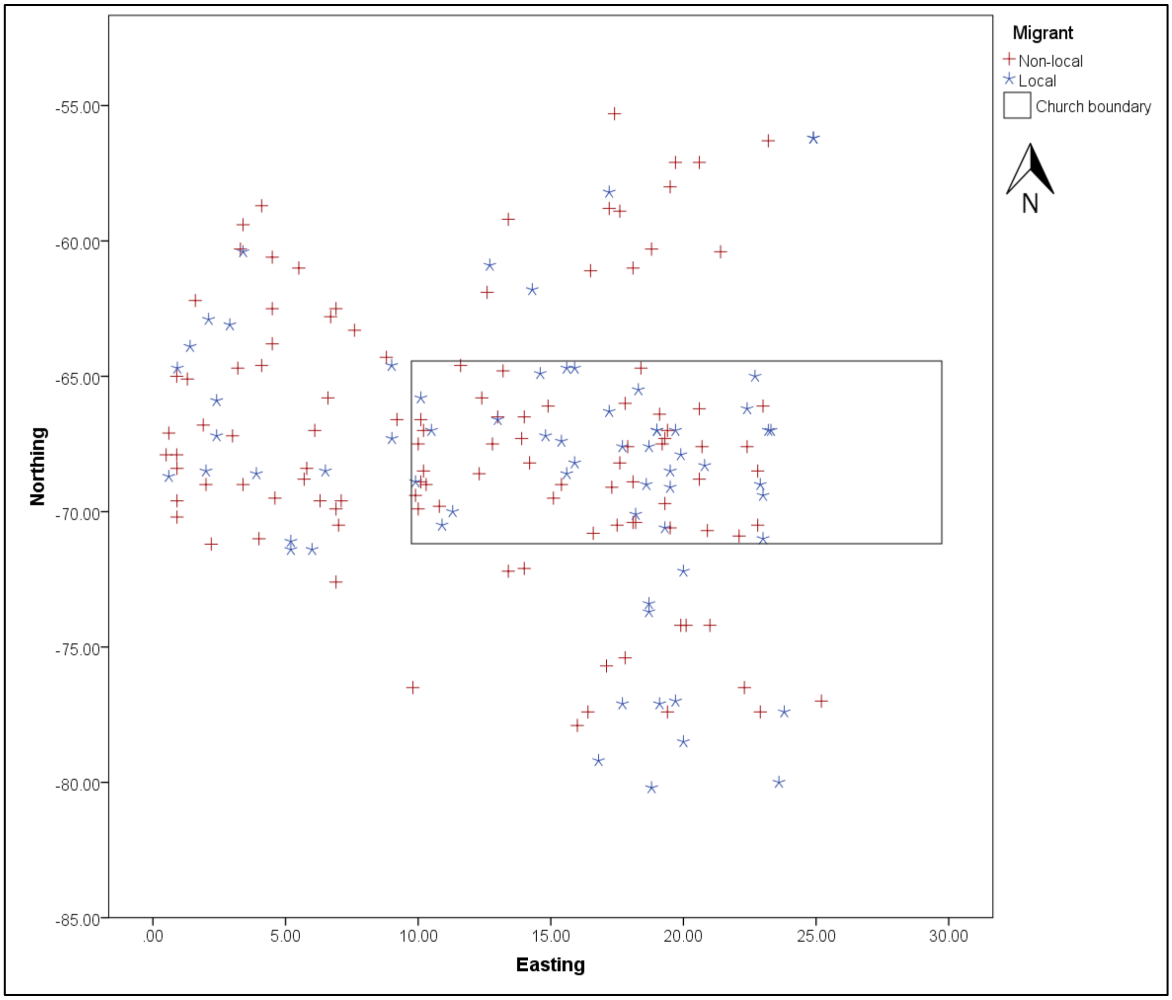


Figure 5.23. Map of Tipu cemetery showing the location of local and non-locally born individuals.

To test for significant differences in frequencies of local and non-locals buried in each of the five cemetery areas a Pearson Chi-Square is used. For all cemetery areas, a Pearson Chi-Square value of 3.562 is obtained, with df=4, and an asymptotic 2-sided significance of p=0.468 (IBM SPSS Statistics Version 23). Using an alpha of 0.05, this indicates that differences between the number of migrants and locals buried in the cemetery areas are not significant.

As a means to account for the somewhat small sample sizes in the outside north, and differences in individuals available to be sampled from each of the areas, the cemetery areas inside the church and outside the church are pooled into the following groups: inside church non-local, outside church non-local, inside church local, outside church local. To identify differences between these groups I use a Pearson Chi-square (IBM SPSS Statistics Version 23). Table 5.10 shows the observed and expected number of individuals for each of the four groups. While the number of local individuals buried inside versus outside the church are similar, there appear to be slightly more non-local individuals buried outside the church than inside. A Pearson Chi-Square test found that there are no significant differences in the numbers of migrants buried inside versus outside the church (Pearson Chi-Square =1.528, df=1, p=0.216.)

Table 5.10. Chi-Square observed and expected counts for local and non-local individuals, based on burial inside versus outside the church.

		Location		
		Outside Church	**Inside Church**	**Total**
Non-local	Observed	65	47	112
	Expected	61.0	51.0	112.0
Local	Observed	32	34	66
	Expected	36.0	30.0	66.0
Total	Observed	97	81	178
	Expected	97.0	81.0	178.0

Spatial Groupings of Individuals within the Cemetery

The strontium and oxygen isotope data may be used as an additional line of evidence to identify potential clusters of individuals with similar homelands that are buried in close proximity to one another. To date, there has only been limited research using spatial proximity of individuals with similar traits to identify possible evidence of family plots within the cemetery (e.g. Jacobi 2000). The presence of similar clustering of individuals based on similar isotope values is explored here.

Jacobi (2000) identified possible small clusters (2-3 individuals) of skeletons with similar, unique dental traits, dispersed throughout the cemetery. Specific data including burial numbers are only available for the one trait, labial grooves of the central incisor, observed on 12 skeletons buried in four clusters around the cemetery (Jacobi 2000:167-168). Unfortunately, I only have isotope data for six of these skeletons, which prevents me from making a systematic comparison of these clusters, though a brief consideration is worthwhile. Of the six skeletons with available isotope data, there are only two clusters for which I have isotopes values for more than one individual in the cluster: MT-157 and MT-232, two individuals buried outside and west of the church, and MT-383 and MT-444 (missing MT-97 from the cluster), three individuals buried outside and south of the church. The strontium isotope values for MT-157 ($^{87}Sr/^{86}Sr$=0.70837, $\delta^{18}O$=-2.68) and MT-232 ($^{87}Sr/^{86}Sr$=0.70856, $\delta^{18}O$=-2.07) are relatively close, as are the oxygen and strontium isotope values for MT-383 ($^{87}Sr/^{86}Sr$= 0.70982, $\delta^{18}O$=-2.52) and MT-444 ($^{87}Sr/^{86}Sr$=0.70974, $\delta^{18}O$=-2.84). This provides very limited, anecdotal evidence that further exploration of spatial relationships between skeletons with similar isotope ratios, dental morphology and dental metrics is warranted.

Spatial Patterning of Isotope Clusters

The isotope clusters defined above (see Figure 5.13) are used as a means to investigate any potential spatial relationship in the burial location of individuals with similar isotope values. Table 5.11 and Figure 5.24 show the number of individuals buried in each of the five cemetery areas, separated by their classification into each of the eight isotope clusters. Although there are too few individuals in the smaller isotope clusters (clusters 5-8) to perform a Chi-square test (75% of the cells have expected counts of less than five), and too many categories to use a Fisher's Exact test, several general observations and patterns will be discussed. The greatest amount of isotope diversity is seen within the inside front and outside west areas, where each has at least one individual from seven of the eight cemetery isotope clusters. Interestingly, the least amount of strontium isotope diversity is seen within the outside north cemetery area, where there are only individuals that fall within isotope clusters 1, 2, 3, and 7. A plot of the oxygen and strontium isotope values for each cemetery area is shown in Figure 5.25. All individuals buried in the north church area that are included in this study have $^{87}Sr/^{86}Sr$ isotope ratios that fall below 0.7090, potentially indicating this cemetery area may have had a special use or purpose, was for a specific group, or may reflect broad chronological patterning in burial practices.

Table 5.11. Number of individuals from each isotope cluster buried within each of the five cemetery areas.

Isotope Cluster	**Location**					**Total**
	Inside front	**Inside back**	**Outside north**	**Outside west**	**Outside south**	
1	26	20	11	29	12	98
2	10	4	1	4	3	22
3	4	10	4	10	5	33
4	2	0	0	5	3	10
5	0	0	0	2	2	4
6	1	2	0	2	0	5
7	1	0	2	2	0	5
8	1	0	0	0	0	1
Total	45	36	18	54	25	178

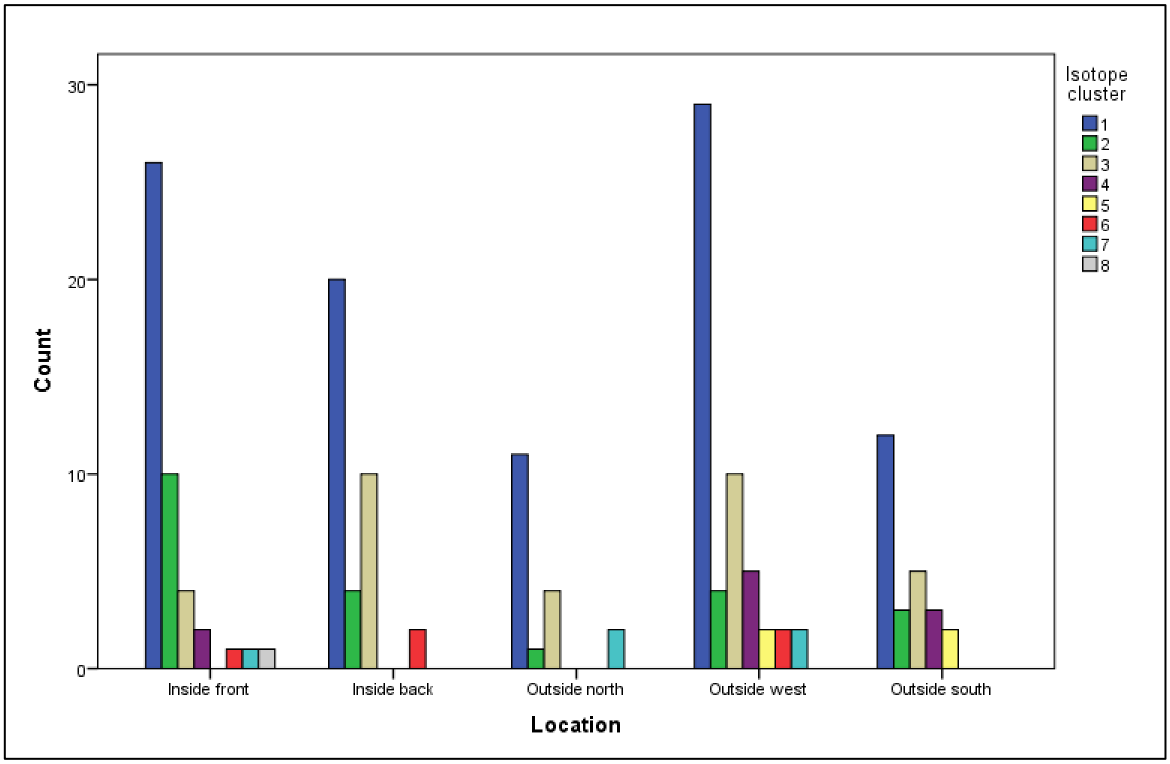


Figure 5.24. Number of individuals classifying into each isotope cluster, separated by cemetery area.

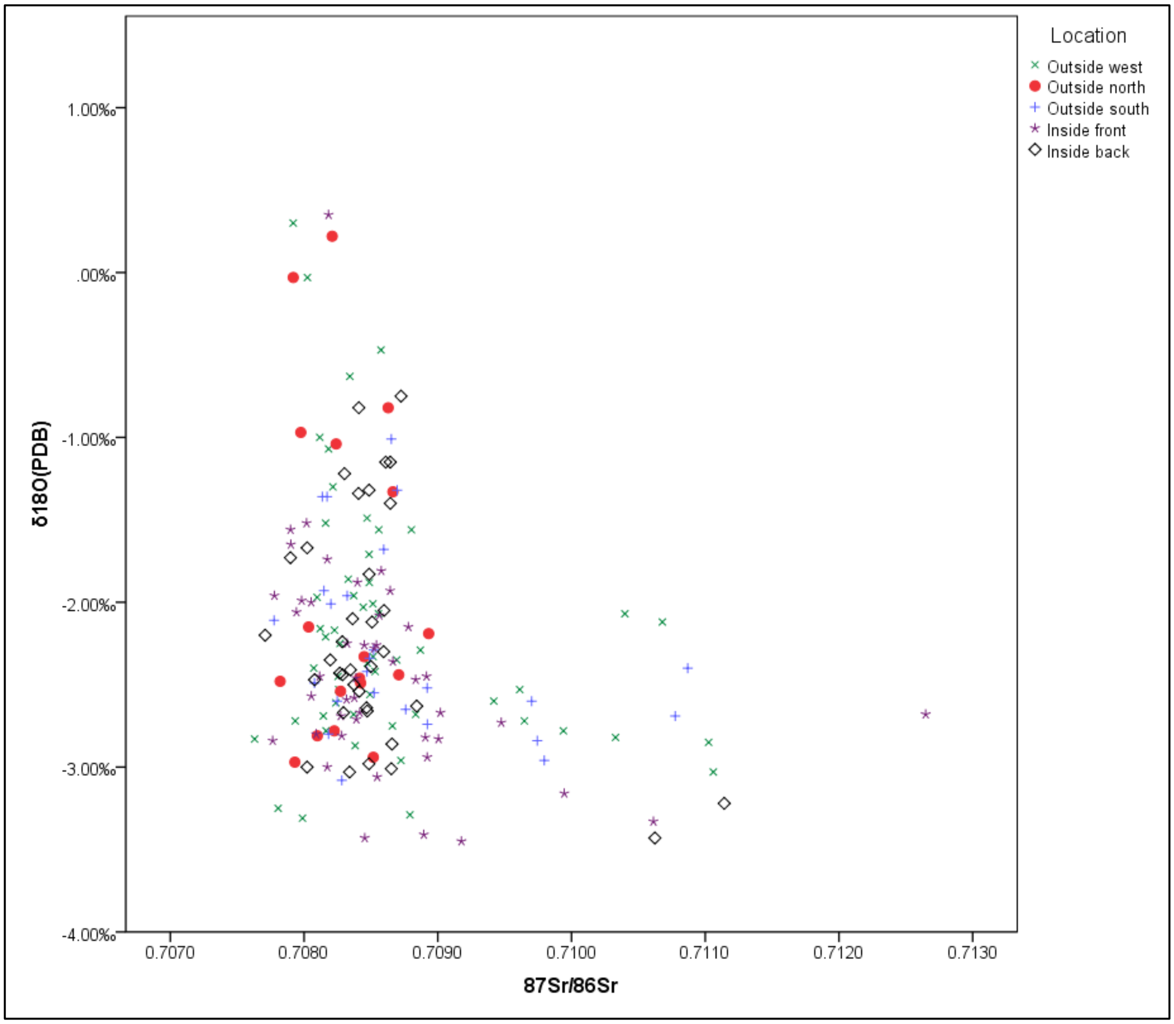


Figure 5.25. Distribution of δ^{18}O and ^{87}Sr/^{86}Sr isotope values by cemetery area.

The two cemetery areas inside the church and three areas outside the church are also combined to look for any evidence of broader patterns in the burial of individuals inside versus outside the church based on birthplace (Table 5.12, Figure 5.26). Again, statistical comparisons are not possible because many of the isotope cluster sizes are small. Several broad observations are possible. For most of the isotope clusters, there appear to be relatively similar numbers of individuals inside and outside the church. Individuals that fall within cluster five, which represents isotope values that fall within the Maya Mountain range but have slightly higher $\delta^{18}O$ ratios than cluster 6, are only found outside the church. This difference may not necessarily be important, as individuals that classify into the three clusters that fall within the Maya Mountain range (clusters 5, 6, and 8) are found both inside and outside the church. Many of the observed differences between the frequency of individuals in each cluster category that are buried inside the church versus outside the church may be an artifact of sample size.

Table 5.12. Number of individuals from each isotope cluster, separated by burial inside versus outside of the church.

	Location		
Isotope cluster	**Inside church**	**Outside church**	**Total**
1	46	52	98
2	14	8	22
3	14	19	33
4	2	8	10
5	0	4	4
6	3	2	5
7	1	4	5
8	1	0	1
Total	81	97	178

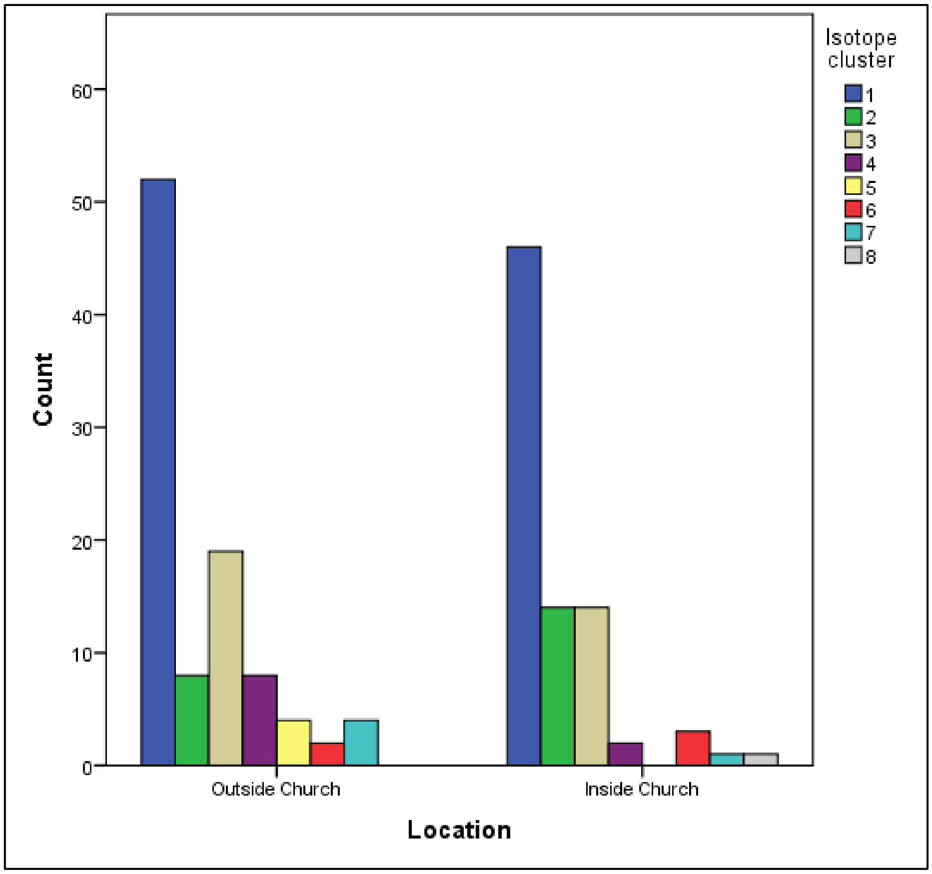


Figure 5.26. Number of individuals classifying into each isotope cluster, separated by burial inside versus outside the church.

A more qualitative approach is also taken to help identify potential spatial relationships in the burial location of individuals with similar isotope values. Again, using the isotope cluster classifications previously determined for the Colonial sample, individuals are plotted using site-specific coordinates recorded during excavation for each burial feature (Figure 5.27). Overall the largest isotope clusters (clusters 1, 2, and 3) appear to be fairly spread out across the cemetery. There are more cluster 2 individuals inside the church than there are outside (especially in the inside front of the church), and only one cluster 2 individual buried to the north of the church. There is not a distinct spatial gap or boundary between cluster 1 and 2, and cluster 1 and 3, creating potential for some misclassification of the individuals falling on the boundary between the clusters. This may slightly obscure some potential patterning.

Most of the individuals from cluster 4 were buried outside of the church. There is a possible group of individuals that fall within the cluster 4 range buried to the northwest of the church. This group of individuals has $\delta^{18}O$ values from around -2.5‰ to around -3.25‰, and $^{87}Sr/^{86}Sr$ values around 0.7100.

Cluster 5 only has four individuals, all of whom were buried outside and south or west of the church. Cluster 6, which is composed of individuals with approximately the same $^{87}Sr/^{86}Sr$ value as cluster 5 but with more depleted oxygen values, has two possible groupings of individuals: two inside the church (inside back) and two to the northwest of the church (outside west). The cluster 6 individuals to the northwest of the church are fairly close to one individual in the cluster 5 group.

Cluster 7 contains the individuals with extremely enriched $\delta^{18}O$ values. Only one cluster 7 individual was buried inside the church (inside front), while the remainder were buried to the north or west of the church. Within the cemetery areas, no clear groupings of the cluster 7 individuals could be identified. Interestingly, two cluster 7 individuals buried west of the church are in close proximity to a group of cluster 3 individuals; individuals that fall within cluster 3 also have $\delta^{18}O$ values that are more enriched than the local range, although not to the extent of those in cluster 7.

Cluster 8 is defined by a single individual with the highest $^{87}Sr/^{86}Sr$ value in the sample (MT-92, $^{87}Sr/^{86}Sr=0.71265$). This individual, a male between the ages of 20 and 30 years, was buried in the middle and front of the church.

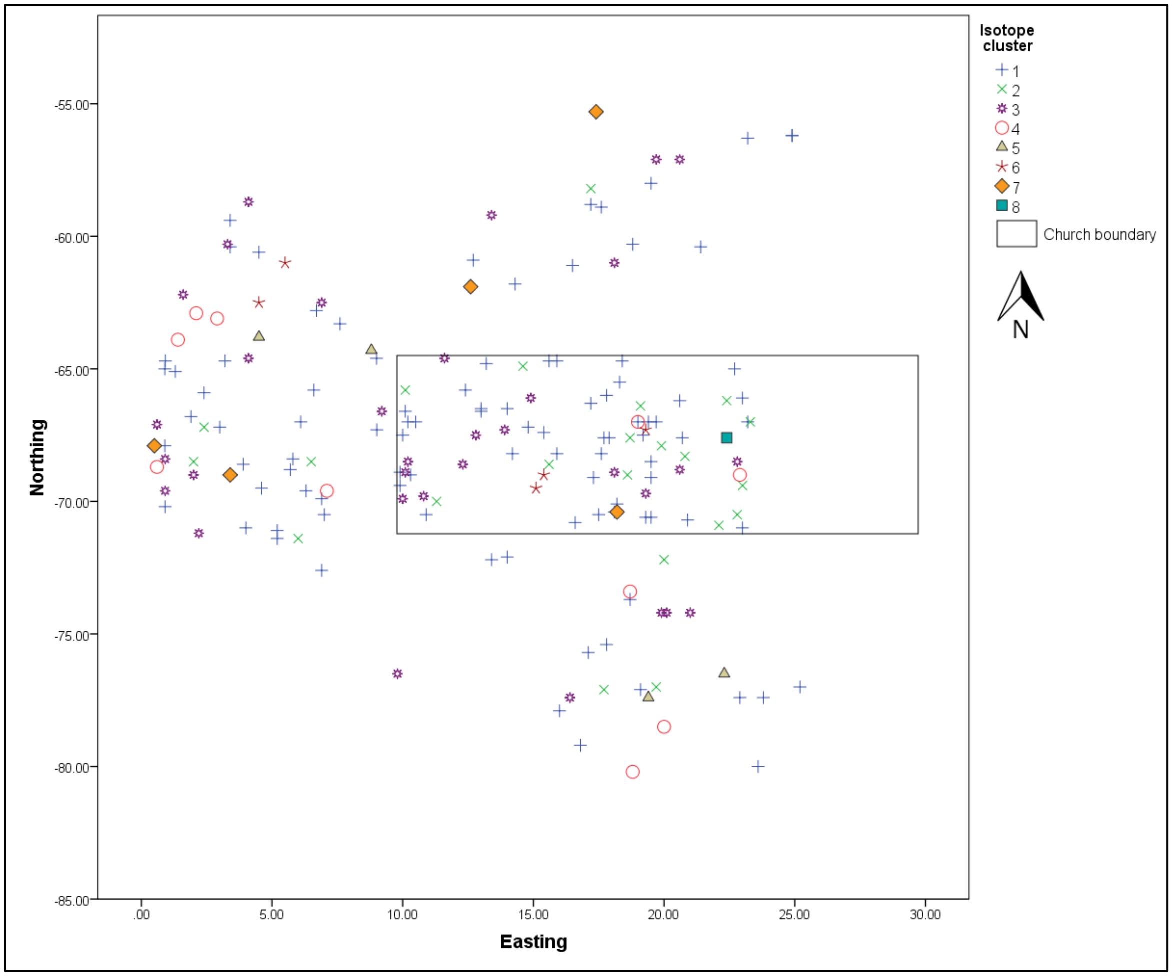


Figure 5.27. Map of Colonial period individuals buried under and around the Tipu church, with individuals separated based on isotope cluster. North is to the top of map.

Chapter Summary

The strontium and oxygen data reveal that migration at Tipu changed markedly between the Postclassic and Colonial periods. Through a detailed statistical investigation of the strontium and oxygen isotope distributions, and an examination of expected isotope values for Tipu based on faunal and geological data, the Tipu Postclassic observed range was determined to be the best available means to estimate the Tipu local ranges for oxygen and strontium isotopes. When comparing the Colonial period data for both strontium and oxygen isotopes, it is clear that most Colonial period individuals fall outside the local range; this suggests that the majority of the Colonial Tipu population are migrants. Comparisons of the Colonial isotope data also identified minor differences between location of burial and frequency of males and females for migrants and local individuals. Several possible spatial patterning or grouping based on isotope values were also identified.

CHAPTER VI

DISCUSSION AND CONCLUSIONS

The previous chapter outlined the results of the strontium and oxygen isotope analyses. I tested the ethnohistoric model, established by previous archaeological and historic studies (e.g. Jones 1989), which suggested that the population increase seen at Tipu during the early Colonial period was the result of a large influx of Maya from the northern Yucatan fleeing Spanish control. To test this model, I used strontium and oxygen isotopes as geologic and climatic tracers to establish the childhood homes for those individuals buried at Tipu. I found the population of Tipu to be overwhelmingly composed of migrants, although the identification of specific homelands was not always possible. Here, I summarize the findings and present directions for future research.

Migration at Tipu

Despite evidence in historical documents, previous researchers have failed to identify direct evidence for the presence of migrants at Tipu. I tested the null hypothesis that the early Colonial period population increase seen at Tipu is the result of local growth or of centralization of people from the immediately surrounding areas, and that the arrival of the Spanish had little impact on the Tipu population. My alternative hypothesis, based on the ethnohistoric model, states that the large population influx seen at Tipu during the Colonial period was the result of a large in-migration of Maya from the northern Yucatan to Tipu.

The strontium and oxygen isotope data clearly demonstrate that the Tipu population was largely composed of migrants during the early Colonial period. Accordingly, I reject the null hypothesis that the population growth seen at Tipu during the Colonial period was the result of endogenous growth. In addition, the results allow me to accept the first part of the alternative hypothesis based on the ethnohistoric model: i.e., that the Tipu population was the result of an influx of migration from elsewhere. There is insufficient data to fully test the second part of the hypothesis, which stated the migrants came from the northern Yucatan, due to the homogeneity in isotope values throughout the Maya Lowlands that prevent identification of specific homelands for many of the migrants buried at Tipu. It is evident that migrants arrived at Tipu from various regions in addition to the northern Yucatan; the likely homelands of these migrants will be discussed later in this chapter.

Impact of Spanish Colonization on Maya Migration and Mobility

The arrival of the Spanish to the New World resulted in varied yet widespread changes to the indigenous populations' way of life. A comparison of the Postclassic and Colonial observed ranges for strontium and oxygen isotope values serves as a simple measure to identify changes in migration to Tipu between the time periods. From the Postclassic to the Colonial time periods there is both an increase in the quantity of individuals with isotope values falling within the observed Postclassic range for strontium and oxygen isotopes, as well as a dramatic increase in the overall variability and range of observed isotope values. These two observations will be addressed in detail below.

First, the Colonial cemetery population exhibits a marked increase in the quantity of individuals with isotope values falling within the Tipu local range, which is based on the Tipu Postclassic range. This increase suggests that there was a surge in movement along existing networks between villages during the early Colonial time period, either directly or indirectly a result of the Spanish. It is likely that several of the Colonial individuals – and even some of the Postclassic individuals for that matter – that fall within the established Postclassic range were not born in Tipu, since many other sites would show similar signals, but there is insufficient data to tease out these individuals during the present study. Given the roughly 70 years (between ~1568 AD and ~1638 AD) the Colonial cemetery was believed to be used (Graham 2011), it is possible that many of the "local" signals are from second generation migrants, or those who were born locally to migrant parents. Second, the $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ values obtained for the Colonial sample are significantly more variable and span a much broader range than the Postclassic sample. The dramatic expansion of the isotope ranges from the Postclassic to the Colonial period suggests the arrival of the Spanish had a swift and substantive impact on first generation migration for the population of Tipu. The increase in variability of isotope values also provides evidence for a considerable expansion of the Tipu interaction sphere.

The broad, continuous, and nearly uninterrupted distribution of strontium and oxygen isotope values observed in the Colonial population may also reflect the type of migration believed to have been occurring at Tipu. The $^{87}Sr/^{86}Sr$ values for the Colonial sample form a continuum of values that spans several strontium isotope geologic zones. Likewise, the

$\delta^{18}O$ ratios span ~4‰$_{PDB}$. Both the strontium and oxygen ranges are far wider than observed at many other single Maya sites. This expansive distribution may indicate that migration at Tipu resulted in an amalgamation of individuals from many different sites and isotope zones, and that the population of Tipu during the early Colonial period was a highly mobile assortment of individuals from throughout the region. Whether directly or indirectly, the arrival of the Spanish in Mesoamerica appears to have made a marked impact on the nature of migration in the southeastern Maya lowlands.

Demography and Mobility at Tipu

Demographic variables also aid in identifying patterning in the Tipu Colonial strontium and oxygen isotope data sets. Nearly two-thirds of the Colonial period Tipu population (62.9%) was classified outside the range established for local individuals, suggesting that during the early Colonial period Tipu was primarily composed of recent, first generation migrants. A largely mobile population is consistent with the available historic records for Tipu (Jones 1989). Jones's (1989) reconstruction of population estimates found the town experienced wide population fluctuations during the early Colonial period (see Chapter 2, Table 2.1). These significant fluctuations in the population are the result of repeated ebb and flow of individuals due to factors such as the *reducciones* conducted around Tipu, flight of people to Tipu from areas under Spanish control, and gradual dispersal back to original communities (Jones 1989). In other words, the fluctuations in the Tipu population may have resulted from the decline in people congregating around a localized population center that usually occurred after a mass migration or *reducción* event (Jones 1989). Dramatic, repeated fluctuations in populations may have had a mixing effect between the migrant and local populations and acted as a contributing factor to the large percentage of migrants identified in the Tipu population. Furthermore, mortality from infectious disease cannot be ruled out as a contributing factor to population fluctuations at Tipu. Apart from the 1623 expedition to Tah Itzá that resulted in the death of 80 males from Tipu (Jones 1989), there is little historic or bioarchaeological evidence to suggest the large fluctuations in population during Colonial period were the result of an epidemic event resulting in mass mortality, as was experienced elsewhere with the arrival of the Spanish. Although, even in the absence of epidemic events of mass mortality, it is very likely that epidemic diseases were carried by migrants or other visitors to Tipu.

Sex-Based Differences in Mobility at Tipu

Significant sex-based differences are identified within the Tipu local and migrant populations. Based on the number of individuals alone, the migrant population at Tipu is nearly evenly split between females (~45%) and males (~51%). This suggests females and males were equally as likely to be involved in relocations to Tipu. Within the total Colonial Tipu female sample, a significantly larger portion of the total Tipu female population (71.4%) had migrated to the site within their lifetimes (p=0.046). The available historical records provide little explanation for why a disproportionately large number of migrant woman would be living at Tipu, or alternatively, little explanation why local males (~67%

of local population) would be more likely to stay at Tipu than local females (~30% of local population).

The reason behind the observed difference in the distribution of sex between local and migrant populations is unknown, and may be a result of exogamous marriage practices, other unknown economic or social factors, or differences in mortuary practices. Spanish records indicate that during the Colonial period Maya residential units were based around a patrilineal extended family, and land used for *milpa* farming was traditionally passed exclusively through the male line (Farriss 1984). Although marriage practices likely did not change substantially between the Postclassic and Colonial time periods, these familial ties to the land may have resulted in men being more reluctant to make permanent moves away from their homelands than woman, especially if the farming lands made available to them near Tipu were less than ideal, either in terms of soil quality or distance. Women and men were also equally subject to taxes under Spanish rule. The burden caused by tax liabilities were especially difficult for young women who were pregnant or caring for small children, as they were expected to maintain their mandatory tax payments of goods or labor with no relief (Farriss 1984). For the women and men drafted for urban labor, it meant the additional burden of neglecting crucial work at home that provided subsistence or the means to pay taxes (*milpas*, gardens, weaving, etc.) so that several times a year they could make the long journey to Merida, often with children in tow (Farriss 1984). It is also possible that there may be an unknown underlying bias that is an artifact of the sample selection process. Individuals were selected based on completeness of dentition and availability of biological profile information, which excluded many poorly preserved, incomplete, or commingled assemblages. It is possible that within cemetery differences in preservation and/ or burial placement of local women (e.g. burial in the crowded back of the church) resulted in a deficit of these individuals in the sample.

Additionally, the local Tipu sample was primarily composed of males (~67% of the local population), although consistent with the patrilineal and patrilocal practices of the Maya during the Colonial period (Farriss 1984), is a direct conflict with expectations from historic accounts. As detailed in Chapter 2, historic records document the death of 80 males from Tipu who died during the 1623 Fray Diego Delgado expedition to Tah Itzá (Jones 1989). Previous studies have not identified any evidence in the collection of high male trauma frequency or a mass burial, both of which would provide evidence for the return of the bodies of the 80 men to Tipu for burial (O'Connor 1995). It is possible that with the large population fluctuations observed during the Colonial period that the loss of these 80 individuals did not make a large impact on the Tipu population. Alternatively, the 80 men brought on the expedition may have identified as members of the Tipu community, despite having been born elsewhere and relocated to the village at some point after early childhood.

Within-Cemetery Patterning

Patterning in burial location within the cemetery of individuals with similar isotope values was identified through hierarchical cluster analysis (see Figure 5.13). Spatial patterning was investigated by both a focused approach looking at placement of individuals and small groups of individuals and a broad-scale approach via broad patterns in isotope values based on cemetery area. Potential explanations for the patterns identified in Chapter 5 are discussed here.

There are several possible examples of groups or clusters of two or more individuals with similar isotope values, which may represent family plots. As discussed in Chapter 5, Jacobi (2000) identified possible groups of individuals sharing unique dental traits who were buried close to one another. Although I only have isotope data for multiple individuals from two of the clusters, the individuals within both clusters have very similar strontium and oxygen isotope values. This provides very limited, anecdotal evidence that further exploration of spatial relationships between skeletons with similar isotope ratios, dental morphology and dental metrics is warranted.

The front of the church is the only area of the cemetery with at least one representative from each eight of the isotope clusters defined in Chapter 5 via hierarchical cluster analysis. Given the altar was located at the front of the church, Jacobi (2000) identified the area nearest the altar (within church front) as a potential higher status burial location. Although the burials in the front of the church are somewhat crowded, there is little evidence for the disturbance of earlier burials as is seen in the back of the church (Jacobi 2000). Furthermore, the average age at death of individuals buried in the front of the church is higher than elsewhere in the cemetery (Cohen, et al. 1989, Jacobi 2000).

I find no clear evidence that unique or special mortuary contexts being a reliable predictor of homeland. Many of the adults buried in the Tipu cemetery are believed to have been interred in simple shrouds and with few non-perishing mortuary goods. The apparently homogenous mortuary behavior prevented any systematic comparisons by social status, although some anecdotal evidence will be addressed here. Two individuals have previously been investigated as strong candidates for Spanish ancestry: MT 78 and MT 96.

MT-78 was the only individual buried in a coffin, an old adult male buried in front of the altar. While the isotope values for MT-78 ($^{87}Sr/^{86}Sr = 0.70883$, $\delta^{18}O = -2.47$) fall within the local Tipu range, these values are also consistent with those expected from some regions of Spain (e.g. Guede, et al. 2017). Although advanced occlusal wear of MT-78's anterior dentition prevented the observation of many of the most diagnostic dental morphological traits, Jacobi reports that this individual shows two morphological traits characteristic of the Maya dental complex: a large tuberculum dentale on the maxillary lateral incisor and a minor expression of Tome's root on the mandibular 1st premolar; additionally, his dental metrics fall near the mean for the Tipu male population, and his estimated stature falls within both the Spanish and Tipu Maya ranges for males (Jacobi 2000:170). There is no known historical record for the burial of any Spanish clergy in the Tipu cemetery, and Tipu's remote location on the edge of the Spanish interaction sphere and the extreme difficulties Spanish encountered while traveling to Tipu prior to 1650, resulted in Tipu receiving fewer numbers of Spanish visitors than towns and missions closer to the Spanish capital in Merida. Although the combination of the unique, seemingly high-status mortuary context for MT-78 and the consistent isotope values suggest there is a possibility that he was born in Spain, the most parsimonious explanation continues to be that this individual was born at or around Tipu.

Two other individuals, one female (MT-96) and one male (MT-92), buried at or near the front and center of the altar have isotope values that fall within the Maya Mountain range (>0.7100). MT-96 was a young adult female buried with a censer ($^{87}Sr/^{86}Sr = 0.71061$, $\delta^{18}O = -3.3$); the censer was in a Spanish style but of Maya manufacture, and the only one of its type recovered from a burial at Tipu. The other individual, a young adult male (MT-92), has the highest $^{87}Sr/^{86}Sr$ value at the site ($^{87}Sr/^{86}Sr=0.71265$, $\delta^{18}O=-2.68$). A Spanish origin cannot be ruled out for either of these burials, as some regions of Spain have $^{87}Sr/^{86}Sr$ isotope values exceeding 0.7100 (Valenzuela-Lamas et al. 2016; Voerkelius et al. 2010). MT-96's dental morphology is clearly Maya, her stature is consistent with the Tipu female mean, and no record of female Spanish travelers to Tipu has been identified in ethnohistoric records (Jacobi 2000:171). Although I do not have access to specific dental morphology or stature data for MT-92, Jacobi did not identify any individuals in the Tipu skeletal population with dental morphology that was inconsistent with the Maya dental complex (Jacobi 2000). As such, the most parsimonious explanation remains that these individuals were Maya. The presence of two Maya Mountain born individuals interred in presumably high-status burial contexts, provides very anecdotal evidence that individuals of both sexes from the Maya Mountains may have had similar access to high status positions in Tipu society. The diversity in homelands of the individuals buried near the altar at Tipu and the presence of clear migrants buried with high status mortuary goods provides circumstantial evidence that migrants may have played important roles in the Tipu community.

Possible evidence for patterning of burial based on birthplace is only seen in the area north of the church. This area saw less variability in point of origin than all other cemetery areas. The area north of the church was the only cemetery area to completely lack any individuals born in the Maya Mountains, and contained no individuals with $^{87}Sr/^{86}Sr$ values less than 0.7089. Furthermore, the $^{87}Sr/^{86}Sr$ values for this area were remarkably homogenous, especially given the variability seen in the other cemetery areas. The demographic composition of the area outside and north of the church is also interesting; it has the highest juvenile to adult ratio, with 45% of the individuals in the section less than 10 years of age at the time of death. Jacobi (2000:107) speculated that this area may have been a special section that was unconsecrated ground, devoted to unbaptized individuals, especially children. Although I only sampled adult individuals, this hypothesis can still be partially explored. If the area north of the church was indeed reserved for individuals who had not been baptized, then that implies several things about the adult Tipu population. First, it suggests all the adult individuals with $^{87}Sr/^{86}Sr$ values above 0.709 had been residing at Tipu long enough to be baptized. Second, this suggests that those individuals decided to either continue to live at Tipu after baptism or were returned to Tipu for burial.

Alternatively, I suggest that the area north of the Tipu church may have been reserved for individuals coming from a specific area or region, specific social hierarchy, or perhaps during a specific time. The burials recovered from the colonial Campeche cemetery, a roughly contemporaneous and multiethnic Colonial cemetery on the Yucatan's northwest coast, were apparently interred indiscriminately, with no evidence of segregation based on age, sex, or ancestry (Price et al. 2012a; Rodriguez 2010), a practice that followed Spain's goal to rapidly assimilate subjugated peoples into Spanish culture (Price et al. 2012a). Campeche was the major trade port for the Yucatan peninsula and Merida, and its proximity to the capital meant there was a stricter adherence to Spanish practices than would be expected from more peripheral and remote towns like Tipu. The Tipu population has no clear evidence of any non-Maya burials, in addition to a well-documented maintenance of Maya cultural practices unseen in areas with a stronger Spanish presence (Graham 2011). The presence of an apparently homogenous population in terms of ancestry and lack of firm or consistent Spanish control may have allowed for some level of segregation within the cemetery based on non-biological factors (social status, place of origin, etc.). Although Price et al. (2012) did collect extensive isotopic data on the Campeche population, their research did not focus on any spatial patterning using isotope data within the Maya population, but rather only addressed the differences between ancestry groups; the ^{87}Sr/^{86}Sr values for the Campeche Maya population are far more homogenous than is seen with Tipu, so it is unclear if any patterns would emerge at Campeche with more fine grained analysis.

Most of the individuals at Tipu have strontium and oxygen isotope values that cluster tightly together, supporting a shared location of origin. The individuals buried to the north of the church also consistently had slightly different frequencies of dental traits compared to other areas (Jacobi 2000). Although Jacobi (2000) attributed this to the small total number of individuals buried in the area, it provides anecdotal evidence that there may be some kind of a population difference for this subset of burials. The incorporation of juvenile isotope ratios or more detailed dental morphological analysis may help elucidate this question.

Homelands of First-Generation Migrants to Tipu

A secondary objective of this research was to identify specific homelands for the first-generation migrants buried at Tipu, whether it be the Northern Yucatan, as stated the ethnohistoric model, or elsewhere in Mesoamerica. For many migrant individuals buried at Tipu, a specific homeland could not be definitively identified. The subtle variability in local ^{87}Sr/^{86}Sr and δ^{18}O isotope ranges throughout the lowlands, as well as the substantial overlap of the local isotope ranges for many potential points of origin, confounded attempts to estimate specific homelands for most of the Tipu migrants. Although isotopes typically cannot pinpoint exact homelands, they are useful to identify broad regions or areas that can are consistent with or can be excluded from consideration. The densest cluster of Colonial migrants is overlapped by both the range for the Belize Valley (located several kilometers north of Tipu), the range for Campeche (located on the northern coast of the Yucatan Peninsula), and many other northern lowland areas in-between. Unfortunately, the origin of these individuals would be needed to answer the question of whether Tipu population largely was the result of migration from the northern Yucatan, or if it was the result of *reducciones* of the local region (which likely would have included individuals from the Belize Valley and other nearby areas). The incorporation of additional isotopes may help further tease out the homelands of these individuals. Recent research investigating lead isotope variability in Mesoamerica shows some promise of its utility for the study of migration in the Maya area (Sharpe et al. 2016).

Despite these limitations, it is possible to suggest homelands for the Tipu first generation migrants with isotope values falling to the extremes of the ranges. Twelve individuals (6.7% of the total Colonial cemetery population), have values consistent with an origin in the Maya Mountains geological zone. Available historic records provide little evidence of interaction or migration between Tipu and groups living further south in the Maya Mountains; however, given Tipu's strategic location, its importance as a center for trade, and close proximity to the Maya Mountains, it is not surprising that individuals from the Maya Mountains were buried at Tipu.

In addition, several individuals have isotope values that fall within the multi-isotope ranges for northern Belize or the southern Yucatan. There is insufficient data to identify if these first-generation migrants came from the Spanish held Bacalar Province or from the rebel Maya occupying the La Pimienta region, both which are broadly located in northern Belize or the southern Yucatan. The Spanish had a strong, but at times tenuous, presence in the northern portion of the Bacalar Province, which occupied the western portions of Northern Belize and southern Quintana Roo (Farriss 1984; Jones 1998). The Maya living in the La Pimienta region remained independent during most of the 17th century, and, in addition to a Maya population that lived in the region since before Spanish arrived, was purported to contain a large population of refugees from the Sierra district in the northern Yucatan and villages near Campeche (Jones 1989). Although this does confirm ties between Tipu and regions to the north, I cannot further tease out specific homelands for the individuals at Tipu with isotopic values consistent with areas to the north.

Furthermore, contact between Tipu and the Itzá Maya in the Petén Lakes region may have been more frequent than ethnohistoric records suggest. Though there is broad overlap between the Petén Lakes isotope ranges and many other sites, there are a few individuals buried at Tipu with values that are consistent with only the Petén Lakes region. The presence of these first-generation migrants suggests that some form of population movement, perhaps in some way related to trade, was actively occurring between the Itzá Maya heartland and Tipu. Although historical records do not specify ongoing contact between the two groups, Tipu's history of fluctuating political alliances suggest it is likely that some form of contact between Tipu and the Petén was maintained during most of the early Colonial Period, and especially after the 1638 rebellion, when the Tipuans desecrated the church and expelled all Spanish clergy (Graham, et al. 1985:210; Jacobi 2000). Although most of the people buried in the Tipu cemetery are believed to have been interred prior to 1638, it is possible the area outside of the church continued to be used as a burial ground until the residents of Tipu were relocated to the Petén in 1707 (Graham, et al. 1985:210; Jacobi 2000; Jones 1989). By 1696, there is substantial evidence of kinship and political ties between Tah Itzá and Tipu, and records note that individuals from Tipu established residence in an Itzá held town east of Lake Petén Itzá (Jones 1989).

There are also several individuals with isotope values that are consistent with an origin somewhere in the southern lowlands, including the Petén or somewhere on the Vaca Plateau near Caracol. Historical evidence for contact with the Petén is covered previously. Although there is little evidence for contact between Tipu and regions to the south and southwest, including Caracol and the Vaca Plateau, it is probable that there was some form of contact between these areas. The only historical evidence for interaction with these regions during the early Colonial period occurred during Garazon's third entrada to capture Maya runaways. During this entrada, he reportedly traveled 100 leagues across the Maya Mountains, which would have taken him to Manche Chol territory in southern Belize (Jones 1989:50). The route he would have gone is unknown, however, the Maya Mountains can be quite difficult to traverse from north to south, and it is more likely he took a route around them than over them. If this was the case, it is possible he may have traveled across the Vaca Plateau, which is directly west of the Maya Mountains. If Garazon did travel through Caracol or the surrounding area, it is possible that these individuals with southern lowland isotope values may have been rounded up during this entrada and forcibly relocated to Tipu.

Given the dynamic population history during the early Colonial period it is very probable the first-generation migrants at Tipu came from many diverse locations. Despite not being able to identify specific homelands in the Yucatan peninsula, the isotope data provides crucial evidence for the movement of individuals from both Maya and Spanish held regions during the early Colonial period at Tipu.

Evidence for Spanish-led *Reducción*

I also investigated whether the isotopic data provided any evidence for the occurrence of a Spanish led *reducción* at Tipu, as is described in the historical record. There was insufficient data to identify clear evidence for the presence or absence of *reducciones* occurring at Tipu based on the isotope data used in this study. The multi-isotope comparison (see Figure 5.19) shows a dense cluster of individuals with $\delta^{18}O$ values similar to the Tipu Postclassic range and with $^{87}Sr/^{86}Sr$ values at or near the lower end of the Tipu Postclassic range. Given the overlap of the lower end of the Tipu Postclassic $^{87}Sr/^{86}Sr$ range and the Belize Valley range, it is possible that some of the skeletons in this dense cluster may represent individuals who were forcibly rounded up by the Spanish from dispersed settlements in the surrounding countryside, including settlements in the nearby Belize Valley, and relocated to Tipu.

Alternatively, the aforementioned skeletons composing the dense cluster of isotope values, may have ended up at Tipu by their own accord, a result of regular, willful, population movements between nearby villages and Tipu – likely a continuation of interactions that occurred prior to the arrival of the Spanish. Throughout the Maya area population movement between villages likely continued at some level after the Spanish arrived, and this would have been even more true for locations like Tipu, which were only rarely visited by the Spanish. Historical records document many Maya villages and hamlets near Tipu, and between Tipu and Colmotz, the next closest mission (Jacobi 1989); many of these may have been the birthplace of these individuals. Finally, it is also possible that baptized individuals who were not resident at Tipu at the time of their death were brought to the church at Tipu so that they may be buried in consecrated ground.

Tipu and the Colonial Frontier

Tipu was situated at a geographical and cultural frontier. As a result, it experienced a dynamic history of fluctuating political alliances between the Itzá Maya and the Spanish, and played a pivotal role in frontier politics and trade. This research documents first-generation migration from diverse, widespread homelands that confirms Tipu's position as an important frontier community during the early Colonial period.

During the early Colonial period, Tipu functioned as a highly fluid and open border town. It was the center of successive waves of multidirectional migration, coming from two or more fronts, which resulted in a population of individuals with remarkably diverse isotope values. As a tidal frontier, it absorbed different waves of immigration, some of which would later disperse. Tipu's broad interaction sphere included contact with areas throughout the Spanish held Yucatan Peninsula, Petén, Maya Mountains, and perhaps the Vaca Plateau. The presence of individuals from the latter sites and regions show that that during the early Colonial period Tipu remained an important location for Maya living outside the control of both the Spanish and the Itzá Maya. The presence of individuals from the Petén is also very interesting, although not necessarily unexpected, given Tipu's proximity on the frontier between the Itzá Maya and Spanish held territories and previous ethnohistoric research on the area (Farriss 1984; Jones 1989; Jones 1998).

The population of Tipu was a highly mobile population. Nearly 63% of the individuals buried at Tipu during the early Colonial period were first-generation migrants. A survey of isotope based mobility studies in Mesoamerica identified several pre-Columbian populations with relatively significant numbers of migrants; however, the estimates provided by the isotope data suggest they typically compose no more than ~25% of the population (Miller 2014). Even large isotope datasets obtained from urban Maya cities do not show rates of migration that exceed more than 40% of the population (e.g. Wright 2012; Miller 2014), and contemporaneous Maya Colonial cemeteries have identified very few migrants within the Maya population (e.g. Price et al. 2012), although insufficient isotope baseline resolution across many areas of Mesoamerica and the lack of strontium and oxygen isotopic variability within some areas of Mesoamerica may further confound these results. The populations of preindustrial cities or urban centers in both the Old World and New World are believed to have been dependent on continuous migration from rural areas to maintain a somewhat stable population size in the face of higher levels of mortality due to disease and other negative consequences of urban life (Storey 1985). Despite ethnohistorical records that suggest Tipu's population may have at one point reached the size of a large urban center, any analysis of the Tipu population cannot operate under an assumption that it was in anyway a stable population. During the early Colonial period, Tipu experienced massive population fluctuations that were, either directly or indirectly, a result of the Spanish presence in the region. I argue that Tipu's seemingly unusual abundance of migrants reflects Tipu's location as a border town, situated on a dynamic frontier between two competing oppositions. The sheer quantity and diversity of migrants in the Tipu cemetery population demonstrates the fluidity of the Maya-Spanish frontier, and the importance of frontier towns in regional interaction spheres and trade networks.

Furthermore, Tipu's remote location from the Spanish New World capital in Merida and distance from the center of Spanish activity in the Yucatan Peninsula is believed to have contributed to Tipu's ability to maintain a strong sense of Maya identity and cultural syncretism that wasn't seen at other missions in the Maya area (Graham 2011). The immigration of Maya from other, isotopically diverse sites, Tipu's broad interaction sphere, and multidirectional migration may have also helped contribute to the sense of Maya identity and culture that persisted at Tipu.

Defining "Local" on the Maya-Spanish Frontier

For many isotope-based mobility studies, a key task is determining what constitutes isotopically "local" at an archaeological site. From the baseline definition of isotopically "local" for any given site, "migrants" or people who moved within their lives can be identified, in addition to the potential homelands of these people. As seen at Tipu, definitions of local based purely on expectations of isotope variability may be strongly contingent on the interaction sphere of a site and mobility of a population at any given time. Furthermore, for sites, like Tipu, located on the borders of distinct isotopic zones, shifts in political boundaries and land use between time periods may result in a corresponding shift in the "local" isotope signature for a population. Expansion of settlement across two adjacent, but isotopically distinct zones may result in a change in $^{87}Sr/^{86}Sr$ values seen at a site. Longitudinal studies of variation in isotope range within a population may help elucidate how and why "local" isotope values for a community change through time.

It is also very important to note that "local" as defined via archaeological or isotopic data does not necessarily translate to any sort of emic definition of local identity, or what it meant for the people buried at Tipu to identify as a member of the Tipu community, if they even did at all. In a highly mobile population like Tipu, many hypothetical questions are raised as to the emic meaning or importance of being local. Did being a migrant matter to the people living at Tipu when most of those people were migrants themselves? Or did the high population of migrants living at Tipu make being of local birth especially important? Examples from ethnographic literature show that groups may form semi-hierarchical sociopolitical categories based on a combination of their immigrant status and importance in their former community (Murphy and Bledsoe 1987). The possibility of bringing in individuals from other sites so that they may be buried on sacred ground also further complicates these questions, although I have no direct evidence that this happened. Future research incorporating isotope values of skeletons from commingled and secondary burial contexts at Tipu may help elucidate these issues.

Instead of the "local" versus "migrant" dichotomy that frames most traditional isotope-based migration studies, the Tipu cemetery population shows that origins and identity on the Maya-Spanish frontier may have been a lot more fluid than this framework allows. The diversity in homelands of individuals buried in the front of the church suggest that birthplace does not necessarily define status in the community, although it is possible they were not seen as foreigners. Most of the Tipu population was from isotopically similar locations, suggesting they may have had a shared identity. Alternatively, for a population with a high immigration rate like Tipu, the absence of any sort of clear discrimination in burial location of “locals” and “migrants” may suggest that these designations were not significant for those living at Tipu. Rather, the Maya in the southern Yucatan may have experienced a form of shifting identity, where – in the face of oppressive Spanish control and complete restructuring of existing cultural norms – the importance of traditional identities tied to specific Postclassic villages, regions, or languages may have been slightly diminished in favor of a more broad, shared identity as Maya. By having a fluid shared commonality of a Maya identity, instead of a community focused on whether a person was “local” versus “migrant”, Tipu would be able to form a more effective and united front against the Spanish and better maintain a sense of Maya culture than other early Colonial period missions in the Maya area.

Conclusion

The arrival of the Spanish had a striking and rapid impact on the nature of migration patterns of the Maya living in the southern Yucatan peninsula, especially on the Maya-Spanish frontier. During the early Colonial period Tipu was a fluid frontier town, composed of a mixture of highly mobile individuals from throughout the region. The number and diversity of homelands of migrants buried at Tipu underscores its importance as a refuge for fleeing Maya, as well as a gateway for trade between Spanish and Maya held territories. Like many aspects of frontier communities, migration at Tipu is more complicated than a simple dichotomy of “local” and “migrant”; it is possible that identity as “local” may have been a more fluid concept at Tipu.

Future research is needed to help better understand migration at Tipu. Further characterization of biologically available strontium around Tipu and the application of additional isotopes will aid in segregating individuals born at Tipu and provide better, more precise estimations of homelands of those individuals who were born elsewhere. This data may also allow for the identification of migrants in the Postclassic Tipu assemblage, potentially expanding knowledge of migration at Tipu prior to the arrival of the Spanish. Expanding the sample to include individuals from commingled and/or disturbed contexts, which may represent some of the earliest internments, and juveniles, will help provide a more complete understanding of the nature and complexity of migration at Tipu shortly after the arrival of the Spanish.

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APPENDIX A

TIPU ISOTOPE DATA

Appendix A. Tipu Isotope Data.

Sample ID	Tooth Sampled	Time Period	Sex	Isotope Cluster	Burial Location	Northing	Easting	$^{87}Sr/^{86}Sr$	$^{87}Sr/^{86}Sr$ Std Error (abs)	$\delta^{13}C_{PDB}$ (‰)	$\delta^{18}O_{PDB}$ (‰)
MT-001	RMaxC	Colonial	Male	2	OW	-67.2	2.4	0.70866	0.0000064	-3.24	-2.75
MT-002	RManC	Colonial	Female	1	OW	-67.2	3	0.70814	0.0000034	-2.50	-2.69
MT-004	RManC	Colonial	Female	3	IB	-66.6	9.2	0.70864	0.0000083	-2.47	-1.15
MT-005	RManC	Colonial	Male	1	IB	-67	10.5	0.70847	0.0000051	-0.15	-2.64
MT-008	LManC	Colonial	Male	1	IB	-67.5	10	0.70829	0.0000047	-2.12	-2.24
MT-011_Control	RManC	Colonial	Male	1	IF	-67.6	17.7	0.70828	0.0000042	-0.64	-2.81
MT-011_Resin	LManC	Colonial	Male		IF	-67.6	17.7	0.70831	0.0000046		
MT-012	LManC	Colonial	Male	2	IF	-67.6	18.7	0.70902	0.0000042	-1.26	-2.67
MT-014	RMaxC	Colonial	Male	1	IB	-70.8	16.6	0.70849	0.0000046	-0.73	-1.83
MT-016_Control	RManC	Colonial	Female		OW	-67.1	0.6	0.70857	0.0000047		
MT-016_Resin	LManC	Colonial	Female	3	OW	-67.1	0.6	0.70857	0.0000059	-2.36	-0.47
MT-019_Control	RManC	Colonial	Male		OW	-67.3	9.01	0.70849	0.0000048		
MT-019_Resin	RManC	Colonial	Male	1	OW	-67.3	9.01	0.70849	0.0006792	-0.80	-2.56
MT-026	LManC	Colonial	Female	1	OW	-68.8	5.7	0.70799	0.0000046	-2.20	-3.31
MT-027	LManC	Colonial	Male	2	OW	-68.5	6.5	0.70879	0.0000046	-0.64	-3.29
MT-031	LManC	Colonial	Male	3	IF	-68.9	18.1	0.70790	0.0000062	-5.43	-1.56
MT-032	RManC	Colonial	Male	1	IF	-69.1	17.3	0.70812	0.0000040	-1.80	-2.45
MT-033	LManC	Colonial	Female	1	IF	-68.2	17.6	0.70794	0.0000049	-1.27	-2.06
MT-034B	LManC	Colonial	Female	1	IF	-70.5	17.5	0.70878	0.0000043	-1.81	-2.15
MT-035(34A)	LManC	Colonial	Male	7	IF	-70.4	18.2	0.70818	0.0000047	-3.97	0.35
MT-036	RManC	Colonial	Male	1	IF	-67.6	17.9	0.70777	0.0000037	-1.65	-2.84
MT-037	RManC	Colonial	Female	1	OW	-68.4	5.8	0.70823	0.0000049	-1.81	-2.17

Appendix A. Tipu Isotope Data (continued).

Sample ID	Tooth Sampled	Time Period	Sex	Isotope Cluster	Burial Location	Northing	Easting	^{87}Sr/^{86}Sr	^{87}Sr/^{86}Sr Std Error (abs)	$\delta^{13}C_{PDB}$ (‰)	$\delta^{18}O_{PDB}$ (‰)
MT-042	LManC	Colonial	Male	1	IB	-67.4	15.4	0.70847	0.0000054	-1.47	-2.66
MT-051	RMaxC	Colonial	Male	1	IF	-70.6	19.3	0.70838	0.0000038	-1.83	-2.58
MT-052 (51/52)	LMaxC	Colonial	Female	1	IF	-70.6	19.5	0.70856	0.0000041	-1.84	-2.08
MT-053	LManC	Colonial	Female	1	IF	-70.4	18.1	0.70840	0.0000040	-1.98	-1.88
MT-054	LManC	Colonial	Female	1	IF	-70.1	18.2	0.70854	0.0000051	-2.51	-2.26
MT-055	RManC	Colonial	Male	1	IB	-68.2	15.9	0.70850	0.0000049	-0.62	-2.39
MT-057	LManC	Colonial	Male	6	IB	-69.5	15.1	0.71062	0.0000055	-3.12	-3.43
MT-058	RMaxC	Colonial	Male	2	IB	-68.6	15.6	0.70866	0.0000047	-1.82	-2.86
MT-060	LMaxC	Colonial	Male	6	IB	-69	15.4	0.71114	0.0000045	-2.32	-3.22
MT-060A (58A)	RManC	Colonial	Juvenile					0.70809	0.0000047		
MT-063 (63B)	RManC	Postclassic	Juvenile		OW	-78.4	5.4	0.70852	0.0000049	-1.42	-2.29
MT-064	RMaxC	Postclassic	Male		G-13-13	-88.8	88.8	0.70868	0.0000054	-2.95	-2.71
MT-066	RManC	Colonial	Male	1	IF	-67	23.2	0.70852	0.0000047	-3.2	-2.28
MT-067B	RMaxC	Colonial	Female	3	IB	-68.6	12.3	0.70802	0.0000058	-2.35	-1.67
MT-070	LManC	Colonial	Male	1	IB	-67.2	14.8	0.70859	0.0000049	-2.09	-2.3
MT-072	RManC	Colonial	Male	3	IF	-68.8	20.6	0.70802	0.0000041	-2.59	-1.52
MT-078	RManC	Colonial	Male	2	IF	-67	23.3	0.70883	0.0000039	-2.23	-2.47
MT-079	RMacC	Colonial	Juvenile					0.70880	0.0000078		
MT-080	RMaxC	Colonial	Female	1	IB	-68.2	14.2	0.70851	0.0000027	-7.00	-2.12
MT-081	LManC	Colonial	Male	3	IB	-67.3	13.9	0.70864	0.0000055	-2.59	-1.40
MT-083_Control	RManC	Colonial	Female		IF	-67.6	20.7	0.70817	0.0000051		
MT-083_Resin	LManC	Colonial	Female	1	IF	-67.6	20.7	0.70817	0.0000042	-2.13	-3.00
MT-085	LMaxC	Colonial	Male	2	IF	-68.3	20.8	0.70891	0.0000047	-1.68	-2.82
MT-086	RManC	Colonial	Female	3	IB	-67.5	12.8	0.70790	0.0000037	-2.25	-1.73
MT-088	RManC	Colonial	Female	2	IF	-69.4	23	0.70855	0.0000041	0.07	-3.06
MT-090	LManC	Colonial	Female	1	IF	-68.5	19.5	0.70842	0.0000039	-1.69	-2.67
MT-092	RManC	Colonial	Male	8	IF	-67.6	22.4	0.71265	0.0000047	-1.63	-2.68

Appendix A. Tipu Isotope Data (continued).

Sample ID	Tooth Sampled	Time Period	Sex	Isotope Cluster	Burial Location	Northing	Easting	^{87}Sr/^{86}Sr	^{87}Sr/^{86}Sr Std Error (abs)	δ^{13}C$_{PDB}$ (‰)	δ^{18}O$_{PDB}$ (‰)
MT-095	RManC	Colonial	Female	3	IF	-69.7	19.3	0.70817	0.0000046	-2.60	-1.74
MT-096	RMaxC	Colonial	Female	6	IF	-67.3	19.3	0.71061	0.0000037	-2.25	-3.33
MT-100	RManC	Colonial	Female	1	IB	-67	10.2	0.70820	0.0000041	-0.51	-2.35
MT-101A	RManC	Colonial	Female	1	IF	-69.1	19.5	0.70839	0.0000039	-0.74	-2.71
MT-102	RManC	Colonial	Female	4	IF	-69	22.9	0.70995	0.0000045	-1.53	-3.16
MT-108	RMaxC	Colonial	Male	2	IF	-67.9	19.9	0.70901	0.0000047	-1.39	-2.83
MT-109	LManC	Colonial	Ind.	1	IF	-67.5	19.2	0.70805	0.0000039	-1.53	-2.57
MT-111B	RManC	Colonial	Ind.	2	IF	-69	18.6	0.70892	0.0000036	-1.50	-2.94
MT-112	LManC	Colonial	Male	3	IF	-68.5	22.8	0.70790	0.0000042	-2.59	-1.65
MT-114	LManC	Colonial	Male	1	IF	-70.7	20.9	0.70778	0.0000055	-1.27	-1.96
MT-115	LManC	Colonial	Female	2	IF	-70.5	22.8	0.70918	0.0000039	-1.66	-3.45
MT-119	LManC	Colonial	Male	3	IB	-68.5	10.2	0.70830	0.0000039	-1.38	-1.22
MT-121	LManC	Colonial	Male	1	IF	-71	23	0.70832	0.0000038	-2.49	-2.59
MT-122 (122&122-124C)	LManC	Colonial	Ind.	2	IF	-70.9	22.1	0.70845	0.0000034	-2.27	-3.43
MT-126A	LManC	Colonial	Male	1	IB	-70.5	10.9	0.70834	0.0000044	-1.07	-3.03
MT-128	RManC	Colonial	Female	1	OW	-70.5	7	0.70825	0.0000042	-3.18	-2.45
MT-132A	LManC	Colonial	Female	1	IB	-69	10.3	0.70802	0.0000038	-0.64	-3.00
MT-133	LManC	Colonial	Male	2	IB	-70	11.3	0.70865	0.0000052	-0.35	-3.01
MT-135	RMaxC	Colonial	Female	1	OW	-72.6	6.9	0.70851	0.0000040	-2.89	-2.01
MT-136 (136A)	LManC	Colonial	Female	3	IB	-68.9	10.1	0.70872	0.0000058	-3.42	-0.75
MT-137	RManC	Colonial	Female	1	IB	-68.9	9.9	0.70835	0.0000041	-2.14	-2.41
MT-138	RManC	Colonial	Male	2	OW	-71.4	6	0.70872	0.0000040	-1.07	-2.96
MT-142	LManC	Colonial	Female	1	OW	-71.1	5.2	0.70852	0.0000040	-1.99	-2.33
MT-144	LManC	Colonial	Male	1	IB	-69.4	9.9	0.70827	0.0000043	-0.55	-2.43
MT-146	RMaxC	Colonial	Female	1	OW	-71	4	0.70827	0.0000052	-1.67	-2.25
MT-151	RManC	Colonial	Male	3	IB	-69.8	10.8	0.70849	0.0000044	-3.33	-1.32
MT-152	LManC	Colonial	Male	3	IB	-69.9	10	0.70841	0.0000063	-3.40	-1.34
MT-157	RMaxC	Colonial	Juvenile	1	OW	-71.4	5.2	0.70837	0.0000066	-2.57	-2.68

Appendix A. Tipu Isotope Data (continued).

Sample ID	Tooth Sampled	Time Period	Sex	Isotope Cluster	Burial Location	Northing	Easting	^{87}Sr/^{86}Sr	^{87}Sr/^{86}Sr Std Error (abs)	δ^{13}C$_{PDB}$ (‰)	δ^{18}O$_{PDB}$ (‰)
MT-163	LManC	Colonial	Male	3	OW	-71.2	2.2	0.70816	0.0000042	-2.53	-1.52
MT-164	LManC	Colonial	Female	1	OW	-69.6	6.3	0.70816	0.0000040	-0.95	-2.21
MT-165	RManC	Colonial	Female	1	OW	-69.5	4.6	0.70833	0.0000046	-2.01	-1.86
MT-169	RManC?	Colonial	Female	1	OS	-73.7	18.7	0.70828	0.0000045	-1.79	-3.08
MT-171	LManC	Colonial	Female	4	OS	-73.4	18.7	0.70970	0.0000042	-3.35	-2.60
MT-172	LManC	Colonial	Female	4	OW	-69.6	7.1	0.71033	0.0000040	-2.09	-2.82
MT-174	LManC	Colonial	Female	1	OW	-69.9	6.9	0.70826	0.0000036	-1.43	-2.53
MT-184	LMaxC	Colonial	Female	5	OW	-63.8	4.5	0.71040	0.0000035	-3.16	-2.07
MT-187	RMaxC	Colonial	Male	3	OW	-64.6	4.1	0.70856	0.0000041	-1.58	-1.56
MT-188	RManC	Colonial	Female	1	OW	-63.3	7.6	0.70763	0.0000040	-0.89	-2.83
MT-194	LManC	Colonial	Female	3	OW	-62.5	6.9	0.70847	0.0000039	-1.71	-1.49
MT-195A/B	LManC	Colonial	Female	1	IF	-64.7	18.4	0.70798	0.0000040	-2.55	-1.99
MT-196	LManC	Colonial	Female	1	IF	-65.5	18.3	0.70832	0.0000036	-1.05	-2.25
MT-197	LManC	Colonial	Female	1	IF	-66	17.8	0.70809	0.0000043	-2.19	-2.80
MT-200	LMaxC	Colonial	Female	2	IF	-66.4	19.1	0.70890	0.0000034	-0.58	-3.41
MT-210	MaxC?	Postclassic	Female		G-13-13	-88.8	88.8	0.70844	0.0000037	-2.66	-2.62
MT-211	LManC	Colonial	Female	3	OS	-74.2	21	0.70814	0.0000041	-1.68	-1.36
MT-213A	RManC	Colonial	Female	1	IF	-67	19.4	0.70827	0.0000046	-1.69	-2.69
MT-213B/C	LManC	Colonial	Male	1	IF	-67	19.7	0.70839	0.0000043	-0.84	-2.46
MT-217	LManI2	Postclassic	Juvenile		OS	-74.3	20.7	0.71009	0.0000048	-2.30	-2.82
MT-218	RManC	Colonial	Male	1	OW	-62.8	6.7	0.70810	0.0000039	-2.88	-1.97
MT-221	RManC	Colonial	Female	6	OW	-61	5.5	0.71103	0.0000042	-2.57	-2.85
MT-224	LManC	Colonial	Male	1	IF	-65	22.7	0.70866	0.0000041	-1.09	-2.36
MT-226	LManC	Postclassic	Male		G-13-13	-88.8	88.8	0.70832	0.0000039	-6.76	-2.90
MT-227	R?ManM1	Postclassic	Ind.		G-13-13	-88.8	88.8	0.70975	0.0000043	-7.75	-3.00
MT-228	LManC	Postclassic	Male		G-13-13	-88.8	88.8	0.70896	0.0000055	-3.21	-3.38
MT-232	LManC	Colonial	Female	1	OW	-60.6	4.5	0.70856	0.0000038	-0.76	-2.07
MT-240A (240)	RManC	Postclassic	Ind.		G-13-13	-88.8	88.8	0.70853	0.0000047	-5.74	-3.24
MT-245	LManC	Colonial	Female	1	OW	-60.4	3.4	0.70887	0.0000046	-3.12	-2.29

Appendix A. Tipu Isotope Data (continued).

Sample ID	Tooth Sampled	Time Period	Sex	Isotope Cluster	Burial Location	Northing	Easting	^{87}Sr/^{86}Sr	^{87}Sr/^{86}Sr Std Error (abs)	$\delta^{13}C_{PDB}$ (‰)	$\delta^{18}O_{PDB}$ (‰)
MT-253	LManC	Colonial	Female	3	OS	-74.2	19.9	0.70860	0.0000039	-3.45	-1.68
MT-253A (Formerly 253X)	LManC	Colonial	Male	3	OS	-74.2	20.1	0.70870	0.0000038	-2.95	-1.32
MT-254	LManC	Colonial	Male	1	IF	-66.1	23	0.70805	0.0000045	-1.30	-2.00
MT-256	LManC	Colonial	Male	1	IB	-64.7	15.9	0.70829	0.0000051	-1.64	-2.44
MT-260	LMaxC	Colonial	Male	3	OW	-60.3	3.3	0.70834	0.0000032	-3.82	-0.63
MT-269	RManC	Colonial	Male	2	IF	-66.2	22.4	0.70892	0.0000038	-1.75	-2.45
MT-271	LManC	Postclassic	Male		G-13-13	-88.8	88.8	0.70959	0.0000036	-5.14	-2.46
MT-272	LManC	Colonial	Male	1	OW	-59.4	3.4	0.70837	0.0000040	-2.13	-1.96
MT-273	RMaxC	Colonial	Male	1	IF	-66.2	20.6	0.70864	0.0000047	-1.58	-1.93
MT-279	RManC	Colonial	Male	2	IB	-64.9	14.6	0.70849	0.0000055	-1.92	-2.98
MT-280	L?MaxPM1?	Postclassic	Juvenile		G-13-13	-88.8	88.8	0.70917	0.0000038	-4.11	-2.62
MT-283	RManC	Colonial	Male	6	OW	-62.5	4.5	0.71106	0.0000039	-3.48	-3.03
MT-290	RManC	Postclassic	Female		IF	-66.5	20.3	0.70828	0.0000030	-0.96	-3.03
MT-293 (Formerly 288)	LManC	Colonial	Male	1	IB	-64.7	15.6	0.70841	0.0000040	-1.78	-2.54
MT-299	RManC	Colonial	Male	1	IB	-65.8	12.4	0.70860	0.0000042	-2.10	-2.05
MT-301X	LManI2	Colonial	Male	1	IB	-66.5	13	0.70836	0.0000052	-1.45	-2.10
MT-302	LManC	Colonial	Male	2	OS	-72.2	20	0.70876	0.0000045	-1.70	-2.65
MT-306	RManC	Colonial	Ind.	1	IF	-64.8	13.2	0.70858	0.0000040	-2.98	-1.81
MT-308	LManC	Colonial	Male	3	IB	-64.6	11.6	0.70861	0.0000040	-7.30	-1.15
MT-309	RManC	Colonial	Male	3	OW	-58.7	4.1	0.70880	0.0000037	-1.17	-1.56
MT-313	LManC	Colonial	Male	1	IF	-66.3	17.2	0.70845	0.0000046	-2.75	-2.26
MT-317	RMaxC	Colonial	Male	1	IB	-66.5	14	0.70808	0.0000042	-1.26	-2.47
MT-318	LManC	Colonial	Ind.	3	IB	-66.1	14.9	0.70841	0.0000055	-3.66	-0.82
MT-322	LManC	Colonial	Male	1	IB	-66.6	13	0.70837	0.0000045	-2.48	-2.50
MT-324	LManC	Colonial	Female	3	OW	-62.2	1.6	0.70818	0.0000056	-2.28	-1.07
MT-326D	RMaxC	Colonial	Male	2	IB	-65.8	10.1	0.70884	0.0000047	-1.13	-2.63

Appendix A. Tipu Isotope Data (continued).

Sample ID	Tooth Sampled	Time Period	Sex	Isotope Cluster	Burial Location	Northing	Easting	^{87}Sr/^{86}Sr	^{87}Sr/^{86}Sr Std Error (abs)	δ^{13}C$_{PDB}$ (‰)	δ^{18}O$_{PDB}$ (‰)
MT-328D (Formerly 328X)	LManC	Colonial	Male	4	IF	-67	19	0.70947	0.0000044	-2.30	-2.73
MT-332A	LMaxC	Colonial	Male	1	IB	-67	19	0.70829	0.0000065	-1.76	-2.67
MT-335	LManC	Postclassic	Female		OW	-62.2	0.3	0.70851	0.0000057	-0.78	-2.63
MT-341	RMaxC	Postclassic	Ind.		G-13-13	-88.8	88.8	0.70856	0.0000051	-6.19	-3.09
MT-348	LManC	Colonial	Ind.	1	IB	-66.6	10.1	0.70771	0.0000036	-0.92	-2.20
MT-352	RManC	Colonial	Male	1	OS	-75.4	17.8	0.70818	0.0000054	-1.02	-2.80
MT-358	LManC	Colonial	Female	1	OS	-75.7	17.1	0.70820	0.0000042	-2.13	-2.01
MT-363	LManC	Colonial	Male	1	ON	-60.3	18.8	0.70782	0.0000043	-4.16	-2.48
MT-366	RManC	Colonial	Male	3	ON	-57.1	19.7	0.70798	0.0000049	-1.54	-0.97
MT-367	LManC	Colonial	Female	1	ON	-58	19.5	0.70793	0.0000036	-0.77	-2.97
MT-369	RManC	Colonial	Male	1	ON	-58.8	17.2	0.70810	0.0000046	-0.23	-2.81
MT-383	LManC	Colonial	Male	2	OS	-77.1	17.7	0.70892	0.0000049	-2.11	-2.52
MT-384	LMaxC	Colonial	Female	5	OS	-77.4	19.4	0.71078	0.0000051	-3.08	-2.69
MT-390	LManC	Colonial	Male	1	ON	-61.1	16.5	0.70893	0.0000044	-1.78	-2.19
MT-391	RManC	Colonial	Female	3	ON	-61	18.1	0.70824	0.0000038	-2.84	-1.04
MT-393	RMaxC	Colonial	Male	1	ON	-58.9	17.6	0.70823	0.0000054	-0.39	-2.78
MT-395	LManC	Colonial	Female	2	ON	-58.2	17.2	0.70852	0.0000045	-0.25	-2.94
MT-400	RManC	Colonial	Male	1	OW	-67	6.1	0.70849	0.0000044	-0.82	-1.88
MT-404	LManC	Colonial	Male	1	OW	-65.8	6.6	0.70793	0.0000042	-1.63	-2.72
MT-407	LManC	Postclassic	Female		OW	-66.9	6.1	0.70842	0.0000048	-2.44	-2.25
MT-415	RManC	Colonial	Male	1	OS	-77.1	19.1	0.70852	0.0000039	-0.59	-2.55
MT-417	RManC	Colonial	Male	2	OS	-77	19.7	0.70892	0.0000041	-1.05	-2.74
MT-427	LManC	Colonial	Female	1	OW	-65.9	2.4	0.70869	0.0000037	-2.28	-2.35
MT-432	LManC	Colonial	Male	7	ON	-61.9	12.6	0.70792	0.0000038	-2.52	-0.03
MT-435	DecRMaxm1	Postclassic	Juvenile		ON	-57.8	17.3	0.70950	0.0000049	-0.71	-3.01
MT-436	RManC	Colonial	Female	1	ON	-61.8	14.3	0.70871	0.0000040	-1.45	-2.44
MT-439	LMaxC	Colonial	Male	3	ON	-59.2	13.4	0.70863	0.0000043	-1.90	-0.82
MT-440	LManC	Colonial	Female	1	OS	-79.2	16.8	0.70852	0.0000036	-1.49	-2.29

Appendix A. Tipu Isotope Data (continued).

Sample ID	Tooth Sampled	Time Period	Sex	Isotope Cluster	Burial Location	Northing	Easting	^{87}Sr/^{86}Sr	^{87}Sr/^{86}Sr Std Error (abs)	δ^{13}C$_{PDB}$ (‰)	δ^{18}O$_{PDB}$ (‰)
MT-441	LManC	Colonial	Male	1	OS	-77.9	16	0.70815	0.0000044	-1.90	-1.93
MT-442	LManC	Colonial	Female	3	OS	-77.4	16.4	0.70817	0.0000039	-1.78	-1.36
MT-444	RManC	Colonial	Male	4	OS	-78.5	20	0.70974	0.0000044	-2.99	-2.84
MT-446 (Formerly 180)	LManC	Colonial	Male	4	OS	-80.2	18.8	0.70980	0.0000041	-1.53	-2.96
MT-452	RManC	Colonial	Male	1	ON	-60.9	12.7	0.70845	0.0000034	-1.69	-2.33
MT-455	LManC	Colonial	Male	7	ON	-55.3	17.4	0.70821	0.0000032	-3.78	0.22
MT-460	RManC	Colonial	Male	1	OW	-65.1	1.3	0.70807	0.0000042	-1.16	-2.40
MT-463	RManC	Colonial	Male	4	OW	-63.9	1.4	0.70942	0.0000048	-1.98	-2.60
MT-465	LManC	Colonial	Male	1	OW	-65	0.9	0.70816	0.0000040	-0.67	-2.78
MT-466	LManC	Colonial	Male	1	OW	-64.7	3.2	0.70844	0.0000035	-1.40	-2.03
MT-469	LManC	Colonial	Male	1	OW	-66.8	1.9	0.70824	0.0000043	-1.39	-2.61
MT-484	LManC	Colonial	Male	5	OW	-64.3	8.8	0.71068	0.0000047	-3.24	-2.12
MT-489	RManC	Colonial	Female	4	OW	-68.7	0.6	0.70994	0.0000054	-2.72	-2.78
MT-491	LManC	Colonial	Male	4	OW	-63.1	2.9	0.70965	0.0000044	-2.67	-2.72
MT-492	DecLMani2	Postclassic	Juvenile		OW	-62.2	0.5	0.70955	0.0000040	-0.93	-3.29
MT-493	LManC	Colonial	Male	4	OW	-62.9	2.1	0.70961	0.0000043	-1.69	-2.53
MT-495	LMaxC	Colonial	Female	1	ON	-56.2	24.9	0.70842	0.0000038	-1.48	-2.49
MT-495	RManC	Colonial	Female	1	ON	-56.2	24.9	0.70841	0.0000040	-1.49	-2.46
MT-496	LManC	Colonial	Male	1	OW	-64.7	0.92	0.70853	0.0000038	-1.33	-2.42
MT-497	LManC	Colonial	Female	1	ON	-56.3	23.2	0.70827	0.0000040	-0.07	-2.54
MT-498	LManC	Colonial	Female	3	ON	-57.1	20.6	0.70866	0.0000040	-4.82	-1.33
MT-500	LManC	Colonial	Male	1	OS	-77.4	22.9	0.70778	0.0000034	-3.93	-2.11
MT-502	RManC	Colonial	Male	1	OS	-72.1	14	0.70832	0.0000044	-1.83	-1.96
MT-503	LManC	Colonial	Male	1	OS	-80	23.6	0.70847	0.0000044	-2.66	-2.42
MT-507	LMaxC	Colonial	Female	5	OS	-76.5	22.3	0.71087	0.0000048	-3.71	-2.40
MT-508	RManI2	Colonial	Female	1	OS	-77.4	23.8	0.70849	0.0000039	-1.42	-2.34
MT-512	RManC	Colonial	Male	1	OS	-77	25.2	0.70825	0.0000047	-2.08	-2.60
MT-522	LManC	Colonial	Female	1	OW	-64.6	9	0.70838	0.0000045	-0.79	-2.87

Appendix A. Tipu Isotope Data (continued).

Sample ID	Tooth Sampled	Time Period	Sex	Isotope Cluster	Burial Location	Northing	Easting	$^{87}Sr/^{86}Sr$	$^{87}Sr/^{86}Sr$ Std Error (abs)	$\delta^{13}C_{PDB}$ (‰)	$\delta^{18}O_{PDB}$ (‰)
MT-523	RManC	Colonial	Female	3	OW	-69	2	0.70812	0.0000043	-2.01	-1.00
MT-525	LManC	Colonial	Male	1	OW	-70.2	0.91	0.70781	0.0000042	-1.68	-3.25
MT-527	LMaxC	Colonial	Male	3	OW	-68.4	0.91	0.70822	0.0000037	-1.55	-1.30
MT-528	LManC	Colonial	Male	7	OW	-69	3.4	0.70803	0.0000041	-1.61	-0.03
MT-529	RMaxC	Colonial	Female	3	OW	-69.6	0.91	0.70849	0.0000037	-1.59	-1.71
MT-531	RManC	Colonial	Male	1	OS	-72.2	13.4	0.70808	0.0000040	-1.44	-2.49
MT-535	RMaxC	Colonial	Male	3	OS	-76.5	9.8	0.70865	0.0000040	-2.67	-1.01
MT-538	DecLMaxc	Postclassic	Juvenile		OS	-76.2	15.9	0.70866	0.0000049	-0.94	-1.78
MT-541	RManC	Colonial	Male	1	ON	-60.4	21.4	0.70803	0.0000050	-2.78	-2.15
MT-543 (dentition formerly MT24)	LManC	Colonial	Female	7	OW	-67.9	0.5	0.70792	0.0000046	-1.43	0.30
MT-545	LManC	Colonial	Female	1	OW	-67.9	0.9	0.70812	0.0000039	-1.15	-2.16
MT-549	RMaxC	Colonial	Male	1	OW	-68.6	3.9	0.70847	0.0000039	-1.35	-2.37
MT-550	RManC	Colonial	Male	2	OW	-68.5	2	0.70883	0.0000046	-1.32	-2.68