Ritual Violence and the Perception of Social Difference:

Migration and Human Sacrifice in the Epiclassic Basin of Mexico

by

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ABSTRACT

Archaeologists have long contended that large-scale human migrations played an essential role in the cultural development of pre-Hispanic central Mexico. During the Epiclassic period (600-900 CE), migration is implicated in the appearance of new forms of material culture, sociopolitical disruptions, and the emergence of new regional polities. Sweeping social changes accompanied these developments, including demographic reorganization and increased levels of violence. Research across the social sciences finds that violence directed at individuals perceived as categorically distinct also typically increases during such periods of socio-political upheaval. This dissertation investigates identity-based violence in the Epiclassic Basin of Mexico to consider how diverse social identities contributed to the selection of victims of ritual violence.

This research examines the skeletal remains from a sacrificial deposit at the Epiclassic shrine site of Non-Grid 4 in the Basin of Mexico, where a minimum of 180 human crania were interred as ritual offerings. The project reconstructs patterns of paleomobility and biological relatedness to determine whether individuals with distinct categorical social identities were more likely to become victims of human sacrifice. It answers the questions: (1) Were the sacrificed individuals predominantly locals who lived in the Basin of Mexico throughout their lives?; (2) Were the sacrificed individuals comprised of a single kin-group biologically continuous with pre-extant populations in the Basin of Mexico?; and (3) If victims were migrants biologically discontinuous with antecedent populations, from where in ancient Mesoamerica did they originate?

Results indicate that a majority of sacrificial victims were immigrants originating north and south of the Basin of Mexico. Biogeochemical analyses of sacrificed individuals find that 80% are non-local migrants into the Basin, suggesting that they were likely targeted for violence based on their divergent residential histories. Multi-scalar biodistance analyses of Non-Grid 4 sacrificial victims demonstrate that they represent two biologically distinct groups. There was evidence, however, for both biological continuity among victims and pre-extant central Mexican populations, as well as for migration from northern and southern Mexico. This project therefore not only improves knowledge of migration during the central Mexican Epiclassic, but also contributes to broader anthropological understandings of the social context of violence.

ACKNOWLEDGMENTS

I decided I wanted to be an archaeologist when I was seven years old. My family lived in Mexico at the time. We were on a road trip, driving up a narrow winding dirt road through dense jungle before finally arriving. Calakmul. No one was around to direct us, so we started toward a pyramid that was half-swallowed by vines and trees. We didn’t realize there were on-going excavations. I remember climbing up the tall steps like a spider monkey, all limbs and exuberance. As I advanced higher and higher, I noticed the rungs of a ladder peeking out from a small rectangular opening in the top of the pyramid. Peering over the edge and into the darkness below, my eyes struggled to make sense of what they were seeing. I was looking inside the pyramid. It was as simple as that. I was sold.

Despite having decided on a career path rather early in life, I hadn’t figured out many details beyond that. It wasn’t until taking a forensic osteology course with Jill Shapiro, a biological anthropologist at Columbia University, that things began to settle into place for me. I was captivated by the direct window into past lives that human skeletal remains provided. From the first class I took with her, Jill’s generosity and mentorship encouraged me to pursue my research interests in bioarchaeology and apply for graduate school. I would not have made it this far without her. Thank you, Jill.

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CHAPTER 1

INTRODUCTION

Human migrations can be powerful catalysts for political, economic, and social change. Here, migration is understood as a process involving the long-term movement and relocation of people across significant socio-cultural, political, or environmental boundaries (Tsuda et al., 2015). Such migrations are ubiquitous across human history (Baker & Tsuda, 2015; Cabana & Clark, 2011; Crawford & Campbell, 2012), and recent studies find evidence of evolutionary origins for the practice (B. C. Campbell & Barone, 2012). While contemporary migration occurs on a greater scope and scale than ancient migration, it remains an acceleration of the same process (Burmeister, 2000; B. C. Campbell & Crawford, 2012; Manning, 2006). As such, archaeologists have used causes and patterns evident in modern migrations as models to better recognize and understand the social dynamics of ancient population movements (Anthony, 1990; Burmeister, 2000; Cameron, 2013; Clark et al., 2019).

Studies of contemporary migrations revolve around the motivation behind and consequences of migration (Tsuda, 2011, p. 315). Motivations for past migrations, however, can be difficult to discern from the archaeological record. Archaeologists have reconstructed environmental factors, such as droughts (Dillehay, 2002; Hoggarth et al., 2017; Lachniet et al., 2012, 2017) and natural disasters (González et al., 2000; Plunket & Uruñuela, 2006; Siebe, 2000) that may have pushed individuals to emigrate from their origin communities. Such environmental factors, however, cannot be invoked as monolithic explanations of complex social reactions spurring migration processes

(Beekman, 2015, p. 79). Indeed, often patterns of cultural development and migration do not coincide with unfavorable environmental conditions (e.g., Elliott et al., 2010; Frederick & Cordova, 2018; Knudson & Torres-Rouff, 2015).

Moreover, environmental conditions are not the only factors motivating migration. Long-term studies of multi-scalar population movements suggest that social factors are among the most important in motivating individual and collective decisions to migrate from their origin communities (Hamnett, 1985). Reviews of ethnographic and ethnohistoric literature of more recent migrations indicate that factors such as social hierarchies, kinship obligations, and warfare all play an essential role in informing mobility decisions (e.g., Cameron, 2013; Schachner, 2012). Accessing these factors archaeologically, however, can be challenging given both the imprecise nature of emigration chronologies and difficulties locating migrant origin communities in the past.

In contrast, archaeology has had greater success investigating the consequences of past migrations. Resultant changes in social organization and past social dynamics in receiving communities are more readily reconstructed through the archaeological record (Anthony, 1990; Burmeister, 2000). Many studies have found that migration has both generative impacts, such as the formation of multicultural societies with expanded socioeconomic networks and the revitalization of host societies through cultural exchange, as well as disruptive impacts, such as social exclusion and factionalism, violence, and even political decline (Beekman & Christensen, 2011; J. H. Bentley, 1993; Cowgill, 2015a; Hills, 2015; Manzanilla, 2015; Van De Mieroop, 2011, pp. 127–149; Zakrzewski, 2015). These studies contradict broadly polarized characterizations of the impact of migration on receiving communities. Rather than clearly supporting oversimplified models of either total assimilation or cultural replacement, archaeological studies of migration demonstrate that migration engenders a complex social landscape where migrant enclaves, zones of cultural hybridization, and areas of local resistance may all represent responses to the same migration event (Clark, 2001).

Migration in Ancient Mesoamerica

A large body of archaeological research on ancient migrations within Mesoamerica has produced evidence of both generative and disruptive impacts (Beekman, 2019; Kelley, 2000; Manzanilla, 2005b; Ragsdale & Edgar, 2018). Migration of elites has been associated with the rise of centralized hierarchical leadership at sites across the Maya region (Price et al., 2010; Stuart, 2000; White et al., 2000; Wright, 2012). Similarly, migration is often implicated in the emergence of new forms of socio-political organization, including the urbanized multi-ethnic states of southern and central Mexico (Beekman, 2015; Feinman & Nicholas, 2013, pp. 63–64; Manzanilla, 2015; Overholtzer & De Lucia, 2016). In particular, at the central Mexican Classic period (250-600 CE) urban center of Teotihuacan, migration has been linked to the creation and maintenance of urban neighborhood districts (Manzanilla, 2015; Rattray, 1989; Smith, 2010), as well as the expansion of socioeconomic exchange networks (Nichols, 2016; Rodríguez Galicia & Valadez Azúa, 2013). Additionally, archaeologists have found evidence that migration also accompanied the spread of novel forms of material culture (Foster, 1999; Hernández & Healan, 2019; Rattray, 1966; Tozzer, 1921), hybrid art styles

(McVicker, 1985; Nagao, 1989, 2014; Turner, 2019), and religious cults (Ringle et al., 1998).

Additionally, there is evidence suggesting that migration within ancient Mesoamerica led to both increased social integration as well as exclusion. Studies of Teotihuacan residential compounds indicate that while some migrants assimilated into the city's multiethnic society (Manzanilla, 2017; White, Storey, et al., 2004), others maintained social boundaries, living in ethnic enclaves (Begun, 2013; Rattray, 1989; Spence, 1992). These patterns of multiculturalism and integration are replicated beyond Teotihuacan as well (Castañeda de la Paz, 2013; Healan & Cobean, 2019; Holt Mehta, 2018; Smith & Lind, 2005; Spence, 2005). However, iconographic and bioarchaeological evidence suggests that, in some cases, periods of increased migration also coincided with higher levels of inter-personal violence (Baird, 1989; Finegold, 2012; Morehart, 2017a; Morehart et al., 2012) and may have ultimately contributed to regional socio-political upheaval (Cowgill, 2015a; Manzanilla, 2015).

Migration in Epiclassic Central Mexico

Despite broader acknowledgement of the importance of migration within the cultural development of Mesoamerica, the role of migration within the socio-political transformation of central Mexico during the Classic (250-600 CE) to Epiclassic (600-900 CE) transition has long been debated (Cowgill, 2013). The Epiclassic period is characterized by the dramatic decline of Teotihuacan's political and economic control of the region (J. H. Anderson et al., 2016; Cowgill, 2015b; Diehl & Berlo, 1989; Healan & Cobean, 2019, p. 82), and the emergence of new competing political centers within central Mexico (García Cook, 2013; Hirth, 2000; Mendoza, 1992). Additionally, the period is marked by the proliferation of militaristic iconography (Finegold, 2012; Hirth, 1989; Koontz, 1994; McVicker, 2007; Nagao, 1989; Ringle et al., 1998), suggesting increased conflict accompanying regional political decentralization during this period.

The Epiclassic also witnessed a large influx of migrants into the region. A novel ceramic complex known as Coyotlatelco appeared in central Mexico during this time period (Crider, 2011; Rattray, 1966; Sánchez, 2013; Solar Valverde, 2006; Tozzer, 1921). Most scholars agree that Coyotlatelco ceramics represent a distinctive break with local central Mexican ceramic traditions (but see Sanders, 1986, 2006; Sugiura Yamamoto, 2006). Instead, Coyotlatelco's strong resemblance to earlier ceramic industries from elsewhere in Mexico suggested that migrants from northwestern Mexico introduced the ceramic complex to central Mexico (Beekman & Christensen, 2003; Hernández, 2016; Hernández & Healan, 2019; Rattray, 1966, 1989, 1996). Combined with the marked demographic reorganization of central Mexico during the Epiclassic (Parsons et al., 2008; Sanders et al., 1979) and shifts in regional settlement patterns from valley floor to dispersed hilltop settlements (J. H. Anderson et al., 2016; Gorenflo & Sanders, 2007; Healan & Cobean, 2019; Hirth, 2000; Mastache et al., 2002; Morehart, 2016a; Parsons et al., 2008), the prevailing consensus among archaeologists is that substantial migration into central Mexico took place during the Epiclassic period.

Bioarchaeological evidence also supports the arrival of migrants into central Mexico during the Epiclassic period. A biogeochemical analysis of Epiclassic burials from Teotihuacan directly identified three immigrants at the site (Price et al., 2000).

Further applications of biogeochemical analyses to identify Epiclassic migrants in the region, however, have been hindered by the paucity of central Mexican skeletal collections dating to the Epiclassic. Other lines of evidence, including both ancient DNA (Aguirre-Samudio et al., 2017; Álvarez-Sandoval et al., 2015; Morales-Arce et al., 2019) and biodistance analyses of phenotypic variation in skeletal and dental traits (Beekman & Christensen, 2003; Christensen, 1997; Gómez-Valdés et al., 2008; González-José et al., 2007; Meza-Peñaloza et al., 2019; Ragsdale & Edgar, 2018) find evidence of biological discontinuity between central Mexican Classic and Postclassic (900-1521 CE) populations. Although few ancient DNA or biodistance analyses examined skeletal remains dating to the Epiclassic, their results are suggestive of an Epiclassic population replacement within central Mexico.

Research Orientation

Thus, although a great deal of effort has been spent establishing the presence of migrants within Epiclassic central Mexico, relatively little research has been done on the migrants themselves (but see Manzanilla, 2005a). Who were these migrants? From where in ancient Mesoamerica did they originate? What happened to them once they arrived in central Mexico?

This dissertation complements previous research on Mesoamerican migration, using multiple lines of evidence to characterize migration at Non-Grid 4, an Epiclassic shrine site in central Mexico where a minimum of 180 individuals were ritually sacrificed and interred (Morehart et al., 2012). Previous studies of these individuals found they were biologically discontinuous with antecedent populations in central Mexico (Meza-

Peñaloza et al., 2019). Furthermore, the sacrificed individuals were not genetically homogenous, but instead represented multiple biological kinship groups (García Velasco, 2019). Here, biogeochemical analyses are used to directly identify first-generation migrants among the sacrificial assemblage, and biodistance methods are used to posit potential origin communities of identified migrants.

Furthermore, although ethnohistoric sources indicate that human sacrifice was a culturally sanctioned form of violence practiced in ancient Mesoamerica (Graulich, 2006; López Luján & Olivier, 2010; Sahagún, 1951), bioarchaeological analyses of victims of ritual violence throughout Mesoamerica indicate that they do not represent a random cross-section of the population at-large (Crandall & Thompson, 2014; De La Cruz et al., 2008; Duncan, 2011; Kieffer, 2017; Moreiras Reynaga, 2019). As such, this dissertation develops a theoretical framework to examine identity-based violence—violence perpetrated against individuals or groups who are perceived as categorically distinct. This research thus examines how individuals with particular categorical social identities were selected or targeted for violence during the Epiclassic period, examining the violent consequences of migration on the migrants themselves.

The goal of this research is to reconstruct Epiclassic central Mexican migration patterns through the analysis of paleomobility and biological relatedness at the Epiclassic ritual shrine site of Non-Grid 4. Additionally, this project examines the interplay between perceptions of social difference and ritual violence, seeking to determine whether individuals with distinct categorical social identities were more likely to become victims of human sacrifice. In the volatile geopolitical landscape of Epiclassic central Mexico, aspects of individuals' social identities—including their residential histories or biological kinship affiliations—could have acted as powerful indicators of social difference that culminated in ritual violence.

A bioarchaeological approach is particularly well suited to investigate migration and identity-based violence at Non-Grid 4. Many facets of identity are grounded in the physical body, such as age, sex, or phenotypic expressions of genetic relatedness. Other aspects of identity leave traces on the body through culturally mitigated behaviors, including dietary preferences or various forms of intentional body modifications (Buikstra & Scott, 2009; Knudson & Stojanowski, 2008, 2009). These corporeal embodiments of multivalent social identities allow for the empirical reconstruction of geographic origins and residential histories using biogeochemical analysis, as well as the characterization of biological affinities through biodistance analysis among individuals at Non-Grid 4. Furthermore, they allow for a nuanced consideration of whether particular social identities were predisposed to suffer ritual violence in Epiclassic central Mexico.

Structure of the Dissertation

This dissertation employs a bioarchaeological approach to examine migration and identity-based violence in Epiclassic central Mexico. It is organized into five chapters. The second chapter presents a biogeochemical baseline for bioavailable radiogenic strontium ($^{87}Sr/^{86}Sr$) values across central Mexico. Radiogenic strontium isotope values vary according to the age and composition of local underlying geologic bedrock (R. A. Bentley, 2006; Faure & Powell, 1972). Examining $^{87}Sr/^{86}Sr$ values in skeletal tissues mineralizing at different times over the life course allows for the reconstruction of past individuals' movements between geologically distinct zones (R. A. Bentley, 2006; Ericson, 1985; Flockhart et al., 2015). However, expected "local" $^{87}Sr/^{86}Sr$ values are essential to the successful implementation of such techniques to characterize past mobility.

While $^{87}Sr/^{86}Sr$ has been used widely in the study of paleomobility within ancient central Mexico, the majority of work in the region has focused on the site of Teotihuacan (Price et al., 2000; Solís Pichardo et al., 2017; White et al., 2007). This chapter expands $^{87}Sr/^{86}Sr$ baseline data throughout central Mexico. It presents generated (*n*=63) and previously published (*n*=16; Price et al., 2008; Schaaf et al., 2012) $^{87}Sr/^{86}Sr$ values from 13 sites across central Mexico to establish a k-means cluster model determining which regions within central Mexico can and cannot be distinguished using radiogenic strontium isotopes.

The third chapter establishes a theoretical framework within which to examine identity-based violence in the past using bioarchaeological methods. Drawing on social science research on the development of in-group preferences and out-group biases (Riek et al., 2006; Tajfel et al., 1971), as well as realistic group conflict theory from social psychology (Jackson, 1993; Sherif, 1966), and empirical data from cross-cultural anthropological, evolutionary psychology, and behavioral case studies (Böhm et al., 2016; Schmidt & Schröder, 2001; Simunovic et al., 2013), the chapter establishes a link between social group formation and identity-based violence in conditions of heightened scarcity and intergroup competition. Bioarchaeological methods are particularly adept at reconstructing multivalent past social identities, but few studies have applied such an identity-based approach to understand social targeting in acts of violence (but see Kurin, 2014, 2016).

After establishing the cultural salience of distinct geographic origins as an important signifier of social difference within pre-Hispanic central Mexico, the chapter then turns to examine the residential histories of a sample of sacrificed individuals at Non-Grid 4 (n=73). Biogeochemical analyses of radiogenic strontium ($^{87}Sr/^{86}Sr$) and stable oxygen ($\delta^{18}O$) isotopes in enamel and bone tissues are used to reconstruct sacrificial victims' residential histories and identify first-generation immigrants. Paleomobility patterns among sampled individuals are then analyzed to discern if and how identity-based violence affected individuals interred at the site.

The fourth chapter examines patterns of biological affinity at Non-Grid 4 and greater Mesoamerica during the Classic-Epiclassic transition. It reviews previous archaeological and bioarchaeological models of Epiclassic migrations into central Mexico to establish testable models and expectations for the subsequent analyses. The chapter investigates patterns of biological affinity (1) among Non-Grid 4 individuals, as well as (2) between Non-Grid 4 individuals and antecedent central Mexican populations, and more broadly (3) between Non-Grid 4 individuals and other Epiclassic populations throughout Mesoamerica.

Multi-scalar biodistance analyses are used to characterize biological diversity at Non-Grid 4 and Epiclassic central Mexico and locate potential origin communities for Epiclassic migrants. Finite mixture analysis (McLachlan & Peel, 2000) of cervicometric tooth dimensions is used to characterize patterns of biological variability among Non-

Grid 4 individuals (*n*=115). Relationship (R) matrix analysis (Relethford et al., 1997; Relethford & Blangero, 1990) is then used to compare Non-Grid 4 individuals with a broader skeletal sample of individuals from across Classic and Epiclassic Mesoamerica (*n*=218) to evaluate archaeological models of biological continuity and population replacement within Epiclassic central Mexico.

The final chapter presents a summary of the dissertation and its conclusions. It evaluates whether the dissertation successfully achieved its stated aims of reconstructing migration patterns among the individuals interred at Non-Grid 4 and examining the impact of that migration on the migrants themselves using an identity-based violence framework. The dissertation closes with a consideration of how future research can contribute to increasingly nuanced research into both the causes and consequences of migration as well as identity-based violence in the past.

CHAPTER 2

EXPANDING RADIOGENIC STRONTIUM ISOTOPE BASELINE DATA FOR CENTRAL MEXICAN PALEOMOBILITY STUDIES

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Researchers have long debated the importance of migration in the cultural development of central Mexico. A number of archaeological (Beekman & Christensen, 2003; Begun, 2013; Millon, 1973; Spence, 1992), morphological (Christensen, 1997; González-José et al., 2007; Meza-Peñaloza et al., 2019; Ragsdale, 2017; Ragsdale & Edgar, 2018), and genetic (Aguirre-Samudio et al., 2017; Kemp et al., 2005), analyses indicate that the Basin of Mexico attracted multiple waves of migrants from across greater Mesoamerica throughout pre-Hispanic times. Biogeochemical studies of radiogenic strontium ($^{87}Sr/^{86}Sr$) isotopes have proven effective in directly testing the presence of migrants within the Basin, particularly at the Classic period city of Teotihuacan (Manzanilla et al., 2012; Nado, 2017; Price et al., 2000; Schaaf et al., 2012; Solís Pichardo et al., 2017; White et al., 2007). While determining "local" ranges of variation in $^{87}Sr/^{86}Sr$ values is essential for the further application of this method, central Mexican radiogenic strontium data outside of Teotihuacan remain limited. Price and colleagues (Price et al., 2008) established a regional expected $^{87}Sr/^{86}Sr$ range for the Basin of Mexico as a whole, but no studies examine $^{87}Sr/^{86}Sr$ variability within the Basin or central Mexico.

This study investigates radiogenic strontium variability within the Basin of Mexico and greater central Mexico, further facilitating paleomobility studies within the region. I first discuss the use of strontium isotopes in paleomobility within Mesoamerica and beyond and then consider geologic expectations for $^{87}Sr/^{86}Sr$ values within central Mexico and the Basin of Mexico. Finally, I present biogeochemical data on modern plant and water samples (*n*=63), analyzing them alongside published data (*n*=16; Price et al., 2000; Schaaf et al., 2012) to characterize biogeochemically distinguishable zones within the Basin of Mexico and central Mexico.

Strontium isotopes in studies of paleomobility

Radiogenic strontium isotopes are one of several isotopic systems that have been used to characterize paleomobility (Ehleringer et al., 2008; Ericson, 1985; Gulson et al., 1997; Luz et al., 1984; Schwarcz et al., 1991). $^{87}Sr/^{86}Sr$ values reflect regional geologic variability (Faure & Powell, 1972). Biologically available strontium present in soil and groundwater is incorporated into local plants and subsequently into hydroxyapatite, the hard tissues (including bone and enamel) of animals ingesting that vegetation (Blum et al., 2000; Flockhart et al., 2015; Sealy et al., 1991; Turekian & Kulp, 1956). By comparing the strontium isotopic values in human and animal hard tissues mineralizing at different times over the life course, bioarchaeologists can reconstruct prehistoric patterns of mobility between distinct geologic zones over the life course (Ericson, 1985; Knudson et al., 2016; Price et al., 1994, 2000; Sealy et al., 1995).

Strontium isotope systematics

Strontium is an alkaline earth metal typically found in rock, water, soil, plants, and animals at the parts-per-million (ppm) level (Faure, 1998; Faure & Powell, 1972). Of the four naturally occurring strontium isotopes, ^{87}Sr is radiogenic and is produced by the slow radioactive decay of rubidium (^{87}Rb). Thus, the abundance of ^{87}Sr in a given region varies by the age and composition of local bedrock minerals (Faure, 1998; Faure & Powell, 1972). Geologically older igneous and granitic formations rich in parent ^{87}Rb are enriched in ^{87}Sr (^{87}Sr/^{86}Sr > 0.750) compared to geologically younger volcanic basalts, rhyolites, or andesites (^{87}Sr/^{86}Sr ≈ 0.702–0.704), while marine carbonates and metamorphic formations often have intermediate values (R. A. Bentley, 2006; Faure & Powell, 1972; Sillen & Sealy, 1989). There is a large range of variation in comparison to the instrumental error of mass spectrometer measurements, which can generate accurate measurements up to the fourth decimal place or better (± 0.00001) (R. A. Bentley, 2006; Knudson et al., 2016). As such, geologic maps of bedrock types and ages can be used to predict expected ^{87}Sr/^{86}Sr variation.

Predictions based solely on geologic maps of bedrock types, however, are not always accurate. A number of factors, including the modification of source rock by erosion and preferential weathering of mineral with more radiogenic signatures, the addition of material from wind-derived material, and sea spray, can be mixed to produce different bioavailable strontium ratios that ultimately end up incorporated in hydroxyapatite (R. A. Bentley, 2006; Burton & Price, 2002; Reynolds et al., 2012). Thus, researchers have undertaken strontium isotope studies of local water sources, soils, plants, and animal bones to more accurately characterize bioavailable strontium variability in a given environment (R. A. Bentley et al., 2004; Evans & Tatham, 2004; Flockhart et al., 2015; Hodell et al., 2004; Knudson, Webb, et al., 2014; Pestle et al., 2013; Price et al., 2002; Wright, 2005).

Strontium isotopes and paleomobility across Mesoamerica

Studies using $^{87}Sr/^{86}Sr$ isotopes to reconstruct paleomobility throughout Mesoamerica have increased dramatically in recent years as archaeologists seek to directly test models of ancient migration, diaspora, and mobility within the region (Spence & White, 2010). Researchers have used radiogenic strontium isotopes to reconstruct ancient migration patterns (K. A. Miller, 2015; Miller Wolf & Freiwald, 2018; Price et al., 2000, 2014, 2015; Solís Pichardo et al., 2017; Wright, 2005, 2012; Wrobel et al., 2017), the geographic origins of sacrificial victims (Price et al., 2007; White et al., 2007), and past animal trade and management networks (Sharpe et al., 2018; Thornton, 2011), as well as long distance material culture trade networks (Thibodeau et al., 2018) and historic diasporas (Price et al., 2006, 2012).

Other studies have focused on characterizing $^{87}Sr/^{86}Sr$ variability across Mesoamerica. Hodell and colleagues (2004) carried out an extensive study of radiogenic strontium variability across the Maya region of southern Mexico, Belize, and Guatemala to identify isotopically distinct sub-regions. Similarly, Price and colleagues (2008) analyzed $^{87}Sr/^{86}Sr$ ranges more broadly across Mesoamerica. While they report a local range of $^{87}Sr/^{86}Sr = 0.7046\text{-}0.7051$ for the Basin of Mexico, little published data exist examining variability within central Mexico and the Basin itself.

Central Mexican geography, geology, and geochemistry

Understanding regional geology is essential to the study of variability in radiogenic strontium isotope values within central Mexico, which is defined here as including the modern Mexican states of Mexico State, Hidalgo, Puebla, Tlaxcala, and

Morelos, as well as Mexico City. Geologists have divided Mexico into several geologically and physiographically distinct morphotectonic provinces (Fig 1). However, only three morphotectonic provinces—the Sierra Madre Oriental, Mexican Volcanic Belt, and Sierra Madre Sur—make up central Mexico.

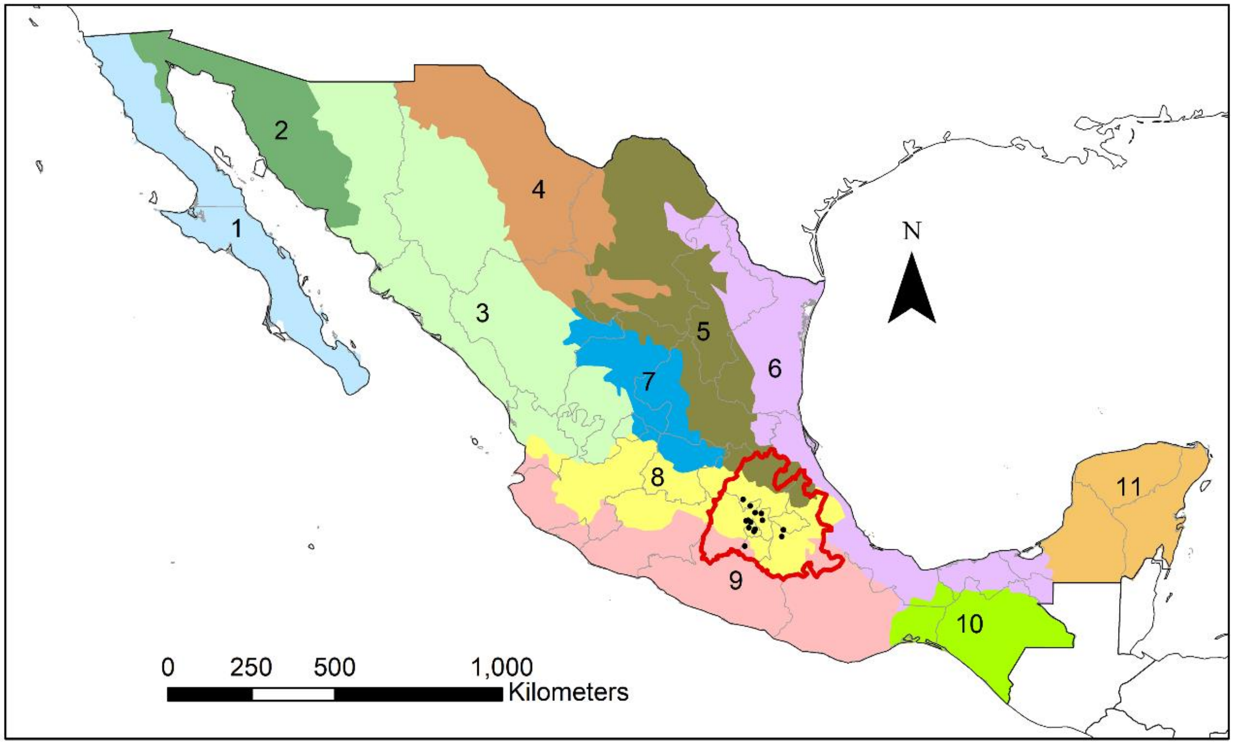

Figure 1. Morphotectonic provinces of Mexico. Central Mexico is outlined in red and is made up by parts of the Sierra Madre Oriental (5), the Mexican Volcanic Belt (8), and the Sierra Madre del Sur (9) morphotectonic provinces. Other morphotectonic provinces include Baja California Peninsula (1), the Northwestern Plains and Sierras (2), the Sierra Madre Occidental (3), the Chihuahua-Coahuila Plateaus and Ranges (4), the Gulf Coast Plain (6), the Central Plateau (7), the Sierra Madre de Chiapas (10), and the Yucatán Platform (11). Sites included in the study are indicated by black dots. Map created with free vector and raster map data (*Natural Earth*, n.d.). Morphotectonic data adapted from the Mexican Geological Service (Servicio Geológico Mexicano, 2007).

The geology of central Mexico is a complex mixture of recent volcanic highlands and older marine sedimentary deposits, along with a variety of metamorphic rocks (de Cserna, 1989; Ferrusquía-Villafranca, 1993; Morán-Zenteno, 1994). The northern portion of central Mexico is comprised of the Sierra Madre Oriental mountain range. The Sierra Madre Oriental is primarily made up of orogenic Mesozoic Jurassic and Cretaceous sedimentary carbonates, sandstones, and shales of marine origin with some metamorphic Precambrian and Paleozoic gneiss and schist outcrops (Morán-Zenteno, 1994; Ohmoto et al., 1966). Immediately to the south and forming the heart of central Mexico is the Mexican Volcanic Belt, which extends from the Pacific to Gulf coasts. The Mexican Volcanic Belt is a Cenozoic volcanic plateau with central basaltic andesites forming during the late Miocene and early Pliocene and younger southern andesites, dacites, and rhyolites forming more recently during the Quaternary (de Cserna, 1989; Demant, 1981; Moorbath et al., 1978; Mooser, 1975; Morán-Zenteno, 1994).

Finally, the southern edge of central Mexico is defined by the Sierra Madre del Sur mountain range. The Sierra Madre del Sur is the most geologically complex morphotectonic province in Mexico, composed of a northern segment of Mesozoic Jurassic and Cretaceous sediments and volcanic rock outcrops partially covered by Cenozoic volcanic and sedimentary rocks, a southern segment of Paleozoic and Mesozoic metamorphic rock outcrops and intrusive Mesozoic and Cenozoic batholiths, and a coastal Pacific area of andesitic Mesozoic Jurassic and Cretaceous volcanic-sedimentary rocks (Ferrusquía-Villafranca, 1993; Morán-Zenteno, 1994).

The Basin of Mexico in geological context

The Basin of Mexico, the primary region of interest in this study, is situated in the central-eastern part of the Mexican Volcanic Belt. It is a late Tertiary and Quaternary graben basin characterized by basaltic and andesitic volcanism with single rhyolite cones, featuring some of the most complex volcanic geology of Mexico (Mooser, 1975; Morán-Zenteno, 1994; Torres-Alvarado et al., 2000; Vázquez-Sánchez & Jaimes-Palomera, 1989). The Basin is enclosed by several mountain ranges, including the Sierra de Tepotzotlán and the Sierra de Pachuca to the north, the Sierra de Río Frío and the Sierra Nevada to the east, the Sierra de Chichinautzin to the south, and the Sierra del Ajusco and Sierra de las Cruces to the west.

While the underlying bedrock geology is likely the dominant contribution to the radiogenic strontium isotope composition of the piedmont and mountains of the Basin of Mexico, the alluvial plain represents a large catchment area for weathered minerals deposited by rivers and streams flowing into the Basin lakes. At high elevations, which tend to have high weathering rates, bioavailable $^{87}Sr/^{86}Sr$ and bedrock $^{87}Sr/^{86}Sr$ values are more often closely correlated (Aubert et al., 2002; Hoogewerff et al., 2001). At lower elevations, however, correlations between underlying bedrock and river content are less clear, as rivers carry suspended loads of upstream rocks and solids as well as precipitation, all of which could contribute geologically distinct strontium values to alluvial deposits (Hodell et al., 2004; Price et al., 2002; Tricca et al., 1999). This suggests that soils in the Basin of Mexico's alluvial plain may vary considerably in strontium isotope values and will likely average source materials. Thus, though the geology of the

Basin of Mexico provides starting expectations for ranges of radiogenic strontium variability, it is necessary to generate expected "local" ranges of bioavailable strontium values within the region to gain a more comprehensive understanding of variability within and beyond the Basin of Mexico.

Materials and Methods

Modern plant and water samples provide an excellent means of characterizing the bioavailable strontium within ecosystems. While soil $^{87}Sr/^{86}Sr$ values in a given geologic zone may vary greatly due to the distinct strontium concentrations and weathering profiles of minerals in the underlying bedrock (R. A. Bentley, 2006; Dasch, 1969), only a proportion of soil strontium is available to plants. As such, plant $^{87}Sr/^{86}Sr$ values provide a consistent average of local bioavailable strontium within a given ecosystem (Budd et al., 2000). Similarly, the majority of strontium in water sources is carried as dissolved or suspended sediment and primarily represents bioavailable strontium from rocks undergoing erosion within an ecosystem (Aubert et al., 2002; R. A. Bentley, 2006; Négrel et al., 2003; Palmer & Edmond, 1992; Price et al., 2002; Tricca et al., 1999).

Plant and water samples were collected between December 2015 and June 2017 from a total of 13 archaeological and agricultural sites from distinct ecological zones throughout the Basin of Mexico and greater central Mexico ($n = 63$). Universal Transverse Mercator (UTM) coordinate and elevation data for each sample were collected using a hand-held GPS unit. Plant samples were only collected if it was clear that they had not been treated with fertilizers or irrigation water, as these could skew signatures of local bioavailable strontium with non-local sources of strontium.

Furthermore, plants of varied rooting depths were sampled opportunistically. Plants with shallow rooting depths in topsoil (<1 m deep), such as grasses and many herbaceous plants, tend to exhibit $^{87}Sr/^{86}Sr$ values closer to atmospheric dust. In contrast, plants with deeper rooting depths, including many species of tree, exhibit $^{87}Sr/^{86}Sr$ values derived from local bedrock in addition to atmospheric sources (Reynolds et al., 2012). Including both of these sources allows for the more accurate characterization of bioavailable strontium in local ecosystems (Grimstead et al., 2017). Similarly, water samples were only collected from uncontaminated springs that would likely have been used by ancient inhabitants of the region (Buzon et al., 2011; Knudson, 2009). The Mexican Instituto Nacional de Antropología e Historia (INAH) does not require specific permissions to collect water or modern plant samples from the study sites. Furthermore, no endangered or protected plant species were involved in the study. Samples were imported to the Arizona State University Archaeological Chemistry Laboratory under permits granted to Pacheco-Forés from the United States Department of Agriculture Animal and Plant Health Inspection Service (PCIP-17-00469).

Additionally, published central Mexican $^{87}Sr/^{86}Sr$ values generated by Price and colleagues (2000) and Schaaf and colleagues (2012) were included in the study dataset (n = 16). Non-human baseline samples such as soils, plants, or faunal materials (Price et al., 2002) were incorporated. Data from published whole rock samples were not included, as these $^{87}Sr/^{86}Sr$ values were likely not bioavailable within the ecosystem. Finally, published data were included only if their provenience could be confirmed via GPS to provide reasonably accurate UTM coordinate and elevation data.

Biogeochemical methods

All samples were prepared at the Arizona State University Archaeological Chemistry Laboratory. Water samples were filtered (2.5μm diameter) and acidified to 5% HCl to prevent precipitates from forming, adsorbtion to bottle walls, and discourage bacterial and algal growth. When possible, pre-Hispanic diets were simulated through the manual isolation and analysis of edible components (e.g., seeds, berries, leaves) of dried plants (Runia, 1987). Plant samples were rinsed with 18.2 MΩ Millipore water to remove adhering dirt and were ashed in a furnace for approximately 10 hours at 800° C. Approximately 25.0 mg of ashed sample was digested in 2 mL of concentrated nitric and hydrochloric acid (HNO3 + 3HCl) at approximately 50° C for 24 hours. This aggressive leach does not break down the silica tetrahedra structure of most silicate minerals, leaving much of the soil in a solid form while prioritizing the release of bioavailable strontium within plants. Leach solution was evaporated, and sample precipitates were redissolved in concentrated nitric acid and diluted to a 2 M stock solution.

Dissolved samples were analyzed at the Metals, Environmental, and Terrestrial Analytical Laboratory at Arizona State University. An aliquot was taken for elemental concentration by a Thermo Fisher Scientific iCAP quadrupole inductively coupled plasma mass spectrometer (Q-ICP-MS). Strontium was then separated with a PrepFAST, an automated low-pressure ion exchange chromatography system (Romaniello et al., 2015). Strontium was isolated from the sample matrix using Elemental Scientific, Inc. supplied Sr-Ca ion exchange resin (Part CF-MC-SrCa-1000) and ultrapure 5 M nitric acid (HNO3). Each strontium cut from the PrepFAST was dried down in a Teflon beaker and digested with concentration nitric acid and 30% hydrogen peroxide to remove organics from the resin. Once digested, samples were again dried down and reconstituted with 0.32 M nitric acid. Using concentration information from the Q-ICP-MS, the samples were diluted with 0.32 M nitric acid to a calculated constant concentration of 50 ppb Sr. Radiogenic strontium isotope ratios were measured on a Thermo-Finnigan Neptune multi-collector inductively coupled plasma mass spectrometer (MC-ICP-MS). The MC-ICP-MS has nine Faraday cups capable of simultaneous ion beam measurement, and this instrument was configured with an Elemental Scientific, Inc., Apex Q high sensitivity sample introduction system with an Elemental Scientific, Inc. 50 or 100 μL/minute PFA-ST microflow nebulizer. This instrument has seven 1011 amplifiers and three 1012 amplifiers which can be designated for any of the Faraday cups.

Data was collected by measuring 60 simultaneous ratios integrating 4.194 seconds each. Samples were corrected for on-peak blanks, and in-line correction of the contributions of ^{84}Kr on ^{84}Sr and ^{86}Kr on ^{86}Sr using ^{83}Kr/^{84}Kr ratio of 0.201750 and ^{83}Kr/^{86}Kr ratio of 0.664533, after instrumental mass bias correction using a normalizing ^{88}Sr/^{86}Sr ratio of 8.375209. Samples were analyzed in three different analytical sessions. Typical sensitivity was >10 V on ^{88}Sr with a 50 ppb Sr solution, with ^{83}Kr values <0.0001 V. ^{85}Rb voltages for samples were typically <0.004 V due to the low Rb/Sr initial ratios of the samples and effective chemical purification, but all data was interference-corrected using a ^{85}Rb/^{87}Rb ratio of 2.588960, normalized to ^{88}Sr/^{86}Sr as above. Ratio outliers two standard deviations outside the mean were removed using a Matlab 2D-mathematical correction routine written by Dr. Stephen Romaniello, now at

University of Tennessee. Typical internal ^{87}Sr/^{86}Sr two standard error (SE) precision was ~1e-6.

Sequences included bracketing concentration-matched SRM 987 standards. SRM 987 was run as a bracketing standard with a measured value of ^{87}Sr/^{86}Sr = 0.710252 ±0.000026 (2σ, *n* = 89). Each analytical session included a sequence incorporating SRM 987 standard in a range of variable concentrations to verify the accuracy of ^{87}Sr/^{86}Sr values for samples; reported values are all above the threshold for accurate ^{87}Sr/^{86}Sr values within the range of error of the bracketing standards. In addition, SRM 987 doped with calcium up to a ratio of Ca/Sr of 500 was run to simulate the accuracy and precision of isotope ratios in poorly purified samples with low yields. SRM 987 run at 50% concentration doped to a Ca/Sr of 500 was run as a check standard with a measured value of ^{87}Sr/^{86}Sr = 0.710253 ± 0.000025 (2σ, *n* = 15). IAPSO seawater (Ocean Scientific International Ltd., Havant, UK) as a secondary check standard had a measured value of 0.709182 ±0.000010 (2σ, *n* = 11), within error of the published value of 0.709182 ±0.000004 (Ma et al., 2013). NIST 1400 purified in parallel with samples had a measured value of 0.713124 ± 0.000023 (2σ, *n* = 12), similar to the published value of 0.713150 ±0.0000160 (Galler et al., 2007).

Analytical methods

K-means cluster analysis was used to sort observed and published ^{87}Sr/^{86}Sr, UTM, and elevation data into groups in R using the cluster and ggplot2 packages (Maechler et al., 2017; R Core Team, 2016; Wickham, 2009). K-means cluster analysis is a divisive iterative non-hierarchical pure locational clustering method (Kintigh, 1990; Kintigh &

Ammerman, 1982) that has been applied to the analysis of analysis of bioavailable $^{87}Sr/^{86}Sr$ isotopes (Hodell et al., 2004). Clusters were defined based on Euclidean distances to minimize the sum of squares error (SSE), thus minimizing variability within clusters while maximizing variability between clusters. A randomization procedure assessing changes in the global SSE for different cluster levels was conducted. A cluster solution was selected by comparing the difference in SSE in the original data to the mean SSE of 1,000 randomized iterations of the data.

Results and Discussion

Appendix B reports observed and published $^{87}Sr/^{86}Sr$ values of water, plant, faunal, and soil samples included the study$^{87}Sr/^{86}Sr$ values varied from 0.70432 to 0.70641. Among plant samples, opportunistically sampled non-native and non-edible plants did not provide significantly different values from native edible plants simulating pre-Hispanic diets (Fig 2).

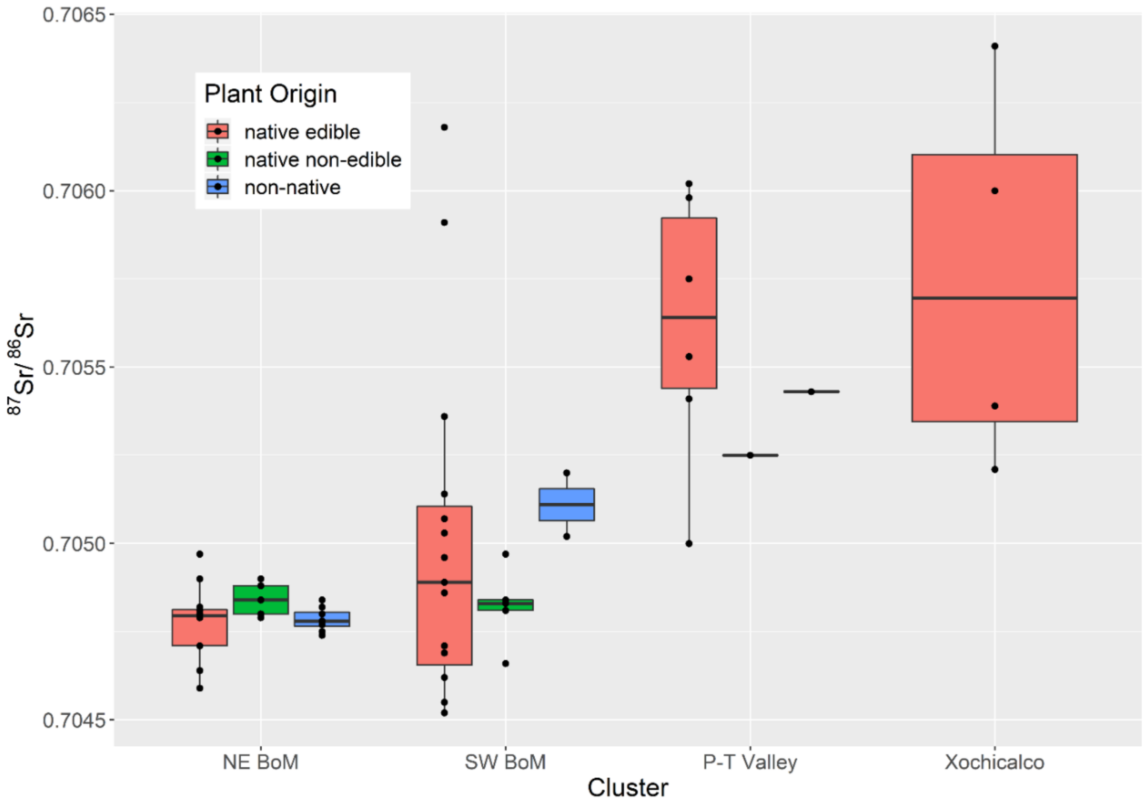

Figure 2. Cluster ^{87}Sr/^{86}Sr values in plant samples by plant origin. There were no significant differences between edible native plants and non-edible native plants or non-native plants. While non-edible native and non-native plants would not have contributed to past human and animal bioavailable ^{87}Sr/^{86}Sr values, they are included in this study to further characterize bioavailable strontium values in local ecosystems.

The randomization procedure indicates a five-cluster solution represents the greatest departure in the global SSE from randomness. The data are not normally distributed. Medians and interquartile ranges are therefore used to characterize ^{87}Sr/^{86}Sr variability within each cluster, following Price and colleagues (2008) (Table 1, Figs 3-4). In cases where sites or clusters have fewer than three samples, simple ranges are provided in lieu of interquartile ranges.

Table 1. $^{87}Sr/^{86}Sr$ medians and interquartile ranges for central Mexican subregions identified through k-means cluster analysis.

Cluster	Geographic Subregion	Median $^{87}Sr/^{86}Sr$	Interquartile $^{87}Sr/^{86}Sr$ Range	*n*
1	North of the Basin of Mexico	0.70469	0.70466 - 0.70488	7
2	Basin of Mexico Northeast	0.70476	0.70464 - 0.70481	38
3	Basin of Mexico Southwest	0.70488	0.70470 - 0.70506	22
4	Puebla-Tlaxcala Valley	0.70548	0.70537 - 0.70581	8
5	Xochicalco	0.70570	0.70535 - 0.70610	4

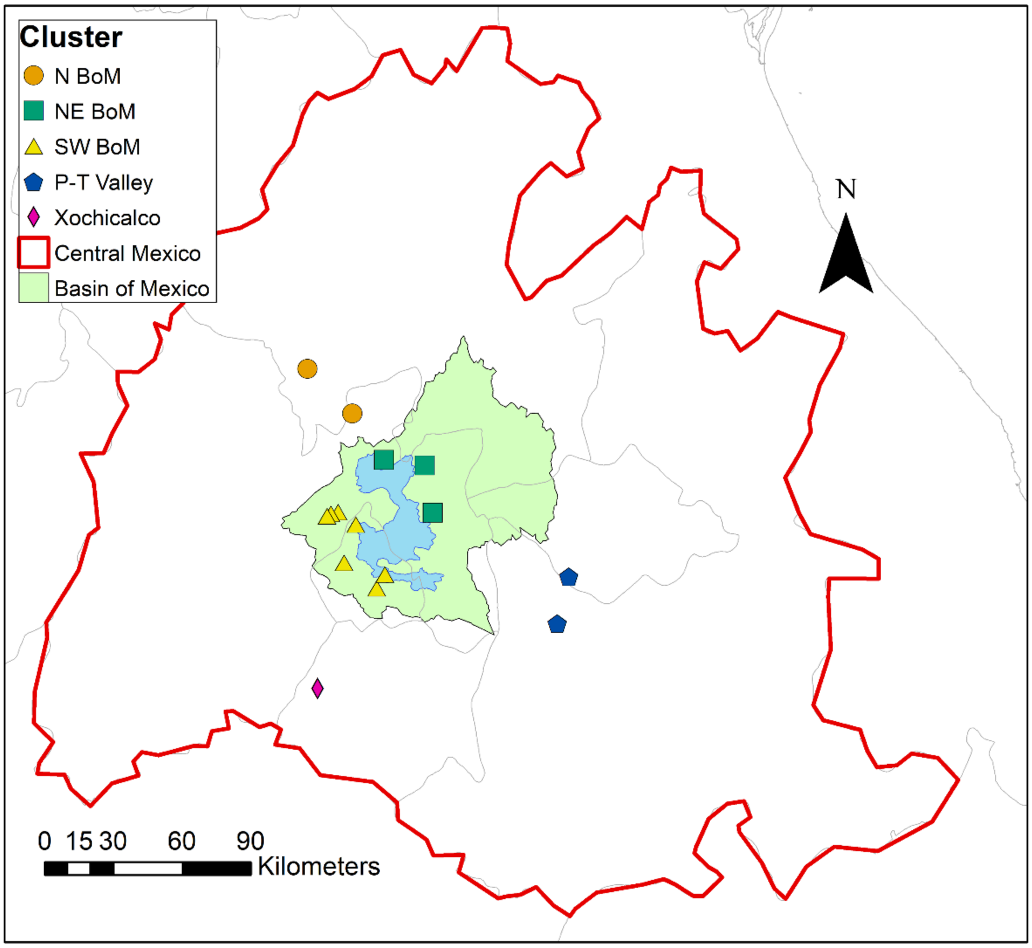

Figure 3. Sampled sites within central Mexico sorted by cluster membership. The Basin of Mexico is highlighted in green, and the extinct highland lake system is shown in blue. Map created with free vector and raster map data (*Natural Earth*, n.d.).

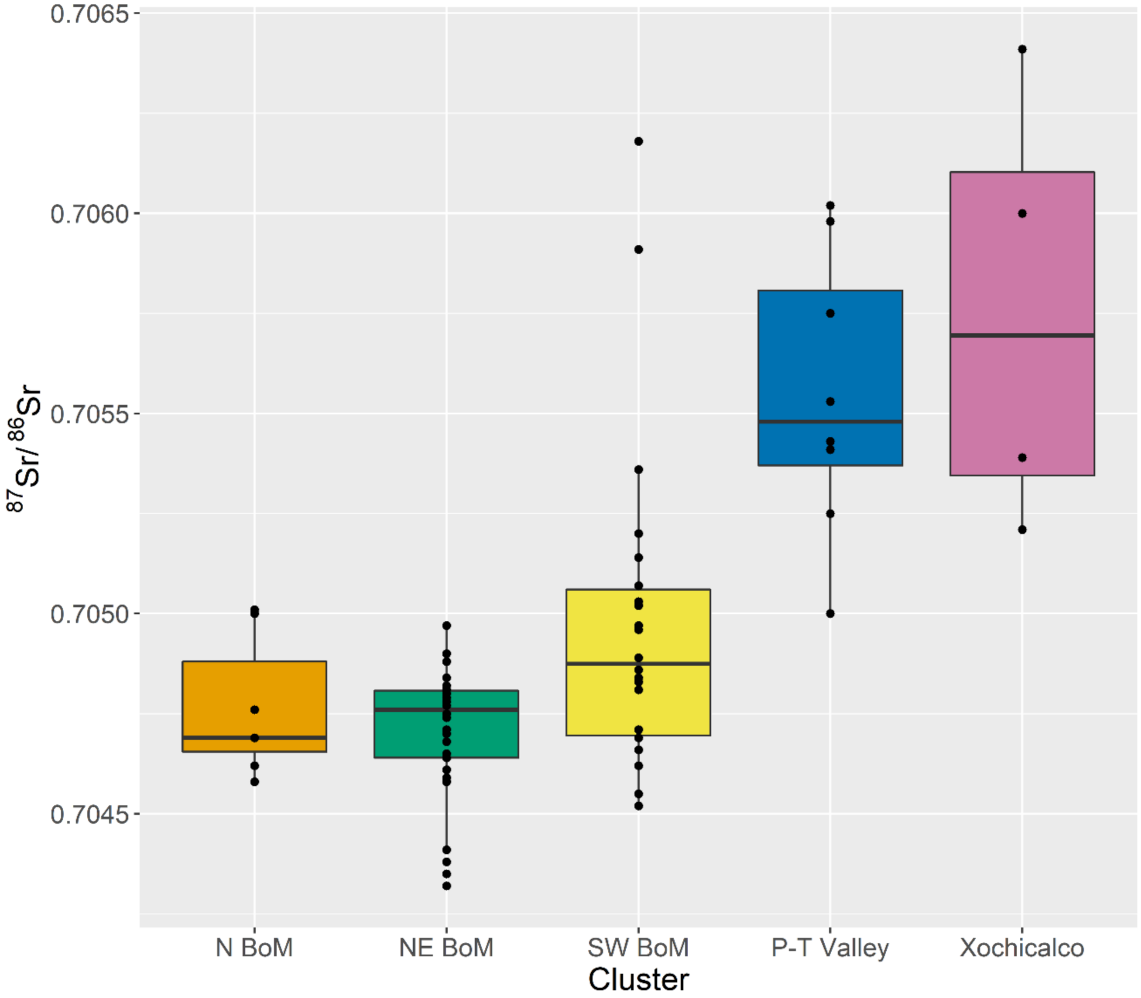

Figure 4. Medians and interquartile ranges of each clustered subregion. Data points are superimposed individual. BoM = Basin of Mexico, P-T = Puebla-Tlaxcala.

Each of the five clusters form culturally meaningful geographically distinct subregions within central Mexico (Fig 4). Cluster 1 is made up of two sites north of the Basin of Mexico. The Basin of Mexico itself is divided into two clusters, Cluster 2 which comprises the northeast of the Basin (three sites), and Cluster 3 which makes up the southwest of the Basin (seven sites). Cluster 4 is comprised of two sites in the Puebla-Tlaxcala Valley, and Cluster 5 is made up of the site of Xochicalco, south of the Basin of Mexico. Overall, cluster $^{87}Sr/^{86}Sr$ ranges conform to geologic expectations. The Basin of

Mexico clusters have the lowest $^{87}Sr/^{86}Sr$ values, reflecting the Basin's origins in Cenozoic volcanism (Servicio Geológico Mexicano, 2009; Vázquez-Sánchez & Jaimes-Palomera, 1989). In contrast, the Xochicalco cluster has the highest $^{87}Sr/^{86}Sr$ values, indicating the region's Mesozoic origins (Fries, Jr., 1958; Servicio Geológico Mexicano, 2009), although the intra-region variability is poorly constrained given the number of data points (n = 4). Finally, the Puebla-Tlaxcala Valley cluster has intermediate values consistent with the region's Mesozoic platforms overlain by Cenozoic volcanic rocks (Servicio Geológico Mexicano, 2008).

While the five-cluster model divides the Basin into two distinct groups, it is notable that there is significant overlap in $^{87}Sr/^{86}Sr$ values between Basin clusters, as well as with $^{87}Sr/^{86}Sr$ values in the cluster north of the Basin (Fig 4). Interestingly, $^{87}Sr/^{86}Sr$ values of the southwest Basin of Mexico cluster are most variable within the Basin of Mexico. This may reflect the greater diversity in age of the geologic substrate, as the southwestern Basin is made up by some of the oldest and youngest geologic formations in the Basin, including the Xochitepec Formation (Oligocene, 33.9-23.0 Ma) and the Chichinautzin mountain range (Quaternary, 2.6 Ma-present). Despite overlapping ranges among Basin of Mexico clusters, $^{87}Sr/^{86}Sr$ interquartile ranges indicate that sites in the Basin of Mexico are readily distinguishable from those in the Puebla-Tlaxcala Valley to the east, as well as Xochicalco to the south. Radiogenic strontium isotopes can thus be used to address questions of paleomobility at the regional level within central Mexico.

The generated Basin of Mexico interquartile range is consistent with previously published ranges. The two Basin of Mexico clusters (2-3) have a combined interquartile range of $^{87}Sr/^{86}Sr$ = 0.70465-0.70487 (*n* = 60). While this range is consistent with the $^{87}Sr/^{86}Sr$ = 0.7046-0.7051 (*n* = 86) published by Price and colleagues (2008), examination of site-specific $^{87}Sr/^{86}Sr$ interquartile ranges indicates that this local range belies a great deal of variability within the Basin. Many sites in Basin of Mexico clusters can still be distinguished using radiogenic strontium analysis (Fig 5, Table 2). Furthermore, with a few notable exceptions, including Teotihuacan in the northeast Basin cluster and Cuicuilco and Tezozomoc in the southwest Basin cluster, all site-specific $^{87}Sr/^{86}Sr$ “local” ranges are narrower than the $^{87}Sr/^{86}Sr$ ranges of their assigned clusters. This suggests that while the k-means cluster analysis is useful on a larger scale for isotopically distinguishing the Basin of Mexico from surrounding regions within central Mexico, it does not perform well dividing the Basin itself into isotopically distinct subregions.

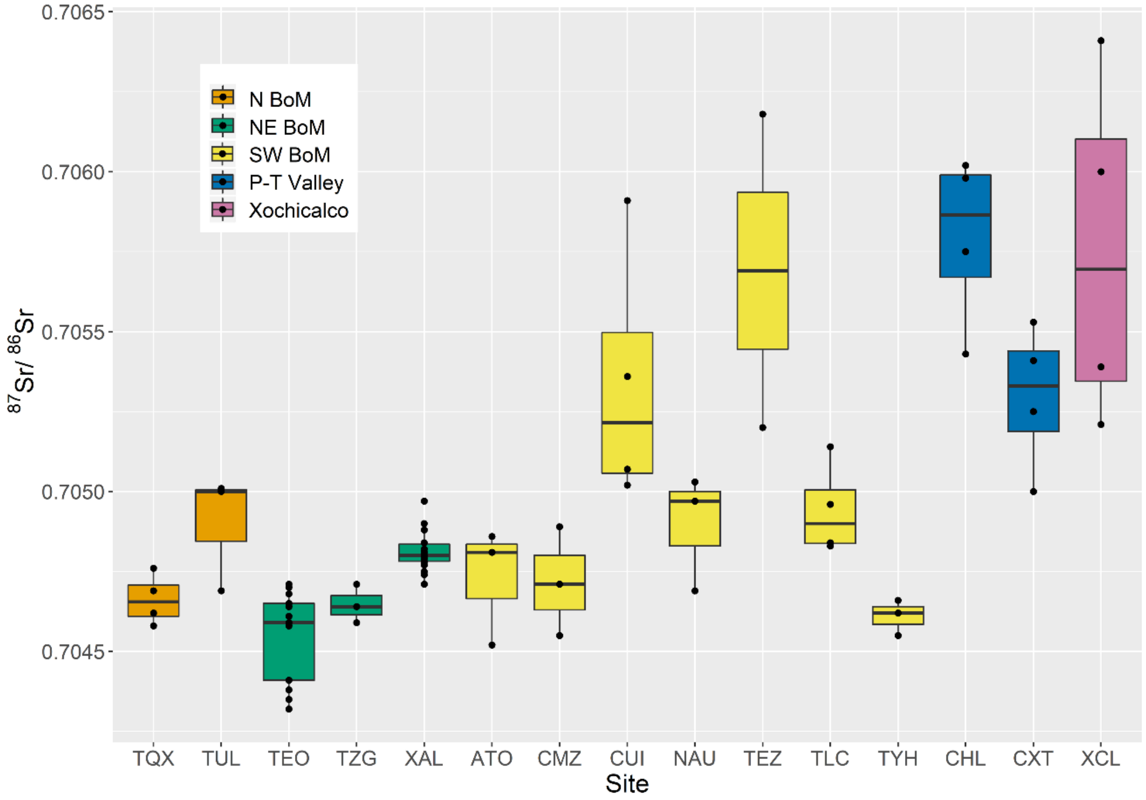

Figure 5. ^{87}Sr/^{86}Sr interquartile ranges of central Mexican sites, shaded by cluster. Individual data points are overlain. TQX = Tequixquiac, TUL = Tula, TEO = Teotihuacan, TZG = Texcotzingo, XAL = Xaltocan, ATO = San Pedro Atocpan, CMZ = Cerro Moctezuma, CUI = Cuicuilco, NAU = Naucalli, TEZ = Tezozomoc, TLC = Tlatelolco, THY = Santiago Tulyehualco, CHL = Cholula, CXT = Cacaxtla, XCL = Xochicalco.

Table 2. Central Mexican site-level $^{87}Sr/^{86}Sr$ medians and interquartile ranges.

Cluster	Site	Median $^{87}Sr/^{86}Sr$	Interquartile $^{87}Sr/^{86}Sr$ Range		*n*
1	TQX	0.70466	0.70461 -	0.70471	4
1	TUL[a]	0.70500	0.70485 -	0.70501	3
2	TEO[a,b]	0.70459	0.70441 -	0.70465	13
2	TZG	0.70464	0.70462 -	0.70468	3
2	XAL	0.70480	0.70478 -	0.70484	22
3	ATO	0.70481	0.70467 -	0.70484	3
3	CMZ	0.70471	0.70463 -	0.70480	3
3	CUI	0.70522	0.70506-	0.70550	4
3	NAU	0.70497	0.70483 -	0.70500	3
3	TEZ[c]	0.70569	0.70520 -	0.70618	2
3	TLC	0.70490	0.70484 -	0.70501	4
3	TYH	0.70462	0.70459 -	0.70464	3
4	CHL	0.70587	0.70567 -	0.70599	4
4	CXT	0.70533	0.70519 -	0.70544	4
5	XCL	0.70570	0.70535 -	0.70610	4

[a] From data on bulk soil samples published in Schaaf et al. (2012)

[b] From data on faunal remains published in Price et al. (2000)

[c] Only two samples were analyzed from Tezozomoc, so a simple range is presented rather than an interquartile range.

In the context of paleomobility studies, the use of cluster (Table 1) or site-specific (Table 2) $^{87}Sr/^{86}Sr$ interquartile ranges as a "local" bioavailable baseline should be determined by the scale of the research question. For example, if a study seeks to identify individuals who migrated into the Basin of Mexico from greater central Mexico and beyond, using cluster "local" $^{87}Sr/^{86}Sr$ ranges provides a robust mechanism for establishing individuals as non-locals within the Basin of Mexico. If, however, a study seeks to identify an individual's residential mobility within the Basin of Mexico, using site-specific "local" $^{87}Sr/^{86}Sr$ ranges will provide a higher resolution analysis. With all such analyses, it is important to keep in mind that $^{87}Sr/^{86}Sr$ values are not unique and may mask the presence of non-locals if these individuals were from a region with similar

^{87}Sr/^{86}Sr values. For this reason, the use of multiple lines of evidence and isotopic systems is essential (Knudson & Price, 2007; Price et al., 2007; White et al., 2007).

Conclusion

Analysis of presented and published bioavailable radiogenic strontium isotope ratios from central Mexico indicates that the Basin of Mexico can be distinguished isotopically from neighboring central Mexican regions. Furthermore, many sites within the Basin of Mexico itself can be distinguished from each other using radiogenic strontium isotopes, despite some overlap in ^{87}Sr/^{86}Sr cluster expected local ranges. This indicates that radiogenic strontium isotopes remain a powerful tool for examining paleomobility within central Mexico, particularly if used in concert with other isotopic systems, such as oxygen (δ^{18}O) (Moreiras Reynaga, 2019).

Expanding knowledge of radiogenic strontium isotope variability within central Mexico is essential for future paleomobility work in the region, particularly given the hypothesized importance of migration in the cultural development of the region (Beekman & Christensen, 2003; Cowgill, 2015a). Future work will focus on augmenting the baseline data presented here with samples from additional sites throughout greater central Mexico. These data will be stored in an open-access comprehensive database of strontium isotopes throughout central Mexico with the ultimate goal of developing an ^{87}Sr/^{86}Sr isoscape for the region.

REFERENCES

Aguirre-Samudio, A., González-Sobrino, B. Z., Álvarez-Sandoval, B. A., Montiel, R., Serrano-Sánchez, C., & Meza-Peñaloza, A. (2017). Genetic history of Classic period Teotihuacan burials in central Mexico. Revista Argentina de Antropología Biológica, 19, 7–20.

Aubert, D., Probst, A., Stille, P., & Viville, D. (2002). Evidence of hydrological control of Sr behavior in stream water (Strengbach catchment, Vosges mountains, France). Applied Geochemistry, 17(3), 285–300. https://doi.org/10.1016/S0883-2927(01)00080-4

Beekman, C. S., & Christensen, A. F. (2003). Controlling for doubt and uncertainty through multiple lines of evidence: A new look at the Mesoamerican Nahua migrations. Journal of Archaeological Method and Theory, 10(2), 111–164. https://doi.org/10.1023/A:1024519712257

Begun, E. M. (2013). Detecting ethnicity at Teotihuacan through archaeology: The West Mexican presence at Structure N1W5:19 [Ph.D. dissertation]. University of Iowa.

Bentley, R. A. (2006). Strontium isotopes from the earth to the archaeological skeleton: A review. Journal of Archaeological Method and Theory, 13(3), 135–187. https://doi.org/10.1007/s10816-006-9009-x

Bentley, R. A., Price, T. D., & Stephan, E. (2004). Determining the 'local' 87Sr/86Sr range for archaeological skeletons: A case study from Neolithic Europe. Journal of Archaeological Science, 31(4), 365–375. https://doi.org/10.1016/j.jas.2003.09.003

Blum, J. D., Taliaferro, E. H., Weisse, M. T., & Holmes, R. T. (2000). Changes in Sr/Ca, Ba/Ca and 87Sr/86Sr ratios between trophic levels in two forest ecosystems in the northeastern U.S.A. Biogeochemistry, 49, 87–101.

Budd, P., Montgomery, J., Barreiro, B., & Thomas, R. G. (2000). Differential diagenesis of strontium in archaeological human dental tissues. Applied Geochemistry, 15(5), 687–694. https://doi.org/10.1016/S0883-2927(99)00069-4

Burton, J. H., & Price, T. D. (2002). The use and abuse of trace elements for paleodietary research. In Biogeochemical approaches to paleodietary analysis (pp. 159–171). Springer. http://link.springer.com/chapter/10.1007/0-306-47194-9_8

Buzon, M. R., Conlee, C. A., & Bowen, G. J. (2011). Refining oxygen isotope analysis in the Nasca region of Peru: An investigation of water sources and archaeological samples. International Journal of Osteoarchaeology, 21(4), 446–455. https://doi.org/10.1002/oa.1151

Christensen, A. F. (1997). Cranial non-metric variation in north and central Mexico. Anthropologischer Anzeiger, 55(1), 15–32.

Cowgill, G. L. (2015). The debated role of migration in the fall of ancient Teotihuacan in central Mexico. In B. J. Baker & T. Tsuda (Eds.), Migration and disruptions: Toward a unifying theory of ancient and contemporary migrations (pp. 97–122). University Press of Florida.

Dasch, E. J. (1969). Strontium isotopes in weathering profiles, deep-sea sediments, and sedimentary rocks. Geochimica et Cosmochimica Acta, 33(12), 1521–1552.

de Cserna, Z. (1989). An outline of the geology of Mexico. In A. W. Bally & A. R. Palmer (Eds.), The geology of North America—An overview: Vol. A (pp. 233–264). Geological Society of America.

Demant, A. (1981). Interpretación geodinámica del volcanismo del Eje Neovolcánico Transmexicano. Revista Mexicana de Ciencias Geológicas, 5(2), 217–222.

Ehleringer, J. R., Bowen, G. J., Chesson, L. A., West, A. G., Podlesak, D. W., & Cerling, T. E. (2008). Hydrogen and oxygen isotope ratios in human hair are related to geography. Proceedings of the National Academy of Sciences, 105(8), 2788–2793.

Ericson, J. E. (1985). Strontium isotope characterization in the study of prehistoric human ecology. Journal of Human Evolution, 14(5), 503–514.

Evans, J. A., & Tatham, S. (2004). Defining ‘local signature’ in terms of Sr isotope composition using a tenth- to twelfth-century Anglo-Saxon population living on a Jurassic clay-carbonate terrain, Rutland, UK. Geological Society, London, Special Publications, 232(1), 237–248. https://doi.org/10.1144/GSL.SP.2004.232.01.21

Faure, G. (1998). Principles and applications of geochemistry: A comprehensive textbook for geology students. Prentice Hall.

Faure, G., & Powell, J. L. (1972). Strontium isotope geology. Springer-Verlag.

Ferrusquía-Villafranca, I. (1993). Geology of Mexico: A synopsis. In T. P. Ramamoorthy, R. Bye, A. Lot, & J. Fa (Eds.), Biological diversity of Mexico: Origins and distribution (pp. 3–107). Oxford University Press.

Flockhart, D. T. T., Kyser, T. K., Chipley, D., Miller, N. G., & Norris, D. R. (2015). Experimental evidence shows no fractionation of strontium isotopes (87Sr/86Sr) among soil, plants, and herbivores: Implications for tracking wildlife and forensic science. Isotopes in Environmental and Health Studies, 51(3), 372–381. https://doi.org/10.1080/10256016.2015.1021345

Fries, Jr., C. (1958). Geology of the state of Morelos and contiguous areas in south-central Mexico [Ph.D. dissertation]. University of Arizona.

Galler, P., Limbeck, A., Boulyga, S. F., Stingeder, G., Hirata, T., & Prohaska, T. (2007). Development of an on-line flow injection Sr/matrix separation method for accurate, high-throughput determination of Sr isotope ratios by multiple collector-inductively coupled plasma-mass spectrometry. Analytical Chemistry, 79(13), 5023–5029. https://doi.org/10.1021/ac070307h

González-José, R., Martínez-Abadías, N., González-Martín, A., Bautista-Martínez, J., Gómez-Valdés, J., Quinto, M., & Hernández, M. (2007). Detection of a population replacement at the Classic–Postclassic transition in Mexico. Proceedings of the Royal Society B: Biological Sciences, 274(1610), 681–688. https://doi.org/10.1098/rspb.2006.0151

Grimstead, D. N., Nugent, S., & Whipple, J. (2017). Why a standardization of strontium isotope baseline environmental data is needed and recommendations for methodology. Advances in Archaeological Practice, 5(02), 184–195. https://doi.org/10.1017/aap.2017.6

Gulson, B. L., Jameson, W. W., & Gillings, B. R. (1997). Stable lead isotopes in teeth as indicators of past domicile-a potential new tool in forensic science? Journal of Forensic Sciences, 42, 787–791.

Hodell, D. A., Quinn, R. L., Brenner, M., & Kamenov, G. (2004). Spatial variation of strontium isotopes (87Sr/86Sr) in the Maya region: A tool for tracking ancient human migration. Journal of Archaeological Science, 31(5), 585–601. https://doi.org/10.1016/j.jas.2003.10.009

Hoogewerff, J., Papesch, W., Kralik, M., Berner, M., Vroon, P., Miesbauer, H., Gaber, O., Künzel, K.-H., & Kleinjans, J. (2001). The last domicile of the Iceman from Hauslabjoch: A geochemical approach using Sr, C and O isotopes and trace element signatures. Journal of Archaeological Science, 28(9), 983–989.

Kemp, B. M., Reséndez, A., Román Berrelleza, J. A., Malhi, R. S., & Smith, D. G. (2005). An analysis of ancient Aztec mtDNA from Tlatelolco: Pre-Columbian relations and the spread of Uto-Aztecan. In D. M. Reed (Ed.), Biomolecular archaeology: Genetic approaches to the past (pp. 22–46). Southern Illinois University Press.

Kintigh, K. W. (1990). Intrasite spatial analysis: A commentary on major methods. In A. Voorrips (Ed.), Mathematics and information science in archaeology: A flexible framework (pp. 165–200). Holos.

Kintigh, K. W., & Ammerman, A. J. (1982). Heuristic approaches to spatial analysis in archaeology. American Antiquity, 47(1), 31–63. https://doi.org/10.2307/280052

Knudson, K. J. (2009). Oxygen isotope analysis in a land of environmental extremes: The complexities of isotopic work in the Andes. International Journal of Osteoarchaeology, 19(2), 171–191. https://doi.org/10.1002/oa.1042

Knudson, K. J., & Price, T. D. (2007). Utility of multiple chemical techniques in archaeological residential mobility studies: Case studies from Tiwanaku- and Chiribaya-affiliated sites in the Andes. American Journal of Physical Anthropology, 132(1), 25–39. https://doi.org/10.1002/ajpa.20480

Knudson, K. J., Stanish, C., Lozada Cerna, M. C., Faull, K. F., & Tantaleán, H. (2016). Intra-individual variability and strontium isotope measurements: A methodological study using 87Sr/86Sr data from Pampa de los Gentiles, Chincha Valley, Peru. Journal of Archaeological Science: Reports, 5, 590–597. https://doi.org/10.1016/j.jasrep.2016.01.016

Knudson, K. J., Webb, E., White, C., & Longstaffe, F. J. (2014). Baseline data for Andean paleomobility research: A radiogenic strontium isotope study of modern Peruvian agricultural soils. Archaeological and Anthropological Sciences, 6(3), 205–219. https://doi.org/10.1007/s12520-013-0148-1

Luz, B., Kolodny, Y., & Horowitz, M. (1984). Fractionation of oxygen isotopes between mammalian bone-phosphate and environmental drinking water. Geochimica et Cosmochimica Acta, 48(8), 1689–1693. https://doi.org/10.1016/0016-7037(84)90338-7

Ma, J., Wei, G., Liu, Y., Ren, Z., Xu, Y., & Yang, Y. (2013). Precise measurement of stable (δ 88/86Sr) and radiogenic (87Sr/86Sr) strontium isotope ratios in geological standard reference materials using MC-ICP-MS. Chinese Science Bulletin, 58(25), 3111–3118. https://doi.org/10.1007/s11434-013-5803-5

Maechler, M., Rousseeuw, P., Struyf, A., Hubert, M., & Hornik, K. (2017). cluster: Cluster analysis basics and extensions. R package version 2.0.6. https://cran.r-project.org/web/packages/cluster/cluster.pdf

Manzanilla, L. R., Mejía, G., Jiménez, G., Schaaf, P., Lailson, B., Solís, G., Morales Puente, P., & Cienfuegos Alvarado, E. (2012). Caracterización de la población multiétnica de Teopancazco por isótopos estables, isótopos de estroncio y elementos traza. In L. R. Manzanilla (Ed.), Estudios arqueométricos del centro de barrio de Teopancazco en Teotihuacan (pp. 449–465). Instituto de Investigaciones Antropológicas, Universidad Nacional Autónoma de México.

Meza-Peñaloza, A., Zertuche, F., García-Velasco, M., & Morehart, C. (2019). A non-metric traits study of skulls from Epiclassic Xaltocan in relation to other Mesoamerican cultures. Journal of Archaeological Science: Reports, 23, 559–566. https://doi.org/10.1016/j.jasrep.2018.11.031

Miller, K. A. (2015). Family, 'foreigners', and fictive kinship: A bioarchaeological approach to social organization at Late Classic Copan [Ph.D. dissertation]. Arizona State University.

Miller Wolf, K. A., & Freiwald, C. (2018). Re-interpreting ancient Maya mobility: A strontium isotope baseline for western Honduras. Journal of Archaeological Science: Reports, 20, 799–807. https://doi.org/10.1016/j.jasrep.2018.04.023

Millon, R. (1973). Urbanization at Teotihuacan, Mexico. University of Texas Press.

Moorbath, S., Thorpe, R. S., & Gibson, I. L. (1978). Strontium isotope evidence for petrogenesis of Mexican andesites. Nature, 271(5644), 437–439. https://doi.org/10.1038/271437a0

Mooser, F. (1975). Historia geológica de la cuenca de México. In Memoria de las obras del sistema de drenaje profundo del Distrito Federal (Vol. 1, pp. 7–38). Departamento del Distrito Federal.

Morán-Zenteno, D. (1994). The geology of the Mexican republic (J. L. Wilson & L. Sanchez-Barreda, Trans.). American Association of Petroleum Geologists.

Moreiras Reynaga, D. (2019). The life histories of Aztec sacrifices: A stable isotope study (C, N, and O) of offerings from Tlatelolco and the Templo Mayor of Tenochtitlan [Ph.D. dissertation, University of Western Ontario]. https://ir.lib.uwo.ca/etd/6448

Nado, K. L. (2017). Dietary practices, socioeconomic status, and social mobility at Teotihuacan, Mexico [Ph.D. dissertation]. Arizona State University.

Natural Earth. (n.d.). Retrieved February 3, 2020, from https://www.naturalearthdata.com/

Négrel, Ph., Petelet-Giraud, E., Barbier, J., & Gautier, E. (2003). Surface water–groundwater interactions in an alluvial plain: Chemical and isotopic systematics. Journal of Hydrology, 277(3–4), 248–267. https://doi.org/10.1016/S0022-1694(03)00125-2

Ohmoto, H., Hart, S. R., & Holland, H. D. (1966). Studies in the Providencia area, Mexico, II, K-Ar and Rb-Sr ages of intrusive rocks and hydrothermal minerals. Economic Geology, 61, 1205–1213.

Palmer, M. R., & Edmond, J. M. (1992). Controls over the strontium isotope composition of river water. Geochimica et Cosmochimica Acta, 56(5), 2099–2111. https://doi.org/10.1016/0016-7037(92)90332-D

Pestle, W. J., Simonetti, A., & Curet, L. A. (2013). 87Sr/86Sr variability in Puerto Rico: Geological complexity and the study of paleomobility. Journal of Archaeological Science, 40(5), 2561–2569. https://doi.org/10.1016/j.jas.2013.01.020

Price, T. D., Burton, J. H., & Bentley, R. A. (2002). The characterization of biologically available strontium isotope ratios for the study of prehistoric migration. Archaeometry, 44(1), 117–135. https://doi.org/10.1111/1475-4754.00047

Price, T. D., Burton, J. H., Cucina, A., Zabala, P., Frei, R., Tykot, Robert H., & Tiesler, V. (2012). Isotopic studies of human skeletal remains from a sixteenth to seventeenth century AD churchyard in Campeche, Mexico: Diet, place of origin, and age. Current Anthropology, 53(4), 396–433. https://doi.org/10.1086/666492

Price, T. D., Burton, J. H., Fullagar, P. D., Wright, L. E., Buikstra, J. E., & Tiesler, V. (2008). Strontium isotopes and the study of human mobility in ancient Mesoamerica. Latin American Antiquity, 19(2), 167–180. https://doi.org/10.2307/25478222

Price, T. D., Burton, J. H., Fullagar, P. D., Wright, L. E., Buikstra, J. E., & Tiesler, V. (2015). Strontium isotopes and the study of human mobility among the ancient Maya. In A. Cucina (Ed.), Archaeology and Bioarchaeology of Population Movement among the Prehispanic Maya (pp. 119–132). Springer International Publishing. https://doi.org/10.1007/978-3-319-10858-2_11

Price, T. D., Burton, J. H., Wright, L. E., White, C. D., & Longstaffe, F. J. (2007). Victims of sacrifice: Isotopic evidence for place of origin. In V. Tiesler & A.

Cucina (Eds.), Human sacrifice and ritual body treatments in ancient Maya society (pp. 263–292). Springer.

Price, T. D., Johnson, C. M., Ezzo, J. A., Ericson, J., & Burton, J. H. (1994). Residential mobility in the prehistoric southwest United States: A preliminary study using strontium isotope analysis. Journal of Archaeological Science, 21(3), 315–330.

Price, T. D., Manzanilla, L., & Middleton, W. D. (2000). Immigration and the ancient city of Teotihuacan in Mexico: A study using strontium isotope ratios in human bone and teeth. Journal of Archaeological Science, 27(10), 903–913. https://doi.org/10.1006/jasc.1999.0504

Price, T. D., Nakamura, S., Suzuki, S., Burton, J. H., & Tiesler, V. (2014). New isotope data on Maya mobility and enclaves at Classic Copan, Honduras. Journal of Anthropological Archaeology, 36, 32–47. https://doi.org/10.1016/j.jaa.2014.02.003

Price, T. D., Tiesler, V., & Burton, J. H. (2006). Early African diaspora in colonial Campeche, Mexico: Strontium isotopic evidence. American Journal of Physical Anthropology, 130(4), 485–490. https://doi.org/10.1002/ajpa.20390

R Core Team. (2016). R: a language and environment for statistical computing. R Foundation for Statistical Computing.

Ragsdale, C. S. (2017). Regional population structure in Postclassic Mexico. Ancient Mesoamerica, 1–13. https://doi.org/10.1017/S0956536117000013

Ragsdale, C. S., & Edgar, H. J. H. (2018). Population continuity and replacement in the pre-contact Valley of Mexico. In C. Willermet & A. Cucina (Eds.), Bioarchaeology of pre-Columbian Mesoamerica: An interdisciplinary approach (pp. 37–69). University Press of Florida.

Reynolds, A. C., Quade, J., & Betancourt, J. L. (2012). Strontium isotopes and nutrient sourcing in a semi-arid woodland. Geoderma, 189–190, 574–584. https://doi.org/10.1016/j.geoderma.2012.06.029

Romaniello, S. J., Field, M. P., Smith, H. B., Gordon, G. W., Kim, M. H., & Anbar, A. D. (2015). Fully automated chromatographic purification of Sr and Ca for isotopic analysis. Journal of Analytical Atomic Spectrometry, 30(9), 1906–1912. https://doi.org/10.1039/C5JA00205B

Runia, Lex. T. (1987). Strontium and calcium distribution in plants: Effect on palaeodietary studies. Journal of Archaeological Science, 14(6), 599–608. https://doi.org/10.1016/0305-4403(87)90078-1

Schaaf, P., Solís, G., Manzanilla, L. R., Hernández, T., Lailson, B., & Horn, P. (2012). Isótopos de estroncio aplicados a estudios de migración humana en el centro de barrio de Teopancazco, Teotihuacan. In L. R. Manzanilla (Ed.), Estudios arqueométricos del centro de barrio de Teopancazco en Teotihuacan (pp. 425–448). Instituto de Investigaciones Antropológicas, Universidad Nacional Autónoma de México.

Schwarcz, H. P., Gibbs, L., & Knyf, M. (1991). Oxygen isotope analysis as an indicator of place of origin. In Snake Hill: An investigation of a military cemetery from the War of 1812 (pp. 263–268). Dundurn Press.

Sealy, J. C., Armstrong, R., & Schrire, C. (1995). Beyond lifetime averages: Tracing life histories through isotopic analysis of different calcified tissues from archaeological human skeletons. Antiquity, 69(263), 290–300. https://doi.org/10.1017/S0003598X00064693

Sealy, J. C., van der Merwe, N. J., Sillen, A., Kruger, F. J., & Krueger, H. W. (1991). 87Sr/86Sr as a dietary indicator in modern and archaeological bone. Journal of Archaeological Science, 18(3), 399–416. https://doi.org/10.1016/0305-4403(91)90074-Y

Servicio Geológico Mexicano. (2007). Carta geológica de la República Mexicana [Map]. Servicio Geológico Mexicano.

Servicio Geológico Mexicano. (2008). Estados de Puebla y Tlaxcala: Carta geológico-minera [Map]. Servicio Geológico Mexicano.

Servicio Geológico Mexicano. (2009). Distrito Federal, Estado de México y Morelos: Carta geológico-minera [Map]. Servicio Geológico Mexicano.

Sharpe, A. E., Emery, K. F., Inomata, T., Triadan, D., Kamenov, G. D., & Krigbaum, J. (2018). Earliest isotopic evidence in the Maya region for animal management and long-distance trade at the site of Ceibal, Guatemala. Proceedings of the National Academy of Sciences, 115, 3605–3610. https://doi.org/10.1073/pnas.1713880115

Sillen, A., & Sealy, J. C. (1989). Chemistry and paleodietary research: No more easy answers. American Antiquity, 54, 504–512.

Solís Pichardo, G., Schaaf, P., Hernández Treviño, T., Lailson, B., Manzanilla, L. R., & Horn, P. (2017). Migrants in Teopancazco: Evidence from strontium isotopic studies. In L. R. Manzanilla (Ed.), Multiethnicity and migration at Teopancazco: Investigations of a Teotihuacan neighborhood center (pp. 143–163). University Press of Florida.

Spence, M. W. (1992). Tlailotlacan, a Zapotec enclave in Teotihuacan. In J. C. Berlo (Ed.), Art, ideology, and the city of Teotihuacan (pp. 59–88). Dumbarton Oaks.

Spence, M. W., & White, C. D. (2010). Mesoamerican bioarchaeology: Past and future. Ancient Mesoamerica, 20(2), 233–240. https://doi.org/10.1017/S0956536109990083

Thibodeau, A. M., Luján, L. L., Killick, D. J., Berdan, F. F., & Ruiz, J. (2018). Was Aztec and Mixtec turquoise mined in the American Southwest? SCIENCE ADVANCES, 9.

Thornton, E. K. (2011). Reconstructing ancient Maya animal trade through strontium isotope (87Sr/86Sr) analysis. Journal of Archaeological Science, 38(12), 3254–3263. https://doi.org/10.1016/j.jas.2011.06.035

Torres-Alvarado, I. S., Verma, S. P., & Carrasco-Núñez, G. (2000). Compilation of radiogenic isotope data in Mexico and their petrogenetic implications. Journal of Earth System Science, 109(1), 67–78. https://doi.org/10.1007/BF02719150

Tricca, A., Stille, P., Steinmann, M., Kiefel, B., Samuel, J., & Eikenberg, J. (1999). Rare earth elements and Sr and Nd isotopic compositions of dissolved and suspended loads from small river systems in the Vosges mountains (France), the river Rhine and groundwater. Chemical Geology, 160, 139–158.

Turekian, K. K., & Kulp, J. L. (1956). Strontium content of human bones. Science, 124(3218), 405–407.

Vázquez-Sánchez, E., & Jaimes-Palomera, R. (1989). Geología de la cuenca de México. Geofísica Internacional, 28, 133–190.

White, C. D., Price, T. D., & Longstaffe, F. J. (2007). Residential histories of the human sacrifices at the Moon Pyramid, Teotihuacan: Evidence from oxygen and strontium isotopes. Ancient Mesoamerica, 18(01), 159–172. https://doi.org/10.1017/S0956536107000119

Wickham, H. (2009). ggplot2: Elegant graphics for data analysis. Springer-Verlag.

Wright, L. E. (2005). Identifying immigrants to Tikal, Guatemala: Defining local variability in strontium isotope ratios of human tooth enamel. Journal of Archaeological Science, 32(4), 555–566. https://doi.org/10.1016/j.jas.2004.11.011

Wright, L. E. (2012). Immigration to Tikal, Guatemala: Evidence from stable strontium and oxygen isotopes. Journal of Anthropological Archaeology, 31(3), 334–352. https://doi.org/10.1016/j.jaa.2012.02.001

Wrobel, G. D., Freiwald, C., Michael, A., Helmke, C., Awe, J., Kennett, D. J., Gibbs, S., Ferguson, J. M., & Griffith, C. (2017). Social identity and geographic origin of Maya burials at Actun Uayazba Kab, Roaring Creek Valley, Belize. Journal of Anthropological Archaeology, 45, 98–114. https://doi.org/10.1016/j.jaa.2016.11.004

CHAPTER 3

MIGRATION, VIOLENCE, AND THE "OTHER": A BIOGEOCHEMICAL APPROACH TO IDENTITY-BASED VIOLENCE AND HUMAN SACRIFICE IN THE EPICLASSIC

Target Journal – Journal of Anthropological Anthropology

A broad base of research in the social sciences demonstrates that identity-based violence—violence directed at individuals or groups perceived as categorically distinct or “other”—typically increases during periods of socio-political upheaval (Arkush & Tung, 2013; Bowman, 2001; Howard, 2014; Kurin, 2016; Messner et al., 2019; Riek et al., 2006; Simunovic et al., 2013; Tajfel & Turner, 2004). While archaeologists have documented innumerable cases of dramatic and punctuated social change in the past (e.g., Diehl & Berlo, 1989; Manahan, 2004; McAnany & Yoffee, 2012), only limited archaeological evidence of identity-based violence in the past exists (see Kurin, 2016). Here, I use a bioarchaeological approach to directly examine identity-based violence at the Epiclassic (600-900 CE) central Mexican shrine site of Non-Grid 4, where the remains of over 180 sacrificial victims were interred (Morehart et al., 2012). I use biogeochemical techniques to consider how diverse geographic origins and residential histories contributed to the selection of victims of ritual violence during a period of political, social, and demographic reorganization in the Basin of Mexico.

This manuscript first delineates a theoretical framework within which to investigate identity-based violence. I integrate social science research on the development of in-group preferences and out-group biases with realistic group conflict theory from social psychology, as well as with empirical data from cross-cultural anthropological, evolutionary psychology, and behavioral case studies to establish a link between social group formation and identity-based violence in conditions of heightened scarcity and intergroup competition. I then contextualize this work within Mesoamerican migration and identity studies and previous research at the Non-Grid 4 shrine site. I introduce the biogeochemical methods used to identify residential mobility and migration among the Non-Grid 4 sacrificed individuals, presenting biogeochemical data on a sample of sacrificed individuals (*n* =73). I conclude with a discussion of paleomobility patterns at Non-Grid 4 and their implications for understanding identity-based violence in Epiclassic central Mexico.

Social boundaries and identities

Social group formation is a fundamental part of the human experience. A large body of social and behavioral science research has shown that as humans, I innately sort ourselves into categories of "self" and "other", creating ingroups and outgroups (Bigler et al., 1997; Tajfel et al., 1971; Tajfel & Turner, 2004). This categorizing behavior begins at an early age (Kelly et al., 2005; Moreira et al., 2017), and even the most minimal and arbitrary categorical differences reliably produce ingroup preferences and outgroup biases in controlled laboratory experiments among children (Bigler et al., 1997; Dunham & Emory, 2014; Dunham Yarrow et al., 2011; Nesdale et al., 2007) and adults (Ashburn-Nardo et al., 2001; Everett et al., 2015; Locksley et al., 1980; Mullen et al., 1992; Otten & Wentura, 1999; Riek et al., 2006; Tajfel et al., 1971).

Contemporary culturally salient social groups based on shared social identities also often produce similarly polarized responses of ingroup preferences and outgroup biases (Tajfel & Turner, 2004). Social identities are constructed via particularistic categorical attributes including but not limited to age, gender, ethnicity, or geographic origin (Brubaker & Cooper, 2000; Knudson & Stojanowski, 2008). These identities exist on both individual and communal scales and are not mutually exclusive but can intersect and interact in myriad ways (Collins, 2015; Walby et al., 2012). While some aspects of social identity can be invoked or deemphasized situationally, many others are highly visible, acting as mechanisms signaling group membership and exclusion (Jenkins, 2004; Tajfel & Turner, 2004). Indeed, particularly salient social identities such as ethnicity (Whitt & Wilson, 2007), race (Bobo, 1983), religiosity (Sosis & Ruffle, 2003), language or accent (Kinzler et al., 2011; Purnell et al., 1999), political affiliation (Fowler & Kam, 2007; Rand et al., 2009), and geographic origin or immigrant status (Esses et al., 2001; Zárate et al., 2004) have all been documented to produce negative stereotyping and prejudicial behavior towards individuals perceived to belong to an outgroup.

Theorizing the link between social identity and violence

Despite this consistent bias against outgroup members, ingroup/outgroup social boundary formation often takes place non-violently through the course of intergroup interactions. In Barth's (1969) seminal essay on ethnic groups and social boundaries, he argues that intergroup interactions are essential in the reification of social boundaries, as there can be no "self" without an "other" against which to identify.

However, social group formation can become violent during periods of scarcity or stress. Within social psychology, the realistic group conflict theory posits that opposing claims to scarce resources, such as power, prestige, or wealth will generate antagonism and hostility between groups (D. T. Campbell, 1965; Jackson, 1993; Sherif, 1966; Tajfel & Turner, 2004). Empirical data from cross-cultural anthropological studies, as well as evolutionary psychology and behavioral studies lend further support to this theory, suggesting that modern humans often carry out preemptive violence to defend their ingroup if they perceive outgroups as posing a potential threat (Böhm et al., 2016; Schmidt & Schröder, 2001; Simunovic et al., 2013).

Socio-political upheaval is thus often accompanied by increased identity-based violence. While states are generally characterized as having a stabilizing effect on violence (Andrushko & Torres, 2011; D'Altroy, 1992; Gómez et al., 2016; Sołtysiak, 2017), comprehensive analyses considering diachronic patterns in violence find that periods of political decentralization and the disintegration of pre-extant authority systems evince the highest rates of bioarchaeological (Andrushko & Torres, 2011; Arkush & Tung, 2013; Duncan, 2005; Serafin et al., 2014; Tiesler & Cucina, 2012) and archaeological evidence of violence (Arkush & Tung, 2013; Inomata, 2003, 2014; Mock, 1994). In such contexts, individuals or groups with distinct social identities may become targets of violence.

Thus, during times of political decentralization or reorganization, the presence of diverse social groups in competition over finite resources may escalate into violence. A social group defined by single or multiple common aspects of identity may perceive an outgroup with a distinct identity as a potential threat or competitor (Riek et al., 2006; Zárate et al., 2004). This perception of threatening social difference can culminate in the enactment of violence against outgroups with divergent social identities (Bowman, 2001; Bush & Keyman, 1997; Sen, 2009). Historical examples of such identity-based violence during periods of political disruption abound, including in the ethnic violence following the collapse of the former Yugoslavia (Bowman, 1994), the tribalist violence in the chaos of the Albanian post-Soviet transition (Schwandner-Sievers, 2001), and the genocidal ethnic violence during the Rwandan Civil War (Mamdani, 2002). Moreover, the contemporary Fragile State Index includes identity-based violence as an indicator of state breakdown (Haken et al., 2014; Messner et al., 2019).

Despite this growing literature demonstrating that the perception of threatening social difference can motivate violence, there are few archaeological examples of identity-based violence. This may be because the subtleties of distinct social identities can be difficult to identify in the past. A bioarchaeological approach, however, is well suited to empirically reconstruct past individuals' multivalent social identities, as many facets of identity such as age, sex, or phenotypic expressions of biological relatedness are grounded in the physical body, while others leave traces on the body through behavior, such as dietary preferences or cultural modification (Buikstra & Scott, 2009; Knudson & Stojanowski, 2008, 2009).

A rare archaeological example from the pre-Hispanic central Andes provides convincing evidence of identity-based violence in the past. The ethnohistorically-documented Chanka ethnic group, marked by a visibly distinct form of cranial modification, experienced increased rates of both non-lethal and lethal trauma during the period of political decentralization following the decline of the Wari Empire, indicating that these individuals were targeted for violence at least in part based on their highly visible ethnic identity (Kurin, 2014, 2016). Thus, historical and limited archaeological evidence indicates that during periods of socio-political disruption, groups with visibly distinct social identities may perceive each other as potentially threatening, culminating in intergroup violence.

This study further develops bioarchaeological approaches to identity-based violence in the past. Although there are countless dimensions of social identity and social difference that can be detected using bioarchaeological techniques, here I focus on one specific aspect of social identity—geographic origin and residential history as reconstructed through biogeochemical analysis. I use the central Mexican shrine site of Non-Grid 4 as a case study to explore how the perception of social difference contributed to the selection of victims of ritual violence.

Geographic origins and social difference in ancient Mesoamerica

The mere existence of differences between social groups is often not sufficient to produce tangible intergroup rivalries (Moya, 2013; Tajfel, 1959). An experimental study examining the evolutionary mechanisms behind social group formation found that while some arbitrary markers of group membership became accurate predictors for in-group favoritism and out-group discrimination, others failed to take on this social symbolism and did not lead to ingroup biases (Efferson et al., 2008). Similarly, in contemporary anthropological and behavioral economic studies, certain categorical aspects of identity such as religious affiliation or political party membership are only salient within particular contexts, such as during prescribed periods of ritual celebration or phases of election campaigning (Moya & Boyd, 2015; Rand et al., 2009). Thus, in order to examine identity-based violence in any context—past or present—the cultural import of the specific categorical attributes of identity must be established (Esses et al., 2001; Jackson, 1993).

Ample ethnohistoric evidence indicates that geographic origin was a salient indicator of social difference in pre-Hispanic Mesoamerica. Contact period Nahua codices such as the Codex Boturini, the Codex Chimalpopoca, the Codex Azcatitlan, and others all emphasize migration stories and the importance of sacred places of origin (Akademische Druck, 1979; *Codex Azcatitlan*, 1949; *Codex Boturini: Tira de la peregrinación mexica*, 1944; *Códice Aubin: Manuscrito azteca de la Biblioteca Real de Berlín*, 1963; Durán, 1867; Feliciano Velázquez, 1975; Kirchhoff et al., 1976). Similarly, the Florentine Codex, which describes daily life within the Aztec Empire, consistently associates non-Nahua peoples with the geographic locations of their city-states of origin. Indeed, many ethnic descriptors in the Florentine Codex come from the name of the lands these peoples inhabited. For example, in a passage describing the Toloque peoples, Sahagún writes: "By [the city of Tolocan] lies their mountain…It is said its name is Tolotzin [or] Tolotepetl. Some say – furthermore the Toloque also say – that because many reeds grow there the city is Tolocan, and the people Toloque" (Sahagún, 1961, p. 182). Moreover, in addition to cataloguing the importance of distinct ethnic groups' places of origin, the Florentine Codex also describes specific customs tied to their place of origin, including characteristic forms of dress, hairstyles, cuisines, languages, forms of worship, and skilled labor. These customs would likely have persisted and marked these peoples as different even after leaving their places of origin.

While ethnohistoric data reflect a Nahua-centric perspective from the Late Postclassic and Contact periods, archaeological evidence provides additional support and time depth for the persistent cultural salience of place of origin throughout ancient Mesoamerica. Some of the best evidence for the symbolic importance of geographic origins comes from the Classic period (200-600 CE) multi-ethnic urban center of Teotihuacan in central Mexico. Phenotypic, isotopic, and genetic studies have all identified the presence of multi-ethnic immigrant groups at Teotihuacan (Álvarez-Sandoval et al., 2015; Meza Peñaloza, 2015; Nado, 2017; Price et al., 2000; Solís Pichardo et al., 2017; Spence, 1974; White et al., 1998; White, Storey, et al., 2004). While many of these immigrants may have assimilated into the Teotihuacano host culture, others maintained a distinctive cultural identity over centuries of life at this massive central Mexican city (Begun, 2013; Manzanilla, 2017; Spence, 2005).

For example, several neighborhoods within Teotihuacan exhibit a persistent identification with and invocation of distant places of origin. The Tlailotlacan and N1W5:19 neighborhoods near the western edge of the city are respectively associated with the Oaxaca Valley approximately 360 kilometers south, and the Zacapu Basin in Michoacán, some 300 kilometers to the west. Archaeologists identified these ethnic enclaves through the presence of high volumes of non-local material culture, including foreign-style ceramics made out of local clays and produced using non-local technologies

(Abascal et al., 1974). Furthermore, non-local mortuary patterns (Begun, 2013; Gómez Chavez, 2002; Spence & Gamboa Cabezas, 1999) and the incorporation of foreign architectonic elements into Teotihuacan-style facades and apartment compounds (Cabrera Castro, 1998; Gómez Chavez, 1998; Spence, 2005) indicate a deliberate maintenance of a distinct social identity tied to residents' place of origin even after having relocated to central Mexico.

Beyond Teotihuacan, archaeologists have identified ethnic enclaves throughout Mesoamerica. In addition to his discussion of the Tlailotlacan Zapotec neighborhood at Teotihuacan, Spence (2005) uses material culture, mortuary practices, and architectural patterns to identify additional ethnic enclaves at several central Mexican sites, suggesting they may have made up a Zapotec diaspora network. Similarly, Winter (1998) identifies a possible Teotihuacano neighborhood at the Zapotec state capital of Monte Albán, offering further material evidence of the intentional invocation of distant places of origin throughout Mesoamerica.

Broad ethnohistoric and archaeological evidence thus indicates that geographic origin was indeed a salient indicator of social difference in pre-Hispanic Mesoamerica. I therefore investigate if geographic place of origin acted as a potential catalyst for identity-based violence during a period of socio-political upheaval in ancient central Mexico. I examine the skeletal human remains deposited as an apparent sacrificial offering at the site of Non-Grid 4, a shrine site in the northern Basin of Mexico dating to the Epiclassic period (Morehart et al., 2012). The site does not appear to be affiliated with a state power, setting it apart from other central Mexican examples of ritual violence which are typically understood through the lens of state or elite power consolidation (e.g., Moreiras Reynaga, 2019; Price et al., 2007; White et al., 2002, 2007). The Non-Grid 4 shrine site is thus ideal for the investigation of identity-based violence as it represents an enigmatic example of large-scale violence during a socio-politically fraught time period. Here, I use biogeochemical methods to reconstruct the geographic origin and residential histories of the apparent sacrificial victims from the Epiclassic Non-Grid 4 shrine site to examine identity-based violence in ancient Mesoamerica.

Epiclassic central Mexico and the Non-Grid 4 shrine site

The Epiclassic period (600-900 CE) in the central Mexican highlands was an epoch of major social and political reorganization. Archaeologists typically characterize this time period on the basis of the decline of the Classic period regional center of Teotihuacan, which had previously exerted political control over most of central Mexico (Cowgill, 2015a; Diehl & Berlo, 1989; Rattray, 1996), as well as the dramatic demographic reorganization of the Basin of Mexico (Parsons et al., 2008; Sanders et al., 1979). Teotihuacan’s rapid political decline seems to have created a political vacuum in the region. New competing political centers emerged in the areas surrounding the Basin (García Cook, 2013; Healan, 2012; Mendoza, 1992). Furthermore, the rise in dispersed hilltop settlements (Anderson et al., 2016; Gorenflo & Sanders, 2007; Hirth, 2000; Mastache et al., 2002; Morehart, 2016a; Parsons et al., 2008) and the proliferation of militaristic iconography (Finegold, 2012; Hirth, 1989; Koontz, 1994; McVicker, 2007; Nagao, 1989; Ringle et al., 1998) suggest increased conflict accompanying the political decentralization of the region during this period.

The Epiclassic period is also associated with large-scale migrations into the Basin of Mexico. The appearance of the Coyotlatelco ceramic complex throughout central Mexico (Tozzer, 1921) has been interpreted as evidence of immigration into the region (Beekman & Christensen, 2003; Cowgill, 2013; Crider, 2013; Healan & Cobean, 2019; Hernández & Healan, 2019; Rattray, 1966; Sánchez, 2013; Solar Valverde, 2006), although some maintain that the complex represents either a local or autonomous development (Fournier & Bolaños, 2007; Sanders, 1986, 2006; Sugiura Yamamoto, 2006). Bioarchaeological evidence, however, further supports Epiclassic migration hypotheses. Limited biogeochemical analyses of Epiclassic human remains have demonstrated the presence of migrant individuals (three of five individuals examined) buried in the Cueva de las Varillas at Teotihuacan (Price et al., 2000). Furthermore, biodistance analyses suggest a population replacement took place in the Basin of Mexico during the Epiclassic period (Beekman & Christensen, 2003; Christensen, 1997; García Velasco, 2019; González-José et al., 2007; Meza-Peñaloza et al., 2019; Ragsdale & Edgar, 2018). Thus, as a period characterized by dramatic social change including political reorganization, competition for access to resources, increased conflict, immigration, and demographic change, the Epiclassic provides an optimal setting within which to examine identity-based violence.

Ritual violence at Non-Grid 4

Identified through the course of regional survey, the site of Non-Grid 4 is located on an anthropogenic rise in the now-extinct Lake Xaltocan in the northern Basin of Mexico (Fig 6). The site has been interpreted as a shrine as it was the locus of repeated ritual activities and lacks a residential component (Morehart, 2010, 2017b; Morehart et al., 2012). It is comprised of a slightly elevated platform associated with multiple temporally distinct deposits of human remains and ritual paraphernalia (Meza-Peñaloza et al., 2019; Morehart et al., 2012). Deposits of incense burners and figurines at the base of the constructed platform indicate that it was likely established to petition and repay deities associated with rain, water, and fertility.

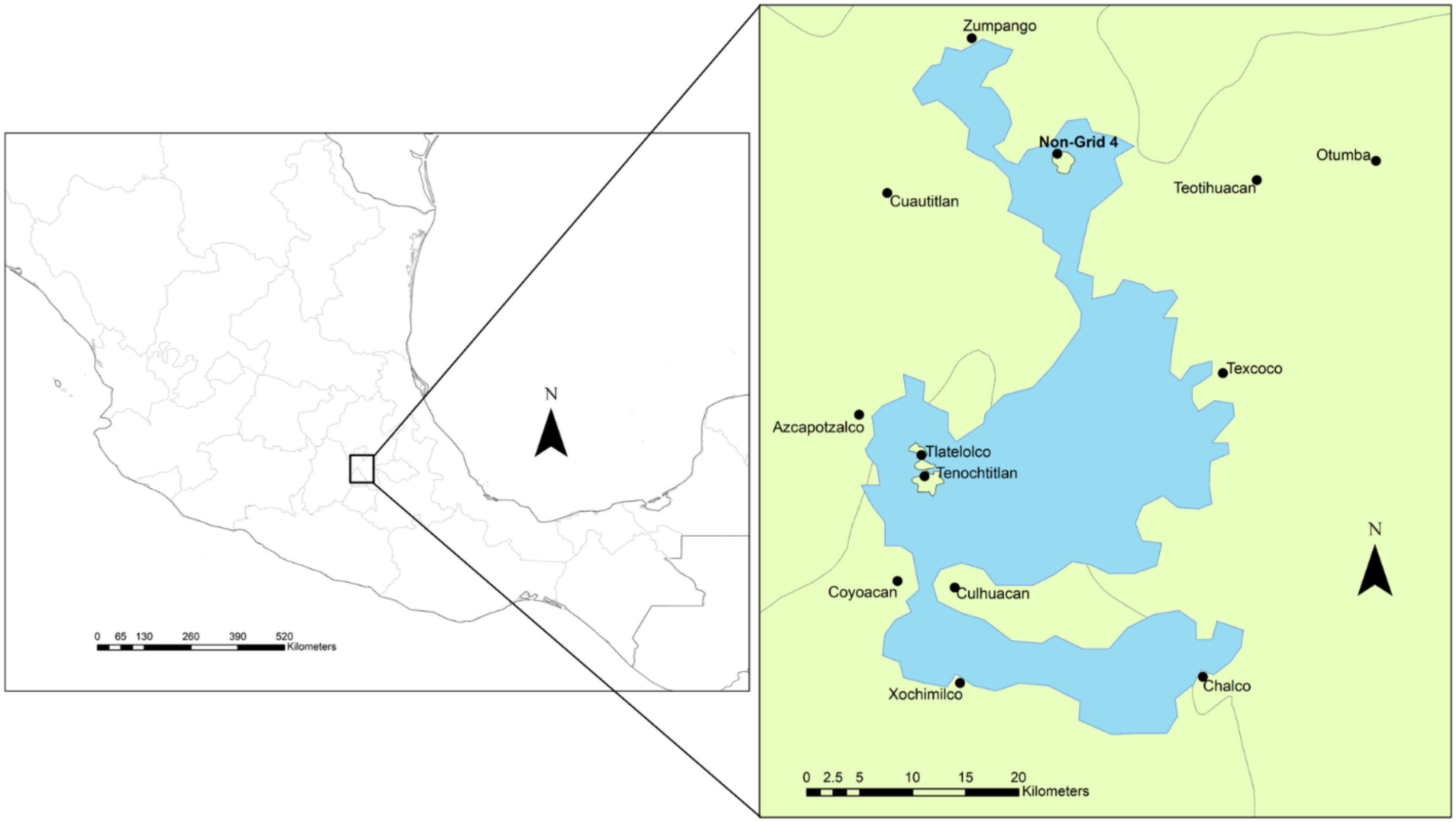

Figure 6. The Non-Grid 4 shrine site and pre-Hispanic highland lake system in central Mexico.

AMS radiocarbon dates of recovered botanical remains ranging from 550 – 890 CE place the site within the Epiclassic period (Morehart et al., 2012), and the creation of the shrine coincides with Teotihuacan's terminal phase after the burning of the city (Cowgill, 2015a; Manzanilla, 2003, p. 94). A range of artifacts recovered from the site, including Coyotlatelco Red on Natural, Garita Black-Brown ollitas, and Mazapan Red on Natural ceramics also suggest the site dates to the Epiclassic period (Morehart, 2010; Morehart et al., 2012), as these ceramics are widely accepted as Epiclassic and transitional Early Postclassic chronological markers (see Crider, 2011 for a regional discussion of the chronology of ceramics from this period).

The human remains interred at Non-Grid 4 postdate Teotihuacan's decline and have been interpreted as sacrificial deposits (Morehart et al., 2012). Although bioarchaeological evidence of violence in central Mexico during the Epiclassic period is rare, the human remains at Non-Grid 4 represent a major exception. Many of the deposited crania exhibit sharp force peri-mortem trauma consistent with throat slitting, exsanguination, and subsequent decapitation (Meza-Peñaloza et al., 2019; Pacheco-Forés, 2017). The presence of articulated mandibles and cervical vertebrae in association with the crania, along with the lack of evidence of sharp force trauma consistent with defleshing or trophy head preparation, and the lack of weathering all suggest that individuals were decapitated in situ and their heads were interred shortly after decapitation (Meza-Peñaloza et al., 2019; Morehart et al., 2012), most likely as part of a ritual offering (Morehart, 2017b). The remains' presence at the shrine site has thus been interpreted as evidence of competition and conflict over political influence in the wake of

Teotihuacan's collapse and access to resources in a possible period of climatic change (Morehart et al., 2012).

The human remains within the sacrificial deposits were extensive. A minimum of 180 human crania associated with mandibles and cervical vertebrae were unearthed in east-facing rows and pits beneath the shrine platform (Morehart, 2017b; Morehart et al., 2012; Pacheco-Forés, 2016). Limited additional postcranial material was recovered from the site, with the exception of distal manual and pedal phalanges, which were found in the eye orbits of sacrificed individuals (Morehart et al., 2012). Most individuals were adult males, although some females and adolescents of both sexes were also present (Table 3), and many of the deposited crania exhibit cranial and dental modification (García Velasco, 2014; Pacheco-Forés, 2016; Sholts et al., 2014).

Table 3. Demography of Non-Grid 4 sacrificial victims.

	Adolescents		Adults		Unobservable		Total	
Sex	*n*	%	*n*	%	*n*	%	*n*	%
Male	12	7%	114	63%	7	4%	133	74%
Female	5	3%	6	3%	0	0%	11	6%
Indeterminate	5	3%	17	9%	14	8%	29	20%
Total	22	12%	137	76%	14	12%	180	100%

Human sacrifice and identity-based violence

Ethnohistoric and archaeological evidence indicate that human sacrifice was a culturally sanctioned form of violence practiced ubiquitously throughout ancient Mesoamerica (Galtung, 2013; Graulich, 2006; López Luján & Olivier, 2010; Sahagún, 1951). Most bioarchaeological analyses of victims of ritual violence are framed in the context of state or elite power consolidation. For example, studies investigating the age-at-death and sex of sacrificed individuals argue that victims represented deity impersonators who were sacrificed at times of great adversity to curry favor with the gods and gain political prestige for ruling elites (De La Cruz et al., 2008; López Luján et al., 2010; Román Berrelleza, 2010). Similarly, researchers investigating the geographic origins of sacrificial victims at Teotihuacan argue the diverse residential histories of sacrificial victims interred at the Pyramid of the Feathered Serpent and the Pyramid of the Moon reflect the city's far-reaching influence and militaristic presence within Mesoamerica (Spence et al., 2004; White et al., 2002, 2007), while isotopic studies finding locals and non-locals among Aztec sacrificial victims at the Templo Mayor in the Postclassic imperial capital of Tenochtitlan have been used to argue for the effectiveness of the Mexica imperial system (Moreiras Reynaga, 2019). Likewise, in the Maya region, analyses of residential mobility have been used to characterize victims in terms of their relationships to powerful elites as either retainer burials or captive warriors put to death to commemorate a military victory or a ruler's passing (Hoffmeister & Wright, 2016; Lorenz et al., 2016; Price et al., 2007). The absence of an affiliated state or centralized power, or indeed even of a residential component of the site at the Non-Grid 4 shrine sets it apart from these previous studies. The site cannot be understood through a lens of state or elite power consolidation.

I thus use the Non-Grid 4 shrine for investigating identity-based violence, as it represents instances of large-scale violence and human sacrifice during a period of socio-political upheaval. Analyses of victims of ritual violence throughout Mesoamerica indicate that sacrificial victims do not represent a random cross-section of the population at various archaeological sites. For example, biologically frail or disabled individuals were specifically selected for sacrifice in some contexts (Crandall & Thompson, 2014; De La Cruz et al., 2008; Kieffer, 2017), while particular kinship groups appear to have been disproportionately selected for sacrifice in others (Duncan, 2011, 2012). All members of society were therefore not equally likely to be selected as sacrificial victims. Sacrificial deposits thus provide an excellent context in which to examine identity-based violence, allowing bioarchaeologists to discern whether specific aspects of victims' social identities predisposed them to suffer violence. In the volatile socio-political landscape of the central Mexican Epiclassic, aspects of victims' social identities, including their geographic origins and residential histories, could have acted as powerful indicators of social difference that culminated in violence.

Reconstructing paleomobility through biogeochemistry

Biogeochemical methods provide a unique opportunity to directly examine paleomobility on an individual scale. Radiogenic strontium ($^{87}Sr/^{86}Sr$) and stable oxygen ($\delta^{18}O$) isotope analyses are often used to reconstruct the residential histories of past peoples (Ericson, 1985; Price et al., 2000; Schwarcz et al., 1991; White et al., 1998). Strontium isotopes are incorporated into calcified tissues from the environment through consumed food and imbibed water (Flockhart et al., 2015; Sealy et al., 1991; Turekian & Kulp, 1956). They reflect the age and composition of geologic bedrock in the region where an individual lived during tissue development (R. A. Bentley, 2006; Dasch, 1969; Faure & Powell, 1972). In contrast, oxygen isotopes are incorporated into human hard tissues primarily through imbibed liquids (Longinelli, 1984; Luz et al., 1984). Oxygen isotopes reflect regional hydrology and are correlated with environmental factors such as elevation, temperature, humidity, and latitude in the region where an individual lived during tissue development (Bowen et al., 2005; Craig, 1957; Dansgaard, 1964; Gat, 1996; M. J. Kohn, 1996; Luz & Kolodny, 1989). Additionally, oxygen isotope data in enamel samples may also be influenced by the consumption of ^{18}O-enriched breast milk in infancy (Herring et al., 1998; Wright & Schwarcz, 1998, 1999), as well as through culturally mediated brewing, cooking, and water storage practices (Brettell et al., 2012; Gagnon et al., 2015).

Strontium isotope baseline variability in central Mexico

The underlying geology of central Mexico indicates that radiogenic strontium isotopes can be used to reconstruct paleomobility throughout the region (Morán-Zenteno, 1994; Price et al., 2008). Younger geologic formations tend to have lower ^{87}Sr/^{86}Sr values, while older formations have higher ^{87}Sr/^{86}Sr values (R. A. Bentley, 2006; Faure & Powell, 1972). The Non-Grid 4 shrine is located in the Basin of Mexico, which lies within the Mexican Volcanic Belt morphotectonic province. This geologic region is characterized by Late Cenozoic andesitic, dacite, and rhyolite pyroclastic flows (Moorbath et al., 1978; Morán-Zenteno, 1994; Salinas Prieto et al., 2007). Late Cenozoic rocks from the Mexican Volcanic Belt exhibit an average of ^{87}Sr/^{86}Sr=0.7040 ± 0.00099 (2σ, n=329; Torres-Alvarado et al., 2000). In contrast, mean radiogenic strontium values from rocks to the north in the Central Mesa province are lower, exhibiting an average of ^{87}Sr/^{86}Sr=0.7032 ± 0.00058 (2σ, n=28; Torres-Alvarado et al., 2000). Rocks from other neighboring morphotectonic provinces all exhibit radiogenic strontium values higher than those reported in the Mexican Volcanic Belt. For example, rocks from Paleozoic marine sedimentary deposits in the Sierra Madre Oriental mountain range to the northeast have an average of $^{87}Sr/^{86}Sr=0.7070 \pm 0.005$ (2σ, *n*=5; Ohmoto et al., 1966), Cenozoic rocks from rhyolitc and andesitic volcanic deposits in the Sierra Madre Occidental mountains to the northwest exhibit mean values of $^{87}Sr/^{86}Sr=0.7058 \pm 0.0034$ (2σ, *n*=105; Torres-Alvarado et al., 2000), and rocks from the complex mixed Cenozoic, Mesozoic, and Paleozoic geology of the Sierra Madre Sur mountains to the south exhibit an average of $^{87}Sr/^{86}Sr=0.7041 \pm 0.00256$ (2σ, *n*=22; Torres-Alvarado et al., 2000). It is important to note that these whole rock strontium values do not necessarily reflect bioavailable $^{87}Sr/^{86}Sr$ values that would be taken up into human and animal hard tissues. Instead, variability in bioavailable $^{87}Sr/^{86}Sr$ values is typically obtained from plant, faunal, alluvial soil, and water samples and often—but not always—mirrors $^{87}Sr/^{86}Sr$ bedrock geology variability (R. A. Bentley, 2006; Evans & Tatham, 2004; Price et al., 2002).

Studies of bioavailable radiogenic strontium sources, including plants, water, and alluvial soils within the Basin of Mexico itself confirm that the Basin can be distinguished from neighboring parts of central Mexico using radiogenic strontium isotopes (Pacheco-Forés et al., 2020; Price et al., 2008). For example, the Basin of Mexico has a reported local range of $^{87}Sr/^{86}Sr=0.7046\text{-}0.7048$ (*n*=60; Pacheco-Forés et al., 2020). This range stands in contrast to other central Mexican subregions with higher reported local ranges of $^{87}Sr/^{86}Sr=0.7053\text{-}0.7058$ (*n*=8; Pacheco-Forés et al., 2020) in the Puebla-Tlaxcala Valley to the east, and $^{87}Sr/^{86}Sr=0.7053\text{-}0.7061$ (*n*=4; Pacheco-Forés et al., 2020) in the Xochicalco Formation in Morelos immediately to the south of the Basin.

Furthermore, significant variability in strontium isotopes exists within the Basin of Mexico itself, allowing many sites within the Basin to be distinguished isotopically using strontium isotopes (Pacheco-Forés et al., 2020).

The Basin of Mexico is also isotopically distinguishable from regions beyond central Mexico. Plant samples from western Mexico exhibit a lower reported local range of ^{87}Sr/^{86}Sr=0.7039-0.7040 (*n*=15; Price et al., 2008), while plant samples from further to the south in the Oaxaca Valley have a higher reported local range of ^{87}Sr/^{86}Sr=0.7059-0.7077 (*n*=95; Pacheco-Forés et al., in preparation) faunal samples from northern Mexico exhibit a higher reported local range of ^{87}Sr/^{86}Sr=0.7066-0.7072 (*n*=28; Offenbecker, 2018). Similarly, the Basin is isotopically distinct from several subregions in the Maya region, including the higher expected local ^{87}Sr/^{86}Sr values in the northern lowlands (^{87}Sr/^{86}Sr=0.7077-0.7092, *n*=40), the southern lowlands (^{87}Sr/^{86}Sr=0.7069-0.7077, *n*=86), and the Maya Mountains (^{87}Sr/^{86}Sr=0.7119-0.7151, *n*=3); lower expected local ^{87}Sr/^{86}Sr values in the volcanic highlands (^{87}Sr/^{86}Sr=0.7038-0.7041, *n*=34); and only partially overlaps with the lower portion of the expected local ^{87}Sr/^{86}Sr range of the Montagua Valley (^{87}Sr/^{86}Sr=0.7041-0.7072, *n*=26; Hodell et al., 2004).

The expected local range for the Non-Grid 4 shrine site is ^{87}Sr/^{86}Sr=0.7047-0.7048 (*n*=22; Pacheco-Forés et al., 2020). However, because the Non-Grid 4 shrine site did not contain a residential component, using the Non-Grid 4 site-specific “local” range may artificially inflate the number of non-local individuals identified, as there is no archaeological evidence that individuals interred at the site lived in and consumed strontium and oxygen sources from the immediate shrine environment. Therefore, for the purposes of this study, I use the combined Basin of Mexico local range of $^{87}Sr/^{86}Sr$=0.7046-0.7048 (*n*=60; Pacheco-Forés et al., 2020) to represent "local" Non-Grid 4 values. This broader "local" range provides a more conservative and robust means of identifying individuals who were non-local not only to the immediate vicinity of the shrine site, but to the whole Basin. Unless otherwise indicated, all expected local $^{87}Sr/^{86}Sr$ ranges represent interquartile ranges of sampled $^{87}Sr/^{86}Sr$ values, as these are often non-normally distributed (Price et al., 2008).

Oxygen isotope baseline variability in central Mexico

In addition to geologic variability, there is also great diversity in rainfall, temperature, humidity, and elevation across central Mexico and Greater Mesoamerica, indicating that stable oxygen isotopes are suitable for examining paleomobility in the region (Wallén, 1955; Wassenaar et al., 2009; White et al., 1998). General models of oxygen isotope behavior indicate that low elevation, hot, humid, or rainy regions typically exhibit higher $\delta^{18}O$ values, while those at higher elevations, or are cooler and dried have lower $\delta^{18}O$ values (Dansgaard, 1964; Gat, 1996). Thus, the Basin of Mexico, which is at a high elevation and receives relatively little rain annually (~750 mm; Wallén, 1955) has a reported meteoric water range of $\delta^{18}O_{mw(VSMOW)}$= –10.8‰ to –8.8‰ (Issar et al., 1984; Ortega-Guerrero et al., 1997). This local range includes data on shallow groundwater as well as surface precipitation, as several studies have found negligible differences in $\delta^{18}O_{VSMOW}$ values between these two water sources throughout Mexico (IAEA, 1992; Issar et al., 1984; Wassenaar et al., 2009).

In contrast to the available $\delta^{18}O_{mw\ (VSMOW)}$ local range for the Basin of Mexico, oxygen isotope isoscapes of $\delta^{18}O_{mw(VSMOW)}$ values throughout Mexico show that the eastern Gulf Coast region of Mexico exhibits a relatively high range of $\delta^{18}O_{mw(VSMOW)}$= –6.0 to –3.0‰, the southern Mexican highlands exhibit an intermediate range of $\delta^{18}O_{mw(VSMOW)}$= –9.0 to –6.0‰, and the western highlands exhibit a wide range of $\delta^{18}O_{mw(VSMOW)}$= –12.0 to –4.0‰ (Moreiras Reynaga, 2019; Wassenaar et al., 2009). These local ranges conform with expected altitudinal and environmental effects.

According to oxygen isotope isoscapes, the Non-Grid 4 shrine site's local range is $\delta^{18}O_{mw(VSMOW)}$= –10.0 to –9.0‰ (Moreiras Reynaga, 2019; Wassenaar et al., 2009). Recent studies, however, have shown that differences in preparation methods and analytical techniques can lead to substantial inter-laboratory differences in reported $\delta^{18}O$ values (Pestle et al., 2014). I therefore use the Minimum Meaningful Difference (MMD) value of ±3.1‰ to establish a $\delta^{18}O_{mw\ (VSMOW)}$ local range for the Non-Grid 4 shrine site that considers inter-laboratory variability as well as observed $\delta^{18}O_{mw}$ variability. Thus, for the purposes of this study, the Non-Grid 4 shrine site's local range is $\delta^{18}O_{mw\ (VSMOW)}$= –12.6‰ to –6.4‰.

Strontium and oxygen isotope sources in the Basin of Mexico

Dietary sources of strontium and oxygen isotopes within the Basin of Mexico were largely from local rather than non-local imported sources (Nado, 2017). The greatest source of high-calcium high-strontium foods in the pre-Hispanic Basin of Mexico was likely terrestrial plant sources, such as beans (*Phaseolus vulgaris*) and amaranth (*Amaranthus spp*.; Santley & Rose, 1979). There is extensive evidence of intensive agricultural field systems throughout the Basin over the course of the pre-Hispanic period (Sanders et al., 1979), including in the Xaltocan lake zone (Morehart, 2012), indicating that peoples living in the Basin were likely consuming primarily locally-produced plants as part of their diet.

While maize (*Zea mays*), the largest component of pre-Hispanic Basin diets (Santley & Rose, 1979), contains negligible amounts of strontium (Harmon et al., 1969), the nixtamalization process represents a substantial source of dietary strontium. This cooking technique involves treating maize with alkaline solution often made from strontium-rich slaked lime to increase nutritional value of maize (Barba Pingarrón, 2013; Johnson & Marston, 2020). While several studies suggest the Tula region just north of the Basin may have served as a source for lime in archaeological plaster (Barba et al., 2009; Miriello et al., 2011; Parsons et al., 2008), there are also rich lime deposits in the Zumpango region in the northwestern Basin of Mexico (Parsons & Gorenflo, 2008; Sanders et al., 1979, p. 145) that could have been exploited for nixtamalization purposes.

Marine resources are also a significant source of strontium and reflect seawater values of $^{87}Sr/^{86}Sr=0.7092$ (Veizer, 1989). Diet in the Basin of Mexico, however, largely excluded marine resources (Nado et al., 2016; Parsons, 2008; Widmer & Storey, 2017). While there is evidence of importation of marine fish to one elite residential compound at Teotihuacan (Manzanilla, 2007; Rodríguez Galicia & Valadez Azúa, 2013), wider paleodietary reconstructions indicate that consumption of marine resources was atypical (Nado, 2017). Similarly, the consumption of marine salt, which was widely traded throughout the Maya region, could also be a non-local source of strontium that would reflect seawater rather than local values (Andrews, 1983; Fenner & Wright, 2014; Wright, 2005). There is extensive evidence, however, of local salt production within the Basin of Mexico along the shores of the three saline highland lakes (Parsons, 2001; Sanders et al., 1979, pp. 57–58). Therefore, individuals living in the Basin would most likely have consumed these local sources of salt.

Similarly, drinking water was likely the single largest source of oxygen isotopes in pre-Hispanic central Mexican diets, and it would also have contributed to strontium values. Past drinking water sources were likely local to the Basin of Mexico. Although three of the five highland lakes on the Basin floor contained non-potable brackish water, the two southernmost lakes contained potable freshwater (Durazo & Farvolden, 1989). Moreover, numerous ethnohistorically-documented freshwater springs throughout the Basin were exploited for drinking water during pre-Hispanic times and into the Colonial era (Berdan & Anawalt, 1997; Morehart, 2016b; Sahagún, 1963). The available evidence thus indicates that strontium and oxygen isotope sources in past peoples' diets were predominantly local to the Basin, making radiogenic strontium and stable oxygen isotope analysis an effective means of reconstructing paleomobility and residential histories among the individuals interred at the Non-Grid 4 shrine.

Materials

Approximately 40% of the total number of individuals (*n*=73) were selected for biogeochemical analysis. Sampled individuals replicate the demographic structure (see Table 3) of the sacrificial deposit and were included in the sample based on a secure association of the cranium with dentition. I compared intra-individual $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ values across several dental and skeletal elements (*N*=194) representing discrete developmental periods to reconstruct sacrificial victims' patterns of mobility between distinct geologic or environmental zones over the life course (Ericson, 1985; Knudson et al., 2016; Luz & Kolodny, 1989; Price et al., 1994; Sealy et al., 1995). Tooth enamel forms during the first years of life and does not remodel, preserving isotopic signatures from the time of its initial mineralization, while bone remodels continuously throughout life (Hillson, 1996; Katzenberg, 2008). I sampled first molars (*n*=73), which mineralize in utero until three years of age, and third molars (*n*=73), which mineralize from 7 to 12 years of age, from all sampled individuals (Hillson, 1996). Additionally, I sampled cranial bone fragments (*n*=48) from a subset of sampled individuals with fragmented crania to limit destruction of osteological material. Cranial bones remodel at a rate of 1.8% per year in adults and reflect an average of the last 40-50 years of life (Pate, 1994; Torres-Lagares et al., 2010).

Methods

Radiogenic strontium and stable oxygen isotope systems are distributed differently across central Mexico (White et al., 2007). All archaeological enamel and bone samples were therefore analyzed for both $^{87}Sr/^{86}Sr$ and $\delta^{18}O$, allowing for further discrimination of individuals' movement between geological or climatically similar areas that would otherwise be indistinguishable using a single isotopic system (Knudson & Price, 2007). All samples were prepared for analysis at the Arizona State University (ASU) Archaeological Chemistry Laboratory.

Radiogenic strontium isotope analysis

Enamel and bone samples were mechanically cleaned to remove contaminants, as well as any dentine or trabecular bone. Additionally, mechanically cleaned cortical bone samples were chemically cleaned in a 0.8M acetic acid (CH_3COOH) solution and ashed at 800º C for 10 hours. Three milligrams of powdered tooth enamel powder or chemically cleaned and ashed bone were then dissolved in concentrated nitric acid (HNO_3) and diluted to a 2M stock solution.

Dissolved samples were analyzed at the Metals, Environmental, and Terrestrial Analytical Laboratory at ASU. An aliquot of stock solution was taken for major, minor, and trace elemental concentration analysis by a Thermo Fisher Scientific iCAP quadrupole inductively coupled plasma mass spectrometer (Q-ICP-MS). Strontium was then separated from the sample matrix with a PrepFAST automated low-pressure ion exchange chromatography system using an established method (Romaniello et al., 2015) to elute the sample matrix (2M HNO_3 + 1 wt% hydrogen peroxide [H_2O_2]) and strontium (6M HNO_3). Lastly, all other elements were removed using 1M hydrofluoric acid (HF). Aliquots from approximately 12% of samples were measured on the Q-ICP-MS before and after chemical purification to determine chemical recovery. Average chemistry yield was 84% ± 0.12 (n=24).

The remaining portion of each strontium cut from the PrepFAST was dried in a Teflon beaker and digested with concentrated HNO_3 and 30% H_2O_2 to remove organics from the resin. Once digested, samples were dried down and reconstituted with 0.32M HNO_3 to a calculated constant concentration of 50 ppb Sr. Radiogenic strontium isotope ratios were then measured on a Thermo-Finnigan Neptune multi-collector inductively coupled plasma mass spectrometer (MC-ICP-MS).

The MC-ICP-MS has nine Faraday cups capable of simultaneous ion beam measurement, and this instrument was configured with an Elemental Scientific, Inc. Apex Q high sensitivity sample introduction system with an Elemental Scientific, Inc. 50 or 100 μL/minute PFA-ST microflow nebulizer. This instrument has seven 1011 amplifiers and three 1012 amplifiers which can be designated for any of the Faraday cups.

Data was collected by measuring 60 simultaneous ratios integrating 4.194 seconds each. Samples were corrected for on-peak blanks and in-line correction of the contributions of ^{84}Kr on ^{84}Sr and ^{86}Kr on ^{86}Sr using ^{83}Kr/^{84}Kr ratio of 0.201750 and ^{83}Kr/^{86}Kr ratio of 0.664533, after instrumental mass bias correction using a normalizing ^{88}Sr/^{86}Sr ratio of 8.375209. Sensitivity was 18 V on ^{88}Sr with a 50 ppb Sr solution, with ^{83}Kr values <0.0001 V. ^{85}Rb voltages were typically <0.01 V due to the low Rb/Sr initial ratios of the samples and effective chemical purification, but all data was interference corrected using a ^{85}Rb/87Rb ratio of 2.588960, normalized to ^{88}Sr/^{86}Sr as above. Ratio outliers two standard deviations outside the mean were removed using a Matlab 2D-mathematical correction routine written by Dr. Stephen Romaniello now at University of Tennessee. Typical internal ^{87}Sr/^{86}Sr two standard error (SE) precision was ~1e-6.

Sequences included bracketing concentration matched SRM 987 standards. SRM 987 was run as a bracketing standard with a measured value of ^{87}Sr/^{86}Sr of 0.710257 ± 0.000020 (2σ, *n*=60), which is in agreement with reported values of ^{87}Sr/^{86}Sr of 0.710251 ± 0.000013,(2 σ, *n*=5; Balcaen et al., 2005). The analytical session included a sequence incorporating SRM 987 standard in a range of variable concentration to verify $^{87}Sr/^{86}Sr$ values for samples. Reported values are all above the threshold for accurate $^{87}Sr/^{86}Sr$ values within the range of error of the bracketing standards. In addition, SRM 987 doped with varying amounts of calcium up to a ratio of Ca/Sr of 500 was run to simulate the accuracy and precision of isotope ratios in poorly purified samples with low yields. SRM 987 run at 50% concentration doped to a Ca/Sr of 500 was run as a check standard with a measured value of $^{87}Sr/^{86}Sr=0.710245 \pm 0.000028$ (2σ, *n*=13). NIST 1400 purified in parallel with samples had a measured value of 0.713100 ±0.000051 (2σ, *n*=7), similar to the published value of 0.713150 ±0.000016 (Galler et al., 2007). Approximately 5% of samples (*n*=11) were run in triplicate, with an average precision on individual measurements of ±0.00004 (2σ).

Stable oxygen isotope analysis

Sample preparation for stable oxygen isotope analysis of archaeological hydroxyapatite carbonate ($\delta^{18}O_{carbonate}$) followed established methods (Koch et al., 1997). Samples of 15-20 mg of mechanically cleaned enamel or bone powder were treated with 0.04 mL of 2% bleach (NaOCl) per each milligram of sample and agitated on a mini-vortexer for 60 seconds and left to sit at room temperature for 24 hours. Samples were rinsed three times with 18.2 MΩ deionized water and treated with 0.04 mL of 0.1 M CH_3COOH per each milligram of tooth enamel or bone powder. Samples were mixed on a Mini-Vortexer for 60 seconds and left to sit at room temperature for 24 hours. Finally, samples were decanted and rinsed three times with 18.2 MΩ deionized water and then dried at 50ºC for 24 hours.

After preparation in the ASU Archaeological Chemistry Laboratory, $\delta^{18}O_{carbonate}$ samples were analyzed at the Colorado Plateau Stable Isotope Laboratory at Northern Arizona University (NAU). Samples were analyzed using a Delta V Advantage isotope ratio mass spectrometer (IRMS) equipped with a Gas Bench II. Sequences included international standards of LSVEC, NBS-18, and NBS-19, and internal NAU laboratory standards of Joplin calcite (CC) and a calcium carbonate ($CaCO_3$) standard. Measured LSVEC values of $\delta^{18}O_{carbonate(VPDB)}$= –26.16 ±0.20‰ (1σ, *n*=8) correspond with published values of $\delta^{18}O_{carbonate(VPDB)}$= –26.46 ±0.25‰ (1σ, *n*=10, Stichler, 1995), while measured NSB-18 values of $\delta^{18}O_{carbonate(VPDB)}$= –23.03 ±0.14‰ (1σ, *n*=14) agree with reported values of $\delta^{18}O_{carbonate(VPDB)}$= –23.04 ±0.17‰ (1σ, *n*=17; Stichler, 1995), and measured NSB-19 values of $\delta^{18}O_{carbonate(VPDB)}$= –2.20 ±0.19‰ (1σ, *n*=14) agree with published values of $\delta^{18}O_{carbonate(VPDB)}$= –2.20‰ (Friedman et al., 1982; Hut, 1987). Similarly, measured Joplin CC values of $\delta^{18}O_{carbonate(VPDB)}$= –23.49 ±0.19‰ (1σ, *n*=23) correspond with reported values of $\delta^{18}O_{carbonate(VPDB)}$= –23.41 ±0.19‰ (1σ, *n*=19), and measured $CaCO_3$ standard values of $\delta^{18}O_{carbonate(VPDB)}$= –12.99 ±0.18‰ (1σ, *n*=19) correspond with reported values of $\delta^{18}O_{carbonate(VPDB)}$= –13.01 ±0.14‰ (1σ, *n*=19; Knudson et al., 2014). Approximately 6% of samples (*n*=12) were run in triplicate, with an average precision on individual measurements of ±0.20‰ (1σ).

Generated data are expressed in per mil (‰) using the standard formula: $\delta^{18}O=[(^{18}O/^{16}O_{sample})/(\,^{18}O/^{16}O_{standard}) - 1] \times 1{,}000$ (Coplen et al., 1983; Craig, 1961). First molar $\delta^{18}O_{carbonate}$ values typically exhibit an average of ~0.7‰ $\delta^{18}O$-enrichment as a result of infant breastfeeding trophic level effects and were adjusted downwards (White et al., 2000; Wright & Schwarcz, 1998, 1999). All $\delta^{18}O_{\text{carbonate(VPDB)}}$ values were converted to $\delta^{18}O_{\text{drinking water(VSMOW)}}$ values for comparison with expected local $\delta^{18}O_{\text{mw(VSMOW)}}$ baseline ranges using the following equations: (1) $\delta^{18}O_{\text{carbonate(VSMOW)}}=(1.03091 \times \delta^{18}O_{\text{carbonate(VPDB)}}) + 30.91$ (Coplen et al., 1983); (2) $\delta^{18}O_{\text{phosphate(VSMOW)}}=(0.98 \times \delta^{18}O_{\text{carbonate(VSMOW)}}) - 8.5$ (Iacumin et al., 1996); (3) $\delta^{18}O_{\text{drinking water(VSMOW)}}=(1.54 \times \delta^{18}O_{\text{phosphate(VSMOW)}}) - 33.72$ (Daux et al., 2008). It is important to note that while these formulae introduce some error into the oxygen values (Pellegrini et al., 2011; Pollard et al., 2011), they allow us to directly compare oxygen isotope values in hydroxyapatite to the oxygen isotope meteoric water values from established baselines.

Results

In 194 enamel and bone samples collected from 73 individuals, Ca/P values varied from 1.94 – 2.33, with a mean of Ca/P=2.03 ±0.12 (1σ, n=194), U/Ca values varied from 3.21E-08 – 6.97E-05, with a mean of U/Ca=6.82E-06 ±1.30E-05 (1σ, n=194), and Nd/Ca values varied from 2.24E-07 – 2.17E-06, with a mean of Nd/Ca=2.98E-07 ±3.15E-07 (1σ, n=193; Appendix C). Observed $^{87}Sr/^{86}Sr$ values ranged from 0.70387 – 0.70738, with a mean of $^{87}Sr/^{86}Sr=0.70500 \pm 0.00061$ (1σ, n=194), and $\delta^{18}O_{\text{carbonate(VPDB}}$ ranged from –11.26 – –0.38‰, with a mean of $\delta^{18}O_{\text{carbonate(VPDB)}}= -6.33 \pm 1.11$‰ (1σ, n=194; Appendix C).

Examining diagenetic contamination at Non-Grid 4

Results from major, minor, and trace elemental concentration analyses suggest little diagenetic contamination affected archaeological enamel and bone tissues recovered from the Non-Grid 4 shrine site. Most samples fall beneath the expected biogenic apatite ratio of Ca/P=2.15 (Price et al., 1992). Bone samples exhibited slightly higher Ca/P values, which may indicate at least some diagenetic contamination in these samples (see Appendix C). However, most enamel and bone observed U/Ca and Nd/Ca ratios fall below reported biogenic U/Ca values of 4.9E-05 ±1.8E-04 (1σ, *n*=52; Knudson et al., 2014) and Nd/Ca values of 2.31E-06 ±3.52E-06 (2σ, *n*=14; Knudson et al., 2012).

Similarly, comparison of analyzed enamel and bone samples' rare earth element (REE) and U concentrations (ppm) relative to Kamenov and colleagues' (2018) experimentally established Maximum Threshold Concentrations (MTC) for each of these elements indicates that the majority of samples exhibit no or only minor diagenetic contamination (Fig 7). REE and U concentrations in most samples fall beneath the MTC threshold of 1, indicating an expected biogenic chemical signal, or beneath the MTC threshold of 10, indicating expected low-grade diagenetic alteration that has not significantly affected the samples' biogenic Sr values (see discussion in Kamenov et al., 2018). Samples exceeding the MTC threshold of 10 exhibit advanced diagenesis that may indicate compromised Sr isotopic values. MTC sample values consistent with major isotopic alteration were primarily made up of U concentrations in bone samples. While this suggests these samples may exhibit significant diagenetic environmental contamination in Sr values, the same samples exhibited unaltered or only mildly altered

MTC values in all other analyzed REE. Furthermore, many of these bone samples with high U concentrations exhibit $^{87}Sr/^{86}Sr$ values distinct from the Non-Grid 4 shrine site expected local range of $^{87}Sr/^{86}Sr=0.70478 – 0.70484$, indicating that they preserve a pristine $^{87}Sr/^{86}Sr$ signal despite some contamination from the deposition environment.

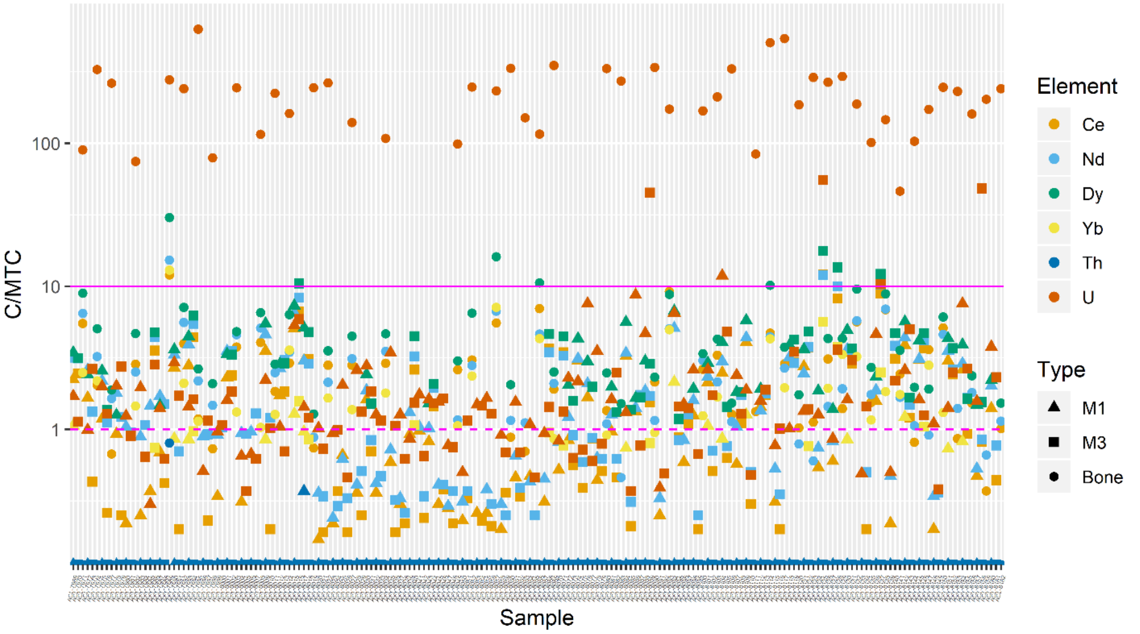

Figure 7. REE and U concentrations (ppm)/MTC for all analyzed human samples. Sample C/MTC values were plotted for each element (color). The dashed line demarcates the C/MTC threshold for biogenic values of 1, while the solid line demarcates the C/MTC threshold for minor diagenetic alteration of 10, following Kamenov et al. (2018). Sample type is indicated by shape.

Residential histories of sacrificial victims at Non-Grid 4

As previously discussed, individuals interred at Non-Grid 4 consuming primarily local sources of strontium were expected to exhibit $^{87}Sr/^{86}Sr$ values falling within the combined Basin of Mexico local range of $^{87}Sr/^{86}Sr=0.70465-0.70487$ (*n*=60; Pacheco-Forés et al., 2020). Similarly, individuals consuming local drinking water sources—the largest contributor to $\delta^{18}O$ values in human hard tissues—were expected to fall within a local range of $\delta^{18}O_{mw(VSMOW)}$)= –12.6 to –6.4‰. Individuals with enamel or bone $^{87}Sr/^{86}Sr$ or $\delta^{18}O_{mw(VSMOW)}$ values falling outside of this conservative local range thus likely represent migrants.

A summary plot of $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ results in all sampled tissues reveals that many of the individuals interred at the Epiclassic Non-Grid 4 shrine were migrants (Fig 8). A majority of first and third molar enamel samples fall outside the expected local Basin of Mexico $^{87}Sr/^{86}Sr$ range. Non-local $^{87}Sr/^{86}Sr$ values in these tissues, which form during infancy and early childhood (first molars), and early adolescence (third molars), indicate that these individuals originated from regions that were geologically distinct from the Basin of Mexico. This provides further supporting evidence of the long-debated presence of Epiclassic migrants within the Basin of Mexico.

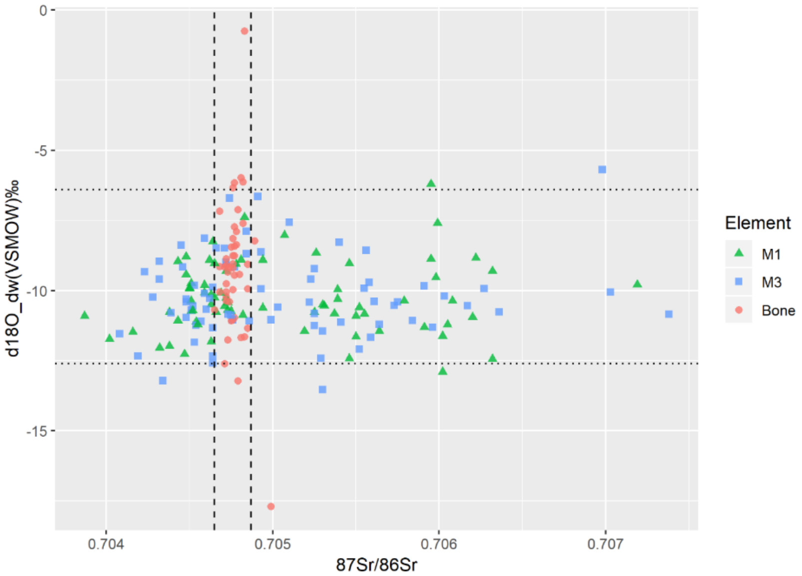

Figure 8. $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ results across all sampled human elements (*N*=194). This includes first molars (*n*=73), third molars (*n*=73), and bone (*n*=48). The expected local $^{87}Sr/^{86}Sr$ range is indicated by the dashed lines, while the expected local $\delta^{18}O$ range is indicated by the dotted lines.

Nearly all of these enamel samples, however, fall within the δ^{18}O range for the Basin of Mexico, suggesting that these individuals hailed from locales environmentally indistinguishable from the Basin of Mexico. Conversely, the relative paucity of non-local δ^{18}O values could also indicate that the established Non-Grid 4 δ^{18}O local range, necessarily expanded by the MMD of 3.1‰ to account for interlaboratory variability in sample treatment, is too broad to capture meaningful variation in distinct environments within ancient Mesoamerica, which tend to range clinally in increments of 1‰ (Moreiras Reynaga, 2019; Wassenaar et al., 2009). In stark contrast to enamel tissues, all bone samples with the exception of two (ACL-7995 XAL-C4-4 and ACL-8126 XAL-C28-2), fall within the combined local Basin of Mexico ^{87}Sr/^{86}Sr and δ^{18}O ranges, suggesting that migrant sacrificed individuals lived locally within the Basin for a significant period of time prior to their deaths.

Interestingly, there is great diversity in non-local ^{87}Sr/^{86}Sr values among migrant and foreign individuals, who together make up 80% of sampled sacrificial victims. Observed non-local ^{87}Sr/^{86}Sr values range from ^{87}Sr/^{86}Sr=0.70387-0.70738, falling significantly outside the expected Basin local range of ^{87}Sr/^{86}Sr=0.70465-0.70487. Because ^{87}Sr/^{86}Sr values are not unique, but rather reflect the age and composition of local bedrock, it is not possible to geolocate from where individuals with non-local ^{87}Sr/^{86}Sr signatures originated. However, comparison of observed ^{87}Sr/^{86}Sr values in sacrificial victims with reported local ^{87}Sr/^{86}Sr ranges throughout Mesoamerica discussed above offer some suggestions as to potential source locations for Non-Grid 4 migrants.

Sacrificial victims with non-local ^{87}Sr/^{86}Sr values falling below the expected local Basin of Mexico range overlap with local ranges from the Maya volcanic highlands, western Mexico, and the Montagua Valley within the Maya metamorphic province (Hodell et al., 2004; Price et al., 2008). Similarly, sacrificed individuals with ^{87}Sr/^{86}Sr values falling above the expected Basin of Mexico range coincide with local ^{87}Sr/^{86}Sr ranges from the Puebla-Tlaxcala Valley and the Xochicalco Formation within central Mexico, as well as with further regions, including northern Mexico, the southern Maya lowlands, and the Oaxaca Valley (Hodell et al., 2004; Offenbecker, 2018; Pacheco-Forés et al., 2020). Countless other regions throughout Mesoamerica have yet to be characterized biogeochemically. Therefore, further investigations using biogeochemistry as well as other bioarchaeological methods are needed to better discern the source of the Non-Grid 4 Epiclassic migrants in the Basin of Mexico.

Examining intra-individual patterns in ^{87}Sr/^{86}Sr values among sacrificial victims at the Non-Grid 4 shrine allows us to reconstruct sacrificial victims' residential histories across the life course to gain a more nuanced understanding of mobility patterns at the site (Fig 9). A majority of sampled individuals (53%, *n*=39) exhibited non-local first molar ^{87}Sr/^{86}Sr values and local third molar and/or bone ^{87}Sr/^{86}Sr values, suggesting they were immigrants who were born in a geologically distinct region but moved to the Basin of Mexico later in life. Similarly, 27% (*n*=20) of sampled individuals exhibited non-local ^{87}Sr/^{86}Sr values among all sampled tissues, suggesting they were foreigners who lived outside the Basin of Mexico for most of their lives, relocating to the Basin only shortly before their deaths, before their bone tissues incorporated a significant Basin ^{87}Sr/^{86}Sr signature. However, due to sampling limitations, only two of these foreigners have data from bone samples. The remaining 18 “foreign” individuals therefore may or may not have exhibited local bone ^{87}Sr/^{86}Sr values.

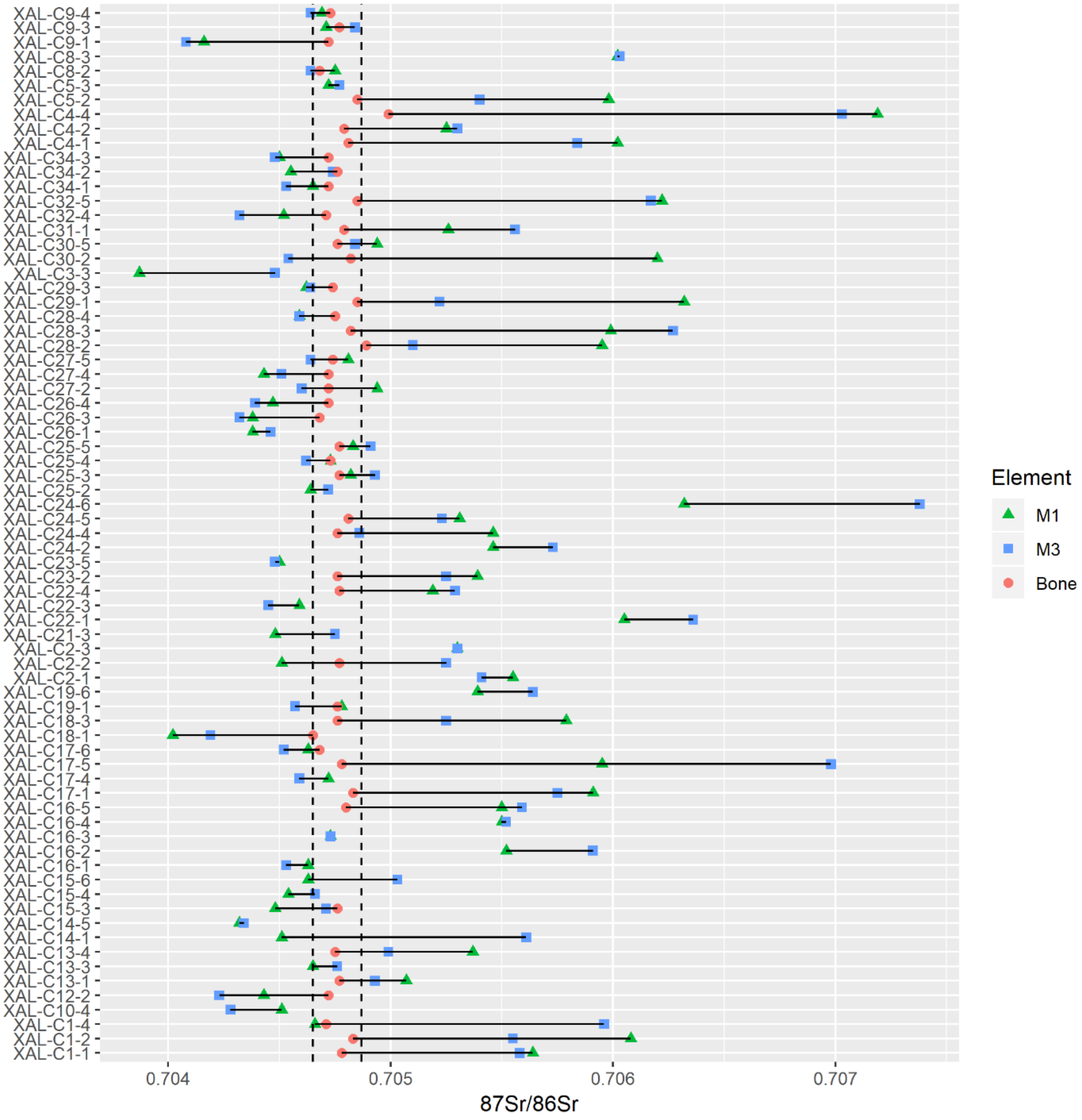

Figure 9. Intra-individual mobility among sacrificial victims interred at Non-Grid 4. Solid horizontal lines connect sampled skeletal elements taken from a single individual. Vertical dashed lines indicate the expected local ^{87}Sr/^{86}Sr range for the Basin of Mexico.

Furthermore, 12% (*n*=9) of sampled individuals were circular migrants who were born in the Basin but would leave and return periodically. Although the $^{87}Sr/^{86}Sr$ values in one individual (XAL-C17-4) suggest he was an emigrant (1% of the total sample) who was born in the Basin of Mexico and left later in life, this interpretation is based solely on enamel samples reflecting his early life and adolescence. He thus may or may not have also been a circular migrant. Finally, only 6% (*n*=4) of sampled individuals exhibited local Basin $^{87}Sr/^{86}Sr$ values among all sampled tissues, suggesting they were locals who lived in the region their entire lives. Thus, while some locals were present among the Non-Grid 4 shrine sacrificial victims, the vast majority of sampled sacrificed individuals were either immigrants or foreigners to the Basin of Mexico.

Identity-based violence at Non-Grid 4

Sacrificial victims' residential histories clarify the relationship between geographic origin, migration, and violence in central Mexico during the Epiclassic period. The high proportion of immigrant and foreign individuals (80%) and the low proportion of locals (6%) among the sampled sacrificial victims at Non-Grid 4 suggests that individuals with divergent geographic origins were more likely to suffer ritual violence during this period of socio-political reorganization.

Given that the Epiclassic is associated with migration into the Basin of Mexico, however, it is possible that local communities simply had higher numbers of migrants who, upon their deaths, may have been interred in normative as well as ritual contexts. Ideally, an examination of identity-based violence at Non-Grid 4 would compare the prevalence of migrants among ritual and normative burial contexts to see if migrants are disproportionately represented in the sacrificial context. The lack of a normative burial context at the Non-Grid 4 site thus complicates interpretations of the prevalence of non-local individuals within the sacrificial deposits. Furthermore, the scarcity of skeletal material from Epiclassic Basin sites limits potential comparisons of Non-Grid 4 migrant prevalence with other normative burial assemblages from this time period.

In the absence of normative Epiclassic central Mexican burial contexts, I compare Non-Grid 4 paleomobility patterns with those from Classic period Teotihuacan. Teotihuacan was known to have maintained its population through immigration (Nichols, 2016; White, Storey, et al., 2004). I thus use the prevalence of migrants at Teotihuacan as a rough approximation for expectations for a normative Epiclassic community dynamic. Previous biogeochemical studies examining migration at Classic Teotihuacan residential compounds found that migrants made up approximately one-third of sampled individuals, ranging from 27% to 37% depending on the compound (Nado, 2017; Schaaf et al., 2012; Solís Pichardo et al., 2017; White, Storey, et al., 2004). Furthermore, biogeochemical studies of other ancient Mesoamerican cities in the Maya region found that migrants made up between 14% to 16% of sampled individuals at Calakmul and Tikal (Price et al., 2018; Wright, 2012). In contrast, at Non-Grid 4, 80% of individuals are migrants. Migrant individuals are thus present in sacrificial contexts in far greater numbers than would be expected in a community experiencing sustained immigration.

As discussed previously, extensive anthropological, behavioral science, evolutionary psychology, and peace studies research indicate that periods of socio-political upheaval are often accompanied by a rise in identity-based violence (Böhm et al., 2016; Bowman, 1994; Haken et al., 2014; Howard, 2014; Kurin, 2016; Mamdani, 2002; Messner et al., 2019; Schmidt & Schröder, 2001; Schwandner-Sievers, 2001; Simunovic et al., 2013). In conjunction with ethnohistoric and archaeological evidence indicating that migrants often intentionally maintained and invoked visible material ties to their places of origin that may have set them apart in their new communities (e.g., Sahagún, 1961; Spence, 2005; Begun, 2013; Manzanilla, 2017), observed paleomobility patterns among sacrificial victims at Non-Grid 4 therefore strongly suggest that these individuals were victims of identity-based violence who were targeted for violence based on their divergent geographic origins in the balkanized socio-political landscape of the Epiclassic Basin of Mexico.

Conclusion

The biogeochemical data presented here provide compelling evidence that the individuals ritually sacrificed and interred at the Epiclassic Non-Grid 4 shrine site in the northern Basin of Mexico were victims of identity-based violence. A large majority of sampled individuals (80%) were born and lived their early lives outside of the Basin of Mexico, though most of these individuals relocated to the Basin and lived there for a significant period of time prior to their deaths (see Fig 9). I therefore provide direct evidence of first-generation migrants in the Epiclassic Basin of Mexico.

Furthermore, the relative paucity of sacrificial victims who were born and lived their entire lives in the Basin (6%) suggests that migrant individuals were disproportionately more likely to suffer ritual violence during the Epiclassic period. As geographic origin was an ethnohistorically and archaeologically demonstrated salient indicator of social difference in pre-Hispanic Mesoamerica, these migrant individuals were most likely targeted for violence based on their divergent residential histories and geographic origins. This work further develops a theoretical framework within which to examine identity-based violence archaeologically, connecting broader research on identity and violence within the social sciences to bioarchaeologically observable aspects of identity in the past in contexts of large-scale violence. It thus contributes to anthropological knowledge of the social context of violence, examining the interaction between specific social identities; complex social processes like political fragmentation, migration, and demographic change; and instances of mass violence.

REFERENCES

Abascal, R., Harbottle, G., & Sayre, E. (1974). Correlation between terra cotta figurines and pottery from the Valley of Mexico and source clays by activation analysis. In C. Beck (Ed.), Archaeological chemistry (pp. 81–99). Washington, D.C.: Chemical Society.

Akademische Druck (Ed.). (1979). Codex Vaticanus A (Codex Ríos). Graz, Austria: Akademische Druck und Verlagsanstalt.

Álvarez-Sandoval, B. A., Manzanilla, L. R., González-Ruiz, M., Malgosa, A., & Montiel, R. (2015). Genetic evidence supports the multiethnic character of Teopancazco, a neighborhood center of Teotihuacan, Mexico (AD 200-600). PLOS ONE, 10(7), e0132371. https://doi.org/10.1371/journal.pone.0132371

Anderson, J. H., Healan, D. M., & Cobean, R. H. (2016). Collapse, regeneration, and the origins of Tula and the Toltec state. In R. K. Faulseit (Ed.), Beyond collapse: archaeological perspectives on resilience, revitalization, and transformation in complex societies (pp. 431–458). Carbondale, Illinois: Southern Illinois University Press.

Andrews, A. P. (1983). Maya salt production and trade. Tucson, AZ: The University of Arizona Press.

Andrushko, V. A., & Torres, E. C. (2011). Skeletal evidence for Inca warfare from the Cuzco region of Peru. American Journal of Physical Anthropology, 146(3), 361–372. https://doi.org/10.1002/ajpa.21574

Arkush, E., & Tung, T. A. (2013). Patterns of war in the Andes from the Archaic to the Late Horizon: insights from settlement patterns and cranial trauma. Journal of Archaeological Research, 21(4), 307–369. https://doi.org/10.1007/s10814-013-9065-1

Ashburn-Nardo, L., Voils, C. I., & Monteith, M. J. (2001). Implicit associations as the seeds of intergroup bias: how easily do they take root? Journal of Personality and Social Psychology, 81(5), 789–799. http://dx.doi.org.ezproxy1.lib.asu.edu/10.1037/0022-3514.81.5.789

Balcaen, L., Schrijver, I. D., Moens, L., & Vanhaecke, F. (2005). Determination of the 87Sr/86Sr isotope ratio in USGS silicate reference materials by multi-collector ICP–mass spectrometry. International Journal of Mass Spectrometry, 242(2–3), 251–255. https://doi.org/10.1016/j.ijms.2004.10.025

Barba, L., Blancas, J., Manzanilla, L. R., Ortiz, A., Barca, D., Crisci, G. M., … Pecci, A. (2009). Provenance of the limestone used in Teotihuacan (Mexico): a methodological approach. Archaeometry, 51(4), 525–545. https://doi.org/10.1111/j.1475-4754.2008.00430.x

Barba Pingarrón, L. (2013). El uso de la cal en el mundo prehispánico mesoamericano. In L. Barba Pingarrón & I. Villaseñor (Eds.), La cal: historia, propiedades y usos (pp. 19–46). Mexico City: Universidad Nacional Autónoma de México Instituto de Investigaciones Antropológicas.

Barth, F. (1969). Introduction: ethnic groups and boundaries. In F. Barth (Ed.), Ethnic groups and boundaries: the social organization of culture difference (pp. 9–38). Prospect Heights, IL: Waveland Press.

Beekman, C. S., & Christensen, A. F. (2003). Controlling for doubt and uncertainty through multiple lines of evidence: a new look at the Mesoamerican Nahua migrations. Journal of Archaeological Method and Theory, 10(2), 111–164. https://doi.org/10.1023/A:1024519712257

Begun, E. M. (2013). Detecting ethnicity at Teotihuacan through archaeology: the West Mexican presence at Structure N1W5:19 (Ph.D. dissertation). University of Iowa, Iowa City, IO.

Bentley, R. A. (2006). Strontium isotopes from the earth to the archaeological skeleton: a review. Journal of Archaeological Method and Theory, 13(3), 135–187. https://doi.org/10.1007/s10816-006-9009-x

Berdan, F., & Anawalt, P. R. (Eds.). (1997). The essential Codex Mendoza. Berkeley: University of California Press.

Bigler, R. S., Jones, L. C., & Lobliner, D. B. (1997). Social categorization and the formation of intergroup attitudes in children. Child Development, 68(3), 530–543. https://doi.org/10.1111/j.1467-8624.1997.tb01956.x

Bobo, L. (1983). Whites’ opposition to busing: symbolic racism or realistic group conflict? Journal of Personality and Social Psychology, 45(6), 1196–1210. http://dx.doi.org.ezproxy1.lib.asu.edu/10.1037/0022-3514.45.6.1196

Böhm, R., Rusch, H., & Gürerk, Ö. (2016). What makes people go to war? Defensive intentions motivate retaliatory and preemptive intergroup aggression. Evolution and Human Behavior, 37(1), 29–34. https://doi.org/10.1016/j.evolhumbehav.2015.06.005

Bowen, G. J., Wassenaar, L. I., & Hobson, K. A. (2005). Global application of stable hydrogen and oxygen isotopes to wildlife forensics. Oecologia, 143(3), 337–348.

Bowman, G. (1994). Xenophobia, fantasy, and the nation: the logic of ethnic violence in Former Yugoslavia. In V. Goddard, L. Josep, & C. Shore (Eds.), Anthropology of Europe: identity and boundaries in conflict (pp. 143–171). Oxford: Berg Press.

Bowman, G. (2001). The violence in identity. In Anthropology of violence and conflict (pp. 25–46). London: Routledge.

Brettell, R., Montgomery, J., & Evans, J. (2012). Brewing and stewing: the effect of culturally mediated behaviour on the oxygen isotope composition of ingested fluids and the implications for human provenance studies. Journal of Analytical Atomic Spectrometry, 27(5), 778. https://doi.org/10.1039/c2ja10335d

Brubaker, R., & Cooper, F. (2000). Beyond "identity." Theory and Society, 29(1), 1–47. https://doi.org/10.1023/A:1007068714468

Buikstra, J. E., & Scott, R. E. (2009). Key concepts in identity studies. In K. J. Knudson & C. M. Stojanowski (Eds.), Bioarchaeology and identity in the Americas (pp. 24–55). Gainesville, FL: University Press of Florida.

Bush, K. D., & Keyman, E. F. (1997). Identity-based conflict: Rethinking security in a post–Cold War world. *Global Governance*, *3*(3), 311–328.

Cabrera Castro, R. (1998). Teotihuacan: nuevos datos para el estudio de las rutas de comunicación. In E. C. Rattray (Ed.), Rutas de intercambio en Mesoamérica: III Coloquio Pedro Bosch Gimpera (pp. 57–75). Mexico City: Universidad Nacional Autónoma de México.

Campbell, D. T. (1965). Ethnocentric and other altruistic motives. In D. Levine (Ed.), Nebraska symposium on motivation (pp. 283–311). Lincoln, NE: University of Nebraska Press.

Christensen, A. F. (1997). Cranial non-metric variation in north and central Mexico. Anthropologischer Anzeiger, 55(1), 15–32.

Codex Azcatitlan. (1949). Paris: Societé des Americanistes.

Codex Boturini: tira de la peregrinación mexica. (1944). Mexico City: Librería Anticuaria.

Códice Aubin: manuscrito azteca de la Biblioteca Real de Berlín. (1963). Madrid: Ediciones José Porrúa Turanzas.

Collins, P. H. (2015). Intersectionality's definitional dilemmas. Annual Review of Sociology, 41(1), 1–20. https://doi.org/10.1146/annurev-soc-073014-112142

Coplen, T. B., Kendall, C., & Hopple, J. (1983). Comparison of stable isotope reference samples. Nature, 302, 236–238.

Cowgill, G. L. (2013). Possible migrations and shifting identities in the central Mexican Epiclassic. Ancient Mesoamerica, 24(01), 131–149. https://doi.org/10.1017/S0956536113000060

Cowgill, G. L. (2015). Ancient Teotihuacan: early urbanism in central Mexico. Cambridge, U.K.: Cambridge University Press.

Craig, H. (1957). Isotopic standards for carbon and oxygen and correction factors for mass-spectrometric analysis of carbon dioxide. Geochimica et Cosmochimica Acta, 12(1), 133–149. https://doi.org/10.1016/0016-7037(57)90024-8

Craig, H. (1961). Standard for reporting concentrations of deuterium and oxygen-18 in natural waters. Science, 133(3467), 1833–1834. https://doi.org/10.1126/science.133.3467.1833

Crandall, J. J., & Thompson, J. L. (2014). Beyond victims: exploring the identity of sacrificed infants and children at La Cueva de los Muertos Chiquitos, Durango, Mexico (AD 571-1168). In Tracing childhood: bioarchaeological investigations of early lives in antiquity (pp. 36–57). Gainesville, FL: University Press of Florida.

Crider, D. L. (2011). Epiclassic and early Postclassic interaction in central Mexico as evidenced by decorated pottery (Ph.D. dissertation). Arizona State University, Tempe, AZ.

Crider, D. L. (2013). Shifting alliances: Epiclassic and early Postclassic interactions at Cerro Portezuelo. Ancient Mesoamerica, 24(01), 107–130. https://doi.org/10.1017/S0956536113000047

D'Altroy, T. N. (1992). Provincial power in the Inka empire. Washington, D.C.: Smithsonian Institution Press.

Dansgaard, W. (1964). Stable isotopes in precipitation. Tellus, 16(4), 436–468. https://doi.org/10.1111/j.2153-3490.1964.tb00181.x

Dasch, E. J. (1969). Strontium isotopes in weathering profiles, deep-sea sediments, and sedimentary rocks. Geochimica et Cosmochimica Acta, 33(12), 1521–1552.

Daux, V., Lécuyer, C., Héran, M.-A., Amiot, R., Simon, L., Fourel, F., … Escarguel, G. (2008). Oxygen isotope fractionation between human phosphate and water revisited. Journal of Human Evolution, 55(6), 1138–1147. https://doi.org/10.1016/j.jhevol.2008.06.006

De La Cruz, I., González-Oliver, A., Kemp, B. M., Román Berrelleza, J. A., Smith, D. G., & Torre-Blanco, A. (2008). Sex identification of children sacrificed to the ancient Aztec rain gods in Tlatelolco. Current Anthropology, 49(3), 519–526. https://doi.org/10.1086/587642

Diehl, R. A., & Berlo, J. C. (Eds.). (1989). Mesoamerica after the decline of Teotihuacan AD 700-900. Washington, D.C: Dumbarton Oaks.

Duncan, W. N. (2005). The bioarchaeology of ritual violence in Postclassic El Peten, Guatemala (AD 950--1524) (Ph.D.). Southern Illinois University at Carbondale, United States -- Illinois.

Duncan, W. N. (2011). Bioarchaeological analysis of sacrificial victims from a postclassic Maya temple from Ixlu, El Peten, Guatemala. Latin American Antiquity, 22(4), 549–572.

Duncan, W. N. (2012). Biological distance analyses in contexts of ritual violence. In D. L. Martin, R. P. Harrod, & V. R. Pérez (Eds.), The bioarchaeology of violence: bioarchaeological interpretations of the human past: local, regional, and global perspectives (pp. 251–275). Gainesville, FL: University Press of Florida.

Dunham, Y., & Emory, J. (2014). Of affect and ambiguity: the emergence of preference for arbitrary ingroups. Journal of Social Issues, 70(1), 81–98. https://doi.org/10.1111/josi.12048

Dunham Yarrow, Baron Andrew Scott, & Carey Susan. (2011). Consequences of “minimal” group affiliations in children. Child Development, 82(3), 793–811. https://doi.org/10.1111/j.1467-8624.2011.01577.x

Durán, D. (1867). Historia de las Indias de Nueva España y islas de tierra firme (Vols. 1–2; J. F. Ramirez, Ed.). México D.F.: J. M. Andrade y F. Escalante.

Durazo, J., & Farvolden, R. N. (1989). The groundwater regime of the Valley of Mexico from historic evidence and field observations. Journal of Hydrology, 112(1–2), 171–190. https://doi.org/10.1016/0022-1694(89)90187-X

Efferson, C., Lalive, R., & Fehr, E. (2008). The coevolution of cultural groups and ingroup favoritism. Science, 321(5897), 1844–1849. https://doi.org/10.1126/science.1155805

Ericson, J. E. (1985). Strontium isotope characterization in the study of prehistoric human ecology. Journal of Human Evolution, 14(5), 503–514.

Esses, V. M., Dovidio, J. F., Jackson, L. M., & Armstrong, T. L. (2001). The immigration dilemma: the role of perceived group competition, ethnic prejudice, and national identity. Journal of Social Issues, 57(3), 389–412. https://doi.org/10.1111/0022-4537.00220

Evans, J. A., & Tatham, S. (2004). Defining 'local signature' in terms of Sr isotope composition using a tenth- to twelfth-century Anglo-Saxon population living on a Jurassic clay-carbonate terrain, Rutland, UK. Geological Society, London, Special Publications, 232(1), 237–248. https://doi.org/10.1144/GSL.SP.2004.232.01.21

Everett, J. A. C., Faber, N. S., & Crockett, M. (2015). Preferences and beliefs in ingroup favoritism. Frontiers in Behavioral Neuroscience, 9, 1–21. https://doi.org/10.3389/fnbeh.2015.00015

Faure, G., & Powell, J. L. (1972). Strontium isotope geology. New York, NY: Springer-Verlag.

Feliciano Velázquez, P. (Ed.). (1975). Codex Chimalpopoca: anales de Cuauhtitlan y leyenda de los soles. Mexico City: Universidad Nacional Autónoma de México Instituto de Investigaciones Históricas.

Fenner, J. N., & Wright, L. E. (2014). Revisiting the strontium contribution of sea salt in the human diet. Journal of Archaeological Science, 44, 99–103. https://doi.org/10.1016/j.jas.2014.01.020

Finegold, A. (2012). Dramatic renditions: battle murals and the struggle for elite legitimacy in Epiclassic Mesoamerica (Ph.D.). Columbia University, New York, NY.

Flockhart, D. T. T., Kyser, T. K., Chipley, D., Miller, N. G., & Norris, D. R. (2015). Experimental evidence shows no fractionation of strontium isotopes (87Sr/86Sr) among soil, plants, and herbivores: implications for tracking wildlife and forensic science. Isotopes in Environmental and Health Studies, 51(3), 372–381. https://doi.org/10.1080/10256016.2015.1021345

Fournier, P., & Bolaños, V. (2007). The Epiclassic in the Tula region beyond Tula Chico. In C. Kristan-Graham & J. Kowalski (Eds.), Twin Tollans: Chichén Itzá, Tula, and the epiclassic to early postclassic Mesoamerican world (pp. 481–529). Washington, D.C.: Dumbarton Oaks.

Fowler, J. H., & Kam, C. D. (2007). Beyond the self: social identity, altruism, and political participation. Journal of Politics, 69(3), 813–827. https://doi.org/10.1111/j.1468-2508.2007.00577.x

Friedman, I., O'Neil, J., & Cebula, G. (1982). Two new carbonate stable isotope standards. Geostandards Newsletter, 6, 11–12.

Gagnon, C. M., Andrus, C. F. T., Ida, J., & Richardson, N. (2015). Local water source variation and experimental chicha de maíz brewing: implications for interpreting human hydroxyapatite δ18O values in the Andes. Journal of Archaeological Science: Reports, 4, 174–181. https://doi.org/10.1016/j.jasrep.2015.09.008

Galler, P., Limbeck, A., Boulyga, S. F., Stingeder, G., Hirata, T., & Prohaska, T. (2007). Development of an on-line flow injection Sr/matrix separation method for accurate, high-throughput determination of Sr isotope ratios by multiple collector-inductively coupled plasma-mass spectrometry. Analytical Chemistry, 79(13), 5023–5029. https://doi.org/10.1021/ac070307h

Galtung, J. (2013). Violence: direct, structural and cultural. In J. Galtung & D. Fischer (Eds.), Johan Galtung: pioneer of peace research (pp. 35–40). New York: Springer.

García Cook, A. (2013). El Epiclásico en la región poblano-tlaxcalteca. In BAR International Series: Vol. 2488. The Olmeca-Xicallanca of Teotihuacan, Cacaxtla, and Cholula: an archaeological, ethnohistorical, and linguistic synthesis (pp. 1–54). Oxford: Archaeopress.

García Velasco, M. (2014). Estudio de un contexto sacrifical en Xaltocan (Estado de México) (M.A. thesis). Universidad Nacional Autónoma de México, Mexico City.

García Velasco, M. (2019). Estudio craneológico de un conjunto de individuos sacrificados en Xaltocan en el periodo epiclásico (Ph.D. dissertation). Universidad Nacional Autónoma de México, Mexico City.

Gat, J. R. (1996). Oxygen and hydrogen isotopes in the hydrologic cycle. Annual Review of Earth and Planetary Sciences, 24(1), 225–262. https://doi.org/10.1146/annurev.earth.24.1.225

Gómez Chavez, S. (1998). Nuevos datos sobre la relación de Teotihuacan y el Occidente de México. In XXIV Mesa Redonda de La Sociedad Mexicana de Antropología. Antropología e historia del Occidente de México (pp. 1461–1493). Mexico City: Sociedad Mexicana de Antropología, Universidad Nacional Autónoma de México.

Gómez Chavez, S. (2002). Presencia del Occidente de México en Teotihuacán: aproximaciones a la política exterior del estado Teotihuacano. In M. E. Ruiz Gallut (Ed.), Ideología y política a través de materiales, imágenes y símbolos (pp. 563–625). Mexico City: Universidad Nacional Autónoma de México Instituto de Investigaciones Antropológicas.

Gómez, J. M., Verdú, M., González-Megías, A., & Méndez, M. (2016). The phylogenetic roots of human lethal violence. Nature, 538, 233–237. https://doi.org/10.1038/nature19758

González-José, R., Martínez-Abadías, N., González-Martín, A., Bautista-Martínez, J., Gómez-Valdés, J., Quinto, M., & Hernández, M. (2007). Detection of a population replacement at the Classic–Postclassic transition in Mexico. Proceedings of the Royal Society B: Biological Sciences, 274(1610), 681–688. https://doi.org/10.1098/rspb.2006.0151

Gorenflo, L. J., & Sanders, W. T. (2007). Archaeological settlement pattern data from the Cuautitlan, Temascalapa, and Teotihuacan regions, Mexico. University Park, PA: Department of Anthropology, Pennsylvania State University.

Graulich, M. (2006). Aztec human sacrifice as expiation. In J. N. Bremmer (Ed.), The strange world of human sacrifice (pp. 9–30). Leuven, Belgium: Peeters Publishers.

Haken, N., Messner, J. J., Hendry, K., Taft, P., Lawrence, K., Brisard, L., & Umaña, F. (2014). Fragile states index 2014. Washington, D.C.: The Fund for Peace.

Harmon, B. G., Becker, D. E., Jensen, A. H., & Baker, D. H. (1969). Nutrient composition of corn and soybean meal. Journal of Animal Science, 28, 459–464.

Healan, D. M. (2012). The archaeology of Tula, Hidalgo, Mexico. Journal of Archaeological Research, 20(1), 53–115. https://doi.org/10.1007/s10814-011-9052-3

Healan, D. M., & Cobean, R. H. (2019). Three migration case studies from the Tula region. In C. S. Beekman (Ed.), Migrations in late Mesoamerica (pp. 66–87). Gainesville, FL: University Press of Florida.

Hernández, C. L., & Healan, D. M. (2019). Migration and the Coyotlatelco ceramic tradition: evidence from El Bajío. In C. S. Beekman (Ed.), Migrations in late Mesoamerica (pp. 88–108). Gainesville, FL: University Press of Florida.

Herring, D. A., Saunders, S. R., & Katzenberg, M. A. (1998). Investigating the weaning process in past populations. American Journal of Physical Anthropology, 105(4), 425–439. https://doi.org/10.1002/(SICI)1096-8644(199804)105:4<425::AID-AJPA3>3.0.CO;2-N

Hillson, S. (1996). Dental anthropology. Cambridge, UK: Cambridge University Press.

Hirth, K. G. (1989). Militarism and social organization at Xochicalco, Morelos. In R. A. Diehl & J. C. Berlo (Eds.), Mesoamerica after the decline of Teotihuacan A.D. 700-900 (pp. 69–82). Washington, D.C.: Dumbarton Oaks.

Hirth, K. G. (2000). Archaeological research at Xochicalco. University of Utah Press.

Hodell, D. A., Quinn, R. L., Brenner, M., & Kamenov, G. (2004). Spatial variation of strontium isotopes (87Sr/86Sr) in the Maya region: a tool for tracking ancient human migration. Journal of Archaeological Science, 31(5), 585–601. https://doi.org/10.1016/j.jas.2003.10.009

Hoffmeister, K., & Wright, L. E. (2016). The origins and identities of the Colha Skull Pit skeletal remains. Presented at the 81st Annual Meeting of the Society for American Archaeology, Orlando, FL.

Howard, T. (2014). Failed states and the origins of violence: a comparative analysis of state failure as a root cause of terrorism and political violence. Burlington, VT: Ashgate Publishing Company.

Hut, G. (1987). Consultants' group meeting on stable isotope reference samples for geochemical and hydrological investigations. Vienna, Austria: International Atomic Energy Agency.

Iacumin, P., Bocherens, H., Mariotti, A., & Longinelli, A. (1996). Oxygen isotope analyses of co-existing carbonate and phosphate in biogenic apatite: a way to monitor diagenetic alteration of bone phosphate? Earth and Planetary Science Letters, 142(1), 1–6. https://doi.org/10.1016/0012-821X(96)00093-3

IAEA. (1992). Statistical treatment of data on environmental isotopes in precipitation. Vienna, Austria: International Atomic Energy Agency (IAEA).

Inomata, T. (2003). War, destruction, and abandonment: the fall of the Classic Maya center of Aguateca, Guatemala. In T. Inomata & R. W. Webb (Eds.), The archaeology of settlement abandonment in Middle America (pp. 43–60). Salt Lake City, UT: University of Utah Press.

Inomata, T. (2014). Fire intensity assessment through the analysis of artifacts and building materials: burning and abandonment at the Classic Maya sites of Aguateca and Ceibal, Guatemala. Advances in Archaeological Practice, 2(1), 50–63. https://doi.org/10.7183/2326-3768.2.1.50

Issar, A., Quijano, J. L., Gat, J. R., & Castro, M. (1984). The isotope hydrology of the groundwaters of central Mexico. Journal of Hydrology, 71(3–4), 201–224. https://doi.org/10.1016/0022-1694(84)90097-0

Jackson, J. W. (1993). Realistic group conflict theory: a review and evaluation of the theoretical and empirical literature. The Psychological Record, 43, 395–414.

Jenkins, R. (2004). Social identity (2nd edition). New York: Routledge.

Johnson, E. S., & Marston, J. M. (2020). The experimental identification of nixtamalized maize through starch spherulites. Journal of Archaeological Science, 113, 105056. https://doi.org/10.1016/j.jas.2019.105056

Kamenov, G. D., Lofaro, E. M., Goad, G., & Krigbaum, J. (2018). Trace elements in modern and archaeological human teeth: implications for human metal exposure and enamel diagenetic changes. Journal of Archaeological Science, 99, 27–34. https://doi.org/10.1016/j.jas.2018.09.002

Katzenberg, M. A. (2008). Stable isotope analysis: a tool for studying past diet, demography, and life history. In M. A. Katzenberg & S. R. Saunders (Eds.), Biological anthropology of the human skeleton (pp. 413–442). New York: Wiley-Liss.

Kelly, D. J., Quinn, P. C., Slater, A. M., Lee, K., Gibson, A., Smith, M., … Pascalis, O. (2005). Three-month-olds, but not newborns, prefer own-race faces. Developmental Science, 8(6), F31–F36. https://doi.org/10.1111/j.1467-7687.2005.0434a.x

Kieffer, C. L. (2017). Sacrifice of the social outcasts: two cases of Klippel–Feil syndrome at Midnight Terror Cave, Belize. International Journal of Osteoarchaeology, 27, 45–55. https://doi.org/10.1002/oa.2456

Kinzler, K. D., Corriveau, K. H., & Harris, P. L. (2011). Children's selective trust in native-accented speakers. Developmental Science, 14(1), 106–111. https://doi.org/10.1111/j.1467-7687.2010.00965.x

Kirchhoff, P., Odena Güemes, L., & Reyes García, L. (Eds.). (1976). Historia tolteca-chichimeca. Puebla, Mexico: Fondo de Cultura Económica, CIESAS.

Knudson, K. J., Goldstein, P. S., Dahlstedt, A., Somerville, A., & Schoeninger, M. J. (2014). Paleomobility in the Tiwanaku diaspora: biogeochemical analyses at Rio Muerto, Moquegua, Peru. American Journal of Physical Anthropology, 155(3), 405–421. https://doi.org/10.1002/ajpa.22584

Knudson, K. J., O'Donnabhain, B., Carver, C., Cleland, R., & Price, T. D. (2012). Migration and Viking Dublin: paleomobility and paleodiet through isotopic analyses. Journal of Archaeological Science, 39(2), 308–320. https://doi.org/10.1016/j.jas.2011.09.014

Knudson, K. J., & Price, T. D. (2007). Utility of multiple chemical techniques in archaeological residential mobility studies: case studies from Tiwanaku- and Chiribaya-affiliated sites in the Andes. American Journal of Physical Anthropology, 132(1), 25–39. https://doi.org/10.1002/ajpa.20480

Knudson, K. J., Stanish, C., Lozada Cerna, M. C., Faull, K. F., & Tantaleán, H. (2016). Intra-individual variability and strontium isotope measurements: A methodological study using 87Sr/86Sr data from Pampa de los Gentiles, Chincha Valley, Peru. Journal of Archaeological Science: Reports, 5, 590–597. https://doi.org/10.1016/j.jasrep.2016.01.016

Knudson, K. J., & Stojanowski, C. M. (2008). New directions in bioarchaeology: recent contributions to the study of human social identities. Journal of Archaeological Research, 16(4), 397–432. https://doi.org/10.1007/s10814-008-9024-4

Knudson, K. J., & Stojanowski, C. M. (Eds.). (2009). The bioarchaeology of identity in the Americas. Gainesville, FL: University Press of Florida.

Koch, P. L., Tuross, N., & Fogel, M. L. (1997). The effects of sample treatment and diagenesis on the isotopic integrity of carbonate in biogenic hydroxylapatite. Journal of Archaeological Science, 24(5), 417–429. https://doi.org/10.1006/jasc.1996.0126

Kohn, M. J. (1996). Predicting animal δ 18 O: accounting for diet and physiological adaptation. Geochimica et Cosmochimica Acta, 60(23), 4811–4829.

Koontz, R. A. (1994). The iconography of El Tajín, Veracruz, Mexico (Ph.D. dissertation). University of Texas, Austin, TX.

Kurin, Danielle S. (2014). Cranial trauma and cranial modification in post-imperial Andahuaylas, Peru. In D. L. Martin & C. P. Anderson (Eds.), Bioarchaeological and forensic perspectives on violence: how violent death is interpreted from skeletal remains (pp. 236–260). Cambridge: Cambridge University Press.

Kurin, Danielle S. (2016). The bioarchaeology of societal collapse and regeneration in ancient Peru. Springer.

Locksley, A., Ortiz, V., & Hepburn, C. (1980). Social categorization and discriminatory behavior: extinguishing the minimal intergroup discrimination effect. Journal of Personality and Social Psychology, 39(5), 773–783. https://doi.org/10.1037/0022-3514.39.5.773

Longinelli, A. (1984). Oxygen isotopes in mammal bone phosphate: a new tool for paleohydrological and paleoclimatological research? Geochimica et Cosmochimica Acta, 48(2), 385–390. https://doi.org/10.1016/0016-7037(84)90259-X

López Luján, L., Chávez Balderas, X., Valentín, N., & Montúfar, A. (2010). Huitzilopochtli y el sacrificio de niños en el Templo Mayor de Tenochtitlan. In El sacrificio humano en la tradición religiosa mesoamericana (pp. 367–394). México D.F.: Instituto Nacional de Antropología e Historia.

López Luján, L., & Olivier, G. (Eds.). (2010). El sacrificio humano en la tradición religiosa mesoamericana. Mexico City: Instituto Nacional de Antropología e Historia, Universidad Nacional Autónoma de México.

Lorenz, S., Marks, N., & Brady, J. (2016). Geographic origins of child sacrifices: radiogenic strontium isotope analyses from Midnight Terror Cave, Belize. Paper presented at the 81st Annual Meeting of the Society for American Archaeology, Orlando, FL.

Luz, B., & Kolodny, Y. (1989). Oxygen isotope variation in bone phosphate. Applied Geochemistry, 4(3), 317–323. https://doi.org/10.1016/0883-2927(89)90035-8

Luz, B., Kolodny, Y., & Horowitz, M. (1984). Fractionation of oxygen isotopes between mammalian bone-phosphate and environmental drinking water. Geochimica et Cosmochimica Acta, 48(8), 1689–1693. https://doi.org/10.1016/0016-7037(84)90338-7

Mamdani, M. (2002). When victims become killers: colonialism, nativism, and the genocide in Rwanda (3. print., and 1. paperback print). Princeton: Princeton Univ. Press.

Manahan, T. K. (2004). The way things fall apart: social organization and the Classic Maya collapse of Copan. Ancient Mesoamerica, 15(01), 107–125. https://doi.org/10.1017/S0956536104151092

Manzanilla, L. R. (2007). Las “casas” nobles de los barrios de Teotihuacan: estructuras exclusionistas en un entorno corporativo. In Memoria 2007 (pp. 453–470). Mexico City: El Colegio Nacional.

Manzanilla, L. R. (Ed.). (2017). Multiethnicity and migration at Teopancazco: investigations of a Teotihuacan neighborhood center. Gainesville, FL: University Press of Florida.

Mastache, A. G., Cobean, R. H., & Healan, D. M. (2002). Ancient Tollan: Tula and the Toltec heartland. Boulder, CO: University Press of Colorado.

McAnany, P. A., & Yoffee, N. (2012). Questioning collapse: human resilience, ecological vulnerability, and the aftermath of empire. Cambridge: Cambridge University Press.

McVicker, D. (2007). Images of violence in Mesoamerican mural art. In R. J. Chacon & R. G. Mendoza (Eds.), Latin American indigenous warfare and ritual violence (pp. 73–90). Tucson, AZ: University of Arizona Press.

Mendoza, R. G. (1992). Conquest polities of the Mesoamerican Epiclassic: circum-Basin regionalism, A.D. 550-850 (Ph.D. dissertation). The University of Arizona, United States.

Messner, J. J., Taft, P., Moges, D., Quinn, A., Bhambani, R., Fiertz, C., … Onyekwere, I. (2019). Fragile States Index annual report 2019 (p. 43). Retrieved from The Fund for Peace website: https://fundforpeace.org/wp-content/uploads/2019/04/9511904-fragilestatesindex.pdf

Meza Peñaloza, A. (2015). Afinidades biológicas y contextos culturales en los antiguos teotihuacanos. Mexico City: Universidad Nacional Autónoma de México, Instituto de Investigaciones Antropológicas.

Meza-Peñaloza, A., Zertuche, F., García-Velasco, M., & Morehart, C. (2019). A non-metric traits study of skulls from Epiclassic Xaltocan in relation to other

Mesoamerican cultures. Journal of Archaeological Science: Reports, 23, 559–566. https://doi.org/10.1016/j.jasrep.2018.11.031

Miriello, D., Barca, D., Crisci, G. M., Barba, L., Blancas, J., Ortíz, A., … Luján, L. L. (2011). Characterization and provenance of lime plasters from the Templo Mayor of Tenochtitlan (Mexico City). Archaeometry, 53(6), 1119–1141. https://doi.org/10.1111/j.1475-4754.2011.00603.x

Mock, S. B. (1994). Destruction and denouement during the Late-Terminal Classic: the Colha skull pit. In T. Hester, H. Shafer, & J. Eaton (Eds.), Continuing archaeology at Colha, Belize (pp. 221–231). Austin, TX: Texas Archaeological Research Laboratory, University of Texas, Austin.

Moorbath, S., Thorpe, R. S., & Gibson, I. L. (1978). Strontium isotope evidence for petrogenesis of Mexican andesites. Nature, 271(5644), 437–439. https://doi.org/10.1038/271437a0

Morán-Zenteno, D. (1994). The geology of the Mexican republic (J. L. Wilson & L. Sanchez-Barreda, Trans.). Cincinnati, OH: American Association of Petroleum Geologists.

Morehart, C. T. (2010). The archaeology of farmscapes: production, place, and the materiality of landscape at Xaltocan, Mexico (Ph.D.). Northwestern University, Chicago, IL.

Morehart, C. T. (2012). Mapping ancient chinampa landscapes in the Basin of Mexico: a remote sensing and GIS approach. Journal of Archaeological Science, 39(7), 2541–2551. https://doi.org/10.1016/j.jas.2012.03.001

Morehart, C. T. (2016a). Let the earth forever remain! Landscape legacies and the materiality of history in the northern Basin of Mexico. Journal of the Royal Anthropological Institute, 22, 939–961. https://doi.org/10.1111/1467-9655.12498

Morehart, C. T. (2016b). Proyecto de ecología histórica del norte de la cuenca de México: informe de la temporada de campo 2015 [Annual excavation report]. Mexico City: Instituto Nacional de Antropología e Historia.

Morehart, C. T. (2017). Ritual time: the struggle to pinpoint the temporality of ritual practice using archaeobotanical data. In M. P. Sayre & M. C. Bruno (Eds.), Social perspectives on ancient lives from paleoethnobotanical data (pp. 145–158). https://doi.org/10.1007/978-3-319-52849-6_7

Morehart, C. T., Peñaloza, A. M., Sánchez, C. S., de Tapia, E. M., & Morales, E. I. (2012). Human sacrifice during the Epiclassic period in the northern Basin of Mexico. Latin American Antiquity, 23(4), 426–448.

Moreira, G., F, J., Bavel, V., J, J., & Telzer, E. H. (2017). The neural development of 'us and them.' Social Cognitive and Affective Neuroscience, 12(2), 184–196. https://doi.org/10.1093/scan/nsw134

Moreiras Reynaga, D. (2019). The life histories of Aztec sacrifices: a stable isotope study (C, N, and O) of offerings from Tlatelolco and the Templo Mayor of Tenochtitlan (Ph.D. dissertation, University of Western Ontario). Retrieved from https://ir.lib.uwo.ca/etd/6448

Moya, C. (2013). Evolved priors for ethnolinguistic categorization: a case study from the Quechua–Aymara boundary in the Peruvian Altiplano. Evolution and Human Behavior : Official Journal of the Human Behavior and Evolution Society, 34(4), 265–272. https://doi.org/10.1016/j.evolhumbehav.2013.03.004

Moya, C., & Boyd, R. (2015). Different selection pressures give rise to distinct ethnic phenomena: a functionalist framework with illustrations from the Peruvian Altiplano. Human Nature, 26(1), 1–27. https://doi.org/10.1007/s12110-015-9224-9

Mullen, B., Brown, R., & Smith, C. (1992). Ingroup bias as a function of salience, relevance, and status: an integration. European Journal of Social Psychology, 22(2), 103–122. https://doi.org/10.1002/ejsp.2420220202

Nado, K. L. (2017). Dietary practices, socioeconomic status, and social mobility at Teotihuacan, Mexico (Ph.D. dissertation). Arizona State University, Tempe, AZ.

Nado, K. L., Zolotova, N., & Knudson, K. J. (2016). Paleodietary analysis of the sacrificial victims from the Feathered Serpent Pyramid, Teotihuacan. Archaeological and Anthropological Sciences, 1–16. https://doi.org/10.1007/s12520-016-0416-y

Nagao, D. (1989). Public proclamation in the art of Cacaxtla and Xochicalco. In R. A. Diehl & J. C. Berlo (Eds.), Mesoamerica after the decline of Teotihuacan A.D. 700-900 (pp. 83–104). Washington, D.C.: Dumbarton Oaks.

Nesdale, D., Griffiths, J. A., Durkin, K., & Maass, A. (2007). Effects of group membership, intergroup competition and out-group ethnicity on children's ratings of in-group and out-group similarity and positivity. British Journal of

Developmental Psychology, 25(3), 359–373. https://doi.org/10.1348/026151006X150382

Nichols, D. L. (2016). Teotihuacan. Journal of Archaeological Research, 24(1), 1–74. https://doi.org/10.1007/s10814-015-9085-0

Offenbecker, A. M. (2018). Geographic origins, status, and identity at Paquimé, northwest Chihuahua, Mexico (Ph.D. dissertation). University of Calgary, Calgary, Alberta.

Ohmoto, H., Hart, S. R., & Holland, H. D. (1966). Studies in the Providencia area, Mexico, II, K-Ar and Rb-Sr ages of intrusive rocks and hydrothermal minerals. Economic Geology, 61, 1205–1213.

Ortega-Guerrero, A., Cherry, J. A., & Aravena, R. (1997). Origin of pore water and salinity in the lacustrine aquitard overlying the regional aquifer of Mexico City. Journal of Hydrology, 197(1–4), 47–69. https://doi.org/10.1016/S0022-1694(96)03280-5

Otten, S., & Wentura, D. (1999). About the impact of automaticity in the minimal group paradigm: evidence from affective priming tasks. European Journal of Social Psychology, 29(8), 1049–1071. https://doi.org/10.1002/(SICI)1099-0992(199912)29:8<1049::AID-EJSP985>3.0.CO;2-Q

Pacheco-Forés, S. I. (2016). Investigaciones preliminares de biodistancia e isótopos en los restos humanos de Non-Grid 4, Xaltocan, México. In C. T. Morehart (Ed.), Proyecto de ecología histórica del norte de la Cuenca de México: informe de la temporada de campo 2015 (pp. 117–133).

Pacheco-Forés, S. I. (2017). Análisis exploratorio de afinidad biológica entre los individuos sacrificados en No-Cuadrícula 4, Xaltocan, Edo. de México. In C. T. Morehart (Ed.), Proyecto de ecología histórica del norte de la Cuenca de México: informe de la temporada de campo 2016 (pp. 145–153). Mexico City: Instituto Nacional de Antropología e Historia.

Pacheco-Forés, S. I., Carpenter, L., & Knudson, K. J. (in preparation). Radiogenic strontium isotope variability in the Oaxaca Valley: a baseline for paleomobility studies. Journal of Archaeological Science: Reports.

Pacheco-Forés, S. I., Gordon, G. W., & Knudson, K. J. (2020). Expanding radiogenic strontium isotope baseline data for central Mexican paleomobility studies. PLOS ONE, 15(2), e0229687. https://doi.org/10.1371/journal.pone.0229687

Parsons, J. R. (2001). The last saltmakers of Nexquipayac, Mexico: an archaeological ethnography. Ann Arbor, MI: Museum of Anthropology, University of Michigan.

Parsons, J. R. (2008). Beyond Santley and Rose (1979): the role of aquatic resources in the prehispanic economy of the Basin of Mexico. Journal of Anthropological Research, 64(3), 351–366. https://doi.org/10.3998/jar.0521004.0064.303

Parsons, J. R., & Gorenflo, L. J. (2008). The patterning of settlement. In J. R. Parsons, L. J. Gorenflo, M. H. Parsons, & D. J. Wilson (Eds.), Prehispanic settlement patterns in the northwestern Valleyof Mexico: the Zumpango region (pp. 61–99). Ann Arbor, MI: Museum of Anthropology, University of Michigan.

Parsons, J. R., Gorenflo, L. J., Parsons, M. H., & Wilson, D. J. (2008). Prehispanic settlement patterns in the northwestern Valley of Mexico: the Zumpango region. Ann Arbor, MI: Museum of Anthropology, University of Michigan.

Pate, F. D. (1994). Bone chemistry and paleodiet. Journal of Archaeological Method and Theory, 1(2), 161–209.

Pellegrini, M., Lee-Thorp, J. A., & Donahue, R. E. (2011). Exploring the variation of the δ18Op and δ18Oc relationship in enamel increments. Palaeogeography, Palaeoclimatology, Palaeoecology, 310(1–2), 71–83. https://doi.org/10.1016/j.palaeo.2011.02.023

Pestle, W. J., Crowley, B. E., & Weirauch, M. T. (2014). Quantifying inter-laboratory variability in stable isotope analysis of ancient skeletal remains. PLoS ONE, 9(7), e102844. https://doi.org/10.1371/journal.pone.0102844

Pollard, A. M., Pellegrini, M., & Lee-Thorp, J. A. (2011). Technical note: some observations on the conversion of dental enamel δ18op values to δ18ow to determine human mobility. American Journal of Physical Anthropology, 145(3), 499–504. https://doi.org/10.1002/ajpa.21524

Price, T. D., Blitz, J., Burton, J., & Ezzo, J. A. (1992). Diagenesis in prehistoric bone: problems and solutions. Journal of Archaeological Science, 19(5), 513–529. https://doi.org/10.1016/0305-4403(92)90026-Y

Price, T. D., Burton, J. H., & Bentley, R. A. (2002). The characterization of biologically available strontium isotope ratios for the study of prehistoric migration. Archaeometry, 44(1), 117–135. https://doi.org/10.1111/1475-4754.00047

Price, T. D., Burton, J. H., Fullagar, P. D., Wright, L. E., Buikstra, J. E., & Tiesler, V. (2008). Strontium isotopes and the study of human mobility in ancient

Mesoamerica. Latin American Antiquity, 19(2), 167–180. https://doi.org/10.2307/25478222

Price, T. D., Burton, J. H., Wright, L. E., White, C. D., & Longstaffe, F. J. (2007). Victims of sacrifice: isotopic evidence for place of origin. In V. Tiesler & A. Cucina (Eds.), Human sacrifice and ritual body treatments in ancient Maya society (pp. 263–292). New York: Springer.

Price, T. D., Johnson, C. M., Ezzo, J. A., Ericson, J., & Burton, J. H. (1994). Residential mobility in the prehistoric southwest United States: a preliminary study using strontium isotope analysis. Journal of Archaeological Science, 21(3), 315–330.

Price, T. D., Manzanilla, L. R., & Middleton, W. D. (2000). Immigration and the ancient city of Teotihuacan in Mexico: a study using strontium isotope ratios in human bone and teeth. Journal of Archaeological Science, 27(10), 903–913. https://doi.org/10.1006/jasc.1999.0504

Price, T. D., Tiesler, V., Folan, W. J., & Tykot, R. H. (2018). Calakmul as a central place: isotopic insights on urban Maya mobility and diet during the first millennium AD. Latin American Antiquity, 29(3), 439–454. https://doi.org/10.1017/laq.2018.31.

Purnell, T., Idsardi, W., & Baugh, J. (1999). Perceptual and phonetic experiments on American English dialect identification. Journal of Language and Social Psychology, 18(1), 10–30. https://doi.org/10.1177/0261927X99018001002

Ragsdale, C. S., & Edgar, H. J. H. (2018). Population continuity and replacement in the pre-contact Valley of Mexico. In C. Willermet & A. Cucina (Eds.), Bioarchaeology of pre-Columbian Mesoamerica: an interdisciplinary approach (pp. 37–69). Gainesville, FL: University Press of Florida.

Rand, D. G., Pfeiffer, T., Dreber, A., Sheketoff, R. W., Wernerfelt, N. C., & Benkler, Y. (2009). Dynamic remodeling of in-group bias during the 2008 presidential election. Proceedings of the National Academy of Sciences, 106(15), 6187–6191. https://doi.org/10.1073/pnas.0811552106

Rattray, E. C. (1966). An archaeological and stylistic study of Coyotlatelco pottery. Mesoamerican Notes, 7–8, 87–211.

Rattray, E. C. (1996). A regional perspective on the Epiclassic period in central Mexico. In A. G. Mastache, J. R. Parsons, R. S. Santley, & M. C. Serra Puche (Eds.), Arqueología mesoamericana: homenaje a William T. Sanders (pp. 213–231). Mexico City: Instituto Nacional de Antropología e Historia.

Riek, B. M., Mania, E. W., & Gaertner, S. L. (2006). Intergroup threat and outgroup attitudes: a meta-analytic review. Personality and Social Psychology Review, 10(4), 336–353. https://doi.org/10.1207/s15327957pspr1004_4

Ringle, W. M., Negrón, T. G., & Bey, G. J. (1998). The return of Quetzalcoatl: evidence for the spread of a world religion during the Epiclassic period. Ancient Mesoamerica, 9(02), 183–232. https://doi.org/10.1017/S0956536100001954

Rodríguez Galicia, B., & Valadez Azúa, R. (2013). Vestigios del recurso costero en el sitio arqueológico de Teopancazco, Teotihuacan, Estado de México. Revista Española de Antropología Americana, 43(1), 9–29. https://doi.org/10.5209/rev_REAA.2013.v43.n1.42294

Román Berrelleza, J. A. (2010). El papel de los infantes en las prácticas sacrificiales Mexicas. In L. López Luján & G. Olivier (Eds.), El sacrificio humano en la tradición religiosa mesoamericana (pp. 345–366). México D.F.: Instituto Nacional de Antropología e Historia.

Romaniello, S. J., Field, M. P., Smith, H. B., Gordon, G. W., Kim, M. H., & Anbar, A. D. (2015). Fully automated chromatographic purification of Sr and Ca for isotopic analysis. Journal of Analytical Atomic Spectrometry, 30(9), 1906–1912. https://doi.org/10.1039/C5JA00205B

Sahagún, B. de. (1951). Florentine codex, general history of the things of New Spain: book II - the ceremonies (A. J. O. Anderson & C. E. Dibble, Trans.). Santa Fe, NM: School of American Research Press.

Sahagún, B. de. (1961). Florentine codex, general history of the things of New Spain: book X - the people (A. J. O. Anderson & C. E. Dibble, Trans.). Santa Fe, NM: School of American Research Press.

Sahagún, B. de. (1963). Florentine codex, general history of the things of New Spain: book XI - earthly things (A. J. O. Anderson & C. E. Dibble, Trans.). Santa Fe, NM: School of American Research Press.

Salinas Prieto, J. C., Montiel Escobar, J., Sánchez Rojas, E., Díaz Salgado, C., de la Calleja, A., Barajas Nigoche, D., … Amezcua Torres, N. (2007). Carta geológica de México. Mexico City: Servicio Geológico Mexicano.

Sánchez, J. E. (2013). Para comprender el Epiclásico en el centro de México: problemas y propuestas teórico-metodológicos. México: Instituto Nacional de Antropología e Historia.

Sanders, W. T. (Ed.). (1986). The Teotihuacan Valley Project, Final Report, Volume 4: the Toltec period occupation. University Park, PA: Department of Anthropology, Pennsylvania State University.

Sanders, W. T. (2006). Late Xolalpan-Metepec/Oxtotipac-Coyotlatelco: ethnic succession or changing patterns of political economy, a reevaluation. In L. Solar Valverde (Ed.), El fenómeno Coyotlatelco en el centro de México: tiempo, espacio y significado (pp. 183–200). Mexico City: Instituto Nacional de Antropología e Historia.

Sanders, W. T., Parsons, J. R., & Santley, R. S. (1979). The Basin of Mexico: ecological processes in the evolution of a civilization. New York: Academic Press.

Santley, R. S., & Rose, E. K. (1979). Diet, nutrition and population dynamics in the Basin of Mexico. World Archaeology, 11(2), 185–207. https://doi.org/10.1080/00438243.1979.9979760

Schaaf, P., Solís, G., Manzanilla, L. R., Hernández, T., Lailson, B., & Horn, P. (2012). Isótopos de estroncio aplicados a estudios de migración humana en el centro de barrio de Teopancazco, Teotihuacan. In L. R. Manzanilla (Ed.), Estudios arqueométricos del centro de barrio de Teopancazco en Teotihuacan (pp. 425–448). Mexico City: Instituto de Investigaciones Antropológicas, Universidad Nacional Autónoma de México.

Schmidt, B. E., & Schröder, I. W. (Eds.). (2001). Anthropology of violence and conflict. London: Routledge.

Schwandner-Sievers, S. (2001). The enactment of “tradition”: Albanian constructions of identity, violence and power in times of crisis. In B. E. Schmidt & I. W. Schröder (Eds.), Anthropology of violence and conflict (pp. 97–120). London: Routledge.

Schwarcz, H. P., Gibbs, L., & Knyf, M. (1991). Oxygen isotope analysis as an indicator of place of origin. In Snake Hill: an investigation of a military cemetery from the War of 1812 (pp. 263–268). Toronto, ON: Dundurn Press.

Sealy, J. C., Armstrong, R., & Schrire, C. (1995). Beyond lifetime averages: tracing life histories through isotopic analysis of different calcified tissues from archaeological human skeletons. Antiquity, 69(263), 290–300. https://doi.org/10.1017/S0003598X00064693

Sealy, J. C., van der Merwe, N. J., Sillen, A., Kruger, F. J., & Krueger, H. W. (1991). 87Sr/86Sr as a dietary indicator in modern and archaeological bone. Journal of

Archaeological Science, 18(3), 399–416. https://doi.org/10.1016/0305-4403(91)90074-Y

Sen, A. (2009). Violence in identity. In I. Karawān, W. McCormack, & S. E. Reynolds (Eds.), Values and violence: intangible aspects of terrorism (pp. 3–14). New York: Springer.

Serafin, S., Lope, C. P., & Uc González, E. (2014). Bioarchaeological investigation of ancient Maya violence and warfare in inland northwest Yucatan, Mexico. American Journal of Physical Anthropology, 154(1), 140–151. https://doi.org/10.1002/ajpa.22490

Sherif, M. (1966). Group conflict and cooperation: their social psychology. London: Routledge & Kegan Paul.

Sholts, S. B., Báez-Molgado, S., Morehart, C. T., & Meza Peñaloza, A. (2014, April 10). Cranial morphometric variation and human sacrifice at the Epiclassic site of Xaltocan, Mexico. Presented at the 83rd Annual Meeting of the American Association of Physical Anthropologists, Calgary, Alberta.

Simunovic, D., Mifune, N., & Yamagishi, T. (2013). Preemptive strike: an experimental study of fear-based aggression. Journal of Experimental Social Psychology, 49(6), 1120–1123. https://doi.org/10.1016/j.jesp.2013.08.003

Solar Valverde, L. (Ed.). (2006). El fenómeno Coyotlatelco en el centro de México: tiempo, espacio y significado. México D.F.: Instituto Nacional de Antropología e Historia.

Solís Pichardo, G., Schaaf, P., Hernández Treviño, T., Lailson, B., Manzanilla, L. R., & Horn, P. (2017). Migrants in Teopancazco: evidence from strontium isotopic studies. In L. R. Manzanilla (Ed.), Multiethnicity and migration at Teopancazco: investigations of a Teotihuacan neighborhood center (pp. 143–163). Gainesville, FL: University Press of Florida.

Sołtysiak, A. (2017). Antemortem cranial trauma in ancient Mesopotamia. International Journal of Osteoarchaeology, 27, 119–128. https://doi.org/10.1002/oa.2478

Sosis, R., & Ruffle, B. J. (2003). Religious ritual and cooperation: testing for a relationship on Israeli religious and secular kibbutzim. Current Anthropology, 44(5), 713–722. https://doi.org/10.1086/379260

Spence, M. W. (1974). Residential practices and the distribution of skeletal traits in Teotihuacan, Mexico. Man, 9(2), 262. https://doi.org/10.2307/2800077

Spence, M. W. (2005). A Zapotec diaspora network in Classic-period central Mexico. In G. J. Stein (Ed.), The archaeology of colonial encounters: comparative perspectives (pp. 173–206). Santa Fe, NM: School of American Research Press.

Spence, M. W., & Gamboa Cabezas, L. M. (1999). Mortuary practices and social adaptation in the Tlailotlacan enclave. In L. R. Manzanilla & C. Serrano Sánchez (Eds.), Prácticas funeraria en la Ciudad de los Dioses: los enterramientos humanos de la antigua Teotihuacan (pp. 173–201). Mexico City: Universidad Nacional Autónoma de México Instituto de Investigaciones Antropológicas.

Spence, M. W., White, C. D., Longstaffe, F. J., & Law, K. R. (2004). Victims of the victims: human trophies worn by sacrificed soldiers from the Feathered Serpent Pyramid, Teotihuacan. Ancient Mesoamerica, 15(1), 1–15. https://doi.org/10.1017/S0956536104151018

Stichler, W. (1995). Interlaboratory comparison of new materials for carbon and oxygen ratio measurements. In IAEA (Ed.), Reference adn intercomparison materials for stable isotopes of light elements: proceedigns of a consultants meeting held in Vienna, 1-3 December 1993 (pp. 67–74). Vienna, Austria: International Atomic Energy Agency (IAEA).

Sugiura Yamamoto, Y. (2006). ¿Cambio gradual o discontinuidad en la cerámica?: discusión acerca del paso del Clásico al Epiclásico, visto desde el Valle de Toluca. In L. Solar Valverde (Ed.), El fenómeno Coyotlatelco en el centro de México: tiempo, espacio y significado (pp. 127–162). Mexico City: Instituto Nacional de Antropología e Historia.

Tajfel, H. (1959). A note on Lambert's "Evaluational reactions to spoken languages." Canadian Journal of Psychology, 13, 86–92.

Tajfel, H., Billig, M. G., Bundy, R. P., & Flament, C. (1971). Social categorization and intergroup behaviour. European Journal of Social Pyschology, 1, 149–177.

Tajfel, H., & Turner, J. C. (2004). The social identity theory of intergroup behavior. In J. T. Jost & J. Sidanius (Eds.), Political psychology: key readings (pp. 276–293). London: Psychology Press.

Tiesler, V., & Cucina, A. (2012). Where are the warriors? Cranial trauma patterns and conflict among the ancient Maya. In D. L. Martin, R. P. Harrod, & V. R. Pérez (Eds.), The bioarchaeology of violence: bioarchaeological interpretations of the human past: local, regional, and global perspectives (pp. 160–179). Gainesville, FL: University Press of Florida.

Torres-Alvarado, I. S., Verma, S. P., & Carrasco-Núñez, G. (2000). Compilation of radiogenic isotope data in Mexico and their petrogenetic implications. Journal of Earth System Science, 109(1), 67–78. https://doi.org/10.1007/BF02719150

Torres-Lagares, D., Tulasne, J.-F., Pouget, C., Llorens, A., Saffar, J.-L., & Lesclous, P. (2010). Structure and remodelling of the human parietal bone: An age and gender histomorphometric study. Journal of Cranio-Maxillofacial Surgery, 38(5), 325–330. https://doi.org/10.1016/j.jcms.2009.07.012

Tozzer, A. M. (1921). Excavations of a site at Santiago Ahuitzotla City, Mexico. Washington, D.C.: Bureau of American Ethnology.

Turekian, K. K., & Kulp, J. L. (1956). Strontium content of human bones. Science, 124(3218), 405–407.

Veizer, J. (1989). Strontium isotopes in seawater through time. Annual Review of Earth and Planetary Sciences, 17, 141.

Walby, S., Armstrong, J., & Strid, S. (2012). Intersectionality: multiple inequalities in social theory. Sociology, 46(2), 224–240. https://doi.org/10.1177/0038038511416164

Wallén, C. C. (1955). Some characteristics of precipitation in Mexico. Geografiska Annaler, 37, 51–85. https://doi.org/10.2307/520169

Wassenaar, L. I., Van Wilgenburg, S. L., Larson, K., & Hobson, K. A. (2009). A groundwater isoscape (δD, δ18O) for Mexico. Journal of Geochemical Exploration, 102(3), 123–136. https://doi.org/10.1016/j.gexplo.2009.01.001

White, C. D., Price, T. D., & Longstaffe, F. J. (2007). Residential histories of the human sacrifices at the Moon Pyramid, Teotihuacan: evidence from oxygen and strontium isotopes. Ancient Mesoamerica, 18(01), 159–172. https://doi.org/10.1017/S0956536107000119

White, C. D., Spence, M. W., Longstaffe, F. J., & Law, K. R. (2000). Testing the nature of Teotihuacán imperialism at Kaminaljuyú using phosphate oxygen-isotope ratios. Journal of Anthropological Research, 535–558.

White, C. D., Spence, M. W., Longstaffe, F. J., Stuart-Williams, H., & Law, K. R. (2002). Geographic identities of the sacrificial victims from the Feathered Serpent Pyramid, Teotihuacan: implications for the nature of state power. Latin American Antiquity, 13(2), 217–236.

White, C. D., Spence, M. W., Stuart-Williams, H. L. Q., & Schwarcz, H. P. (1998). Oxygen isotopes and the identification of geographical origins: the Valley of Oaxaca versus the Valley of Mexico. Journal of Archaeological Science, 25(7), 643–655. https://doi.org/10.1006/jasc.1997.0259

White, C. D., Storey, R., Longstaffe, F. J., & Spence, M. W. (2004). Immigration, assimilation, and status in the ancient city of Teotihuacan: stable isotopic evidence from Tlajinga 33. Latin American Antiquity, 15(2), 176–198.

Whitt, S., & Wilson, R. K. (2007). The dictator game, fairness and ethnicity in postwar Bosnia. American Journal of Political Science, 51(3), 655–668. https://doi.org/10.1111/j.1540-5907.2007.00273.x

Widmer, R. J., & Storey, R. (2017). Skeletal health and patterns of animal food consumption at S3W1:33 (Tlajinga 33), Teotihuacan. Archaeological and Anthropological Sciences, 9(1), 51–60. https://doi.org/10.1007/s12520-016-0417-x

Winter, M. C. (1998). Monte Alban and Teotihuacan. In E. C. Rattray (Ed.), Rutas de intercambio en Mesoamérica: III Coloquio Pedro Bosch Gimpera (pp. 153–184). Mexico City: Universidad Nacional Autónoma de México.

Wright, L. E. (2005). Identifying immigrants to Tikal, Guatemala: defining local variability in strontium isotope ratios of human tooth enamel. Journal of Archaeological Science, 32(4), 555–566. https://doi.org/10.1016/j.jas.2004.11.011

Wright, L. E. (2012). Immigration to Tikal, Guatemala: evidence from stable strontium and oxygen isotopes. Journal of Anthropological Archaeology 31(3), 334–52. https://doi.org/10.1016/j.jaa.2012.02.001.

Wright, L. E., & Schwarcz, H. P. (1998). Stable carbon and oxygen isotopes in human tooth enamel: identifying breastfeeding and weaning in prehistory. American Journal of Physical Anthropology, 106(1), 1–18. https://doi.org/10.1002/(SICI)1096-8644(199805)106:1<1::AID-AJPA1>3.0.CO;2-W

Wright, L. E., & Schwarcz, H. P. (1999). Correspondence between stable carbon, oxygen and nitrogen isotopes in human tooth enamel and dentine: infant diets at Kaminaljuyú. Journal of Archaeological Science, 26(9), 1159–1170. https://doi.org/10.1006/jasc.1998.0351

Zárate, M. A., Garcia, B., Garza, A. A., & Hitlan, R. T. (2004). Cultural threat and perceived realistic group conflict as dual predictors of prejudice. Journal of Experimental Social Psychology, 40(1), 99–105. https://doi.org/10.1016/S0022-1031(03)00067-2

CHAPTER 4

MIGRATION AND BIOLOGICAL CONTINUITY IN CENTRAL MEXICO DURING THE CLASSIC-EPICLASSIC TRANSITION

Target Journal – American Journal of Physical Anthropology

The role of migration within the cultural development of central Mexico has long been debated. Archaeologically, migration has been implicated in the appearance of new forms of material culture within central Mexico (Z. Nelson, 2009; Rattray, 1966, 1987), as well as in sociopolitical disruptions including the dissolution of the Teotihuacan state (Cowgill, 2013, 2015a), and the emergence of new polities within central Mexico (Beekman, 2015; Beekman & Christensen, 2011). Moreover, indigenous accounts of migration play a central role in the ethnohistory of Postclassic central Mexican populations (see review in Beekman & Christensen, 2003), and Nahuatl, the language dominating central Mexico at the time of the Spanish Conquest, is not native to central Mexico (Hopkins, 1984; Kaufman, 2001; W. R. Miller, 1983), suggesting that migrants introduced it into the region. Despite multiple lines of evidence indicating that in-migration likely did take place within central Mexico, precise chronologies and trajectories of migration into the region remain unclear.

In this manuscript, I take a bioarchaeological approach to examine migration within central Mexico, evaluating possible sources of migrants into the region during the Epiclassic period (600-900 CE). I analyze a skeletal assemblage from Non-Grid 4, an Epiclassic ritual shrine site in the northern Basin of Mexico where approximately 180 individuals were sacrificed and interred (Meza-Peñaloza et al., 2019; Morehart et al., 2012). Recent biogeochemical analyses found that among sampled individuals (*n*=73), 80% exhibited isotopic values identifying them as non-local migrants into the Basin of Mexico (Pacheco-Forés, Morehart, et al., in preparation). With the exception of three individuals interred in Cueva de las Varillas in Teotihuacan and identified biogeochemically as Epiclassic period migrants (Manzanilla, 2005a; Manzanilla et al., 1996; Price et al., 2000), the Non-Grid 4 individuals represent the first directly identified migrants within the Epiclassic Basin of Mexico. I use multivariate biodistance analyses to compare Non-Grid 4 individuals with Classic (250-600 CE) and Epiclassic skeletal populations throughout Mesoamerica to investigate the relationship between Non-Grid 4 individuals and pre-extant central Mexican groups, as well as from where migrant individuals at Non-Grid 4 may have originated.

Migration in Epiclassic Central Mexico

The Epiclassic period was an epoch of major social and political change in the central Mexican highlands (Diehl & Berlo, 1989; Rattray, 1996). In addition Teotihuacan's decline as a regional power (Anderson et al., 2016; Cowgill, 2015a, 2015b; Parsons & Sugiura, 2012) and the demographic reorganization of the Basin of Mexico (Parsons et al., 2008; Sanders et al., 1979), this period is associated with large-scale migrations into the Basin of Mexico. Here, migration is understood as the movement and long-term relocation of peoples across significant socio-cultural, political, or environmental boundaries (Tsuda et al., 2015).

Archaeological evidence of migration

The appearance of the Coyotlatelco red-on-buff ceramic complex in Epiclassic central Mexico has long been a central focus of migration debates within the archaeology of the region. This ceramic tradition occurs throughout central Mexico and is widely accepted as an Epiclassic chronological marker (Crider, 2011; Solar Valverde, 2006; Tozzer, 1921). Rattray (1966, 1996, 2006) argues that Coyotlatelco ceramics represent a complete break from previous ceramic forms in central Mexico, indicative of population replacement. Based on stylistic and technological similarities, many have suggested the Bajío region of north-central Mexico, which includes parts of the modern Mexican states of Michoacán, Guanajuato, Querétaro, Jalisco, and Aguascalientes as a possible source for the central Mexican Coyotlatelco ceramic complex (Beekman, 2015; Beekman & Christensen, 2003; Braniff, 2005; Cobean & Mastache, 1989; Healan, 2012; Healan & Cobean, 2019; Hernández, 2016; Hernández & Healan, 2019; Mastache et al., 2002). Other proposed origins for Coyotlatelco ceramics include the Malpaso Valley-La Quemada settlement system region of Zacatecas (Mastache et al., 2002; B. A. Nelson & Crider, 2005).

In contrast, others argue that Coyotlatelco ceramics developed directly out of Classic period Teotihuacan ceramic traditions (Fournier & Bolaños, 2007; Sanders, 1986, 1989; Sugiura Yamamoto, 2006). This argument of cultural continuity within central Mexico is used to bolster arguments against in-migration and support claims of biological continuity within the region during the Epiclassic period (Sanders, 2006). It thus dismisses possible influences of northern and western Mexican groups on the cultural development of central Mexico (Sugiura Yamamoto, 2006).

More recently, scholars have identified important spatial and temporal variants in Coyotlatelco ceramics (Crider, 2011, 2013; Cyphers, 2000; Gaxiola González, 2006). These studies allow for the introduction of new styles through immigration into Epiclassic central Mexico, while also maintaining a degree of demographic and cultural continuity with Classic period Teotihuacan. Nevertheless, Cowgill (2013, 2015a) notes that migration is only one possible interpretation of the apparent stylistic break between Coyotlatelco and earlier Teotihuacan ceramic traditions. Other potential explanations of the stylistic discontinuity could include ideological, political, or moral distancing from the Teotihuacan state following its decline and the burning of its ritual center, or local emulations of foreign styles.

Interestingly, however, the distinctive change in ceramics during the Epiclassic also corresponds with other broad regional cultural changes. The appearance of Coyotlatelco coincides with changes in lithic production forms throughout central Mexico (Carballo, 2011; Z. Nelson, 2009; Rattray, 1987). Furthermore, lithic assemblages at many central Mexican Coyotlatelco sites are dominated by obsidian from the Ucareo-Zinapécuaro source area located in northeastern Michoacán within the Bajío region (Healan, 1997). Some authors therefore suggest that Coyotlatelco ceramics and Ucareo-Zinapécuaro sourced obsidian form two parts of a single intrusive material culture complex suggestive of migration into Epiclassic central Mexico (Cowgill, 2013; Hernández & Healan, 2019).

Additionally, archaeological surveys note major shifts in Epiclassic settlement patterns within central Mexico. Epiclassic settlements are primarily located on dispersed hilltops, in contrast with Classic period valley floor settlements (Mastache et al., 2002; Parsons et al., 2008; Sanders et al., 1979). Furthermore, many Classic period central Mexican settlements believed to be Teotihuacan colonies are abandoned during the Epiclassic (Healan & Cobean, 2019). While demographic shifts could be a result of the collapse of the Teotihuacan state (Cowgill, 2013), the abandonment of many structures at Teotihuacan itself with later Epiclassic reoccupations (Cabrera Castro & Gómez Chavez, 2008; Rattray, 2006) suggests that these cultural changes could be a result of an influx of migrants into central Mexico during the Epiclassic period.

Bioarchaeological evidence of migration

Bioarchaeological investigations of migration within Epiclassic central Mexico have been hampered by the limited availability of relevant Epiclassic skeletal assemblages. Biogeochemical studies identifying immigrants within central Mexico during the Classic period abound (e.g., Buckley, Storey, Hirth, Kennett, & Culleton, 2016; Manzanilla, 2005; Nado, 2017; Price et al., 2000; Schaaf et al., 2012; Solís Pichardo et al., 2017; White, Spence, Longstaffe, Stuart-Williams, & Law, 2002; White, Spence, Stuart-Williams, & Schwarcz, 1998; White, Storey, Longstaffe, & Spence, 2004). To date, however, only three central Mexican Epiclassic individuals interred in the Cueva de las Varillas at Teotihuacan have been directly identified as migrants using biogeochemical methods (Price et al., 2000).

Genetic analyses of central Mexican populations also provide support for an Epiclassic migration into central Mexico. Nuclear DNA studies of the Epiclassic Cueva de las Varillas burials, as well as of Epiclassic Cueva del Pirul burials at Teotihuacan found genetic discontinuities between these individuals and antecedent Classic period burials from residential and ritual contexts at Teotihuacan, suggesting they were migrants from outside of central Mexico (Manzanilla, 2005a). Interestingly, these Epiclassic Teotihuacan burials were also genetically distinct from contemporaneous Epiclassic individuals from Chapatongo, Hidalgo in the Tula region (Fournier & Vargas Sanders, 2002), indicating that they may have migrated from farther away. Similarly, in a mitochondrial DNA study of Postclassic central Mexican burials, Morales-Arce and colleagues (2019) find evidence of genetic divergence from Classic central Mexican populations (Aguirre-Samudio et al., 2017; Álvarez-Sandoval et al., 2015), suggesting a population replacement took place during the Epiclassic period. Conclusions from these studies, however, are limited by the scarcity of available comparative ancient DNA data from ancient Mesoamerica. As such, they do not indicate possible source regions for hypothesized migration events.

Examining Epiclassic migrations through biodistance analysis

Biodistance analyses of phenotypic variability among pre-Hispanic Mesoamerican populations provide essential further clarification of potential Epiclassic migrations. Biodistance is the measure of biological relatedness or divergence between individuals or populations based on genetic relationships (Buikstra, 1980; Larsen, 1999; Stojanowski & Schillaci, 2006). Biodistance analyses use phenotypic variation in polygenic skeletal and dental traits to estimate the degree of genetic relatedness and reconstruct microevolutionary processes such as genetic drift and gene flow within and between populations (Buikstra et al., 1990; Cheverud, 1988; Harpending & Jenkins, 1973; Relethford & Blangero, 1990; Stojanowski & Schillaci, 2006).

Analyses of between-group phenotypic variation have been used to elucidate population histories and evaluate migration hypotheses within Mesoamerica. Studies using cranial non-metric skeletal variants (Beekman & Christensen, 2003; Christensen, 1997), facial morphology (González-José et al., 2007), dental morphology (Aubry, 2009; Gómez-Valdés, Bautista Martínez, Pompa y Padilla, Talavera González, & Castrejón-Caballero, 2008; Ragsdale & Edgar, 2018), and cervicometrics (Aubry, 2009) all find evidence of biological discontinuity between central Mexican Classic and Postclassic skeletal populations. These findings provide further support for migration and population replacement during the Epiclassic period.

Importantly, these studies also suggest possible origins of hypothesized migrants. The majority of these studies found that Postclassic central Mexican groups shared the closest biological affinities with Postclassic populations from northwestern (Beekman & Christensen, 2003; Gómez-Valdés et al., 2008; González-José et al., 2007; Ragsdale & Edgar, 2018) and northern (Aubry, 2009; Christensen, 1997) Mexico. These findings are consistent with archaeological models that suggest the Bajío or Malpaso Valley-La Quemada settlement system region as possible sources of Coyotlatelco ceramics and Epiclassic migrants. It is important to note, however, that González-José and colleagues (2007) found Postclassic central Mexican groups did not share close affinities with other sampled populations, including northern populations, but hypothesized potential migrant origins in west Mexico based on lacunae in the study sample. Furthermore, while these studies provide compelling evidence for population replacements coinciding with the Epiclassic period, none of the studies examined skeletal remains dating to the Epiclassic.

Migration at the Non-Grid 4 Epiclassic shrine site

The skeletal remains recovered from the Non-Grid 4 shrine site provide an invaluable opportunity to further elucidate Epiclassic migration into central Mexico. The shrine site consists of an anthropogenic raised platform with associated sacrificial deposits of at least 180 human crania located in the now-extinct Lake Xaltocan in the northern Basin of Mexico (Meza-Peñaloza et al., 2019; Morehart et al., 2012). AMS radiocarbon dates of recovered botanical remains ranging from 550-890 CE, as well as the presence of Coyotlatelco ceramics confirm the site dates to the Epiclassic period (Morehart et al., 2012).

Biogeochemical analyses have directly identified large numbers of first-generation immigrants among the individuals interred at Non-Grid 4. An analysis of radiogenic strontium ($^{87}Sr/^{86}Sr$) and stable oxygen ($\delta^{18}O$) isotopes found that in a sample (n=73) of sacrificial victims, approximately 80% of sampled individuals exhibited isotope signatures identifying them as non-local migrants into the Basin of Mexico (Pacheco-Forés, Morehart, et al., in preparation). While the Non-Grid 4 migrants are among the first Epiclassic migrants to be biogeochemically identified within central Mexico, such analyses are limited in the information they provide about migrants' geographic origins. Radiogenic strontium and stable oxygen isotope values are not unique, but instead reflect local geologic and hydrologic variation (Faure & Powell, 1972; Gat, 1996). It is therefore not possible to conclusively associate non-local isotopic signatures with specific locations within Mesoamerica.

Recent biodistance analyses shed more light on the potential origins of the Non-Grid 4 migrants. In a study of cranial non-metric traits at Non-Grid 4, Meza-Peñaloza and colleagues (2019) found that the Non-Grid 4 individuals (*n*=118) were biologically discontinuous with Formative and Classic, as well as other Epiclassic populations from central Mexico. Similarly, in a craniometric study, García Velasco (2019) found Non-Grid 4 individuals (*n*=65) to be biologically distinct from other central Mexican as well as northern Mexican populations. The latter analysis, however, was limited by the presence of cranial modification among 63% of Non-Grid 4 crania included in the study. Because cranial modification represents a substantial alteration of heritable phenotypic variation in the craniometric dimensions considered in the study (Anton, 1989; Cheverud et al., 1992; Cheverud & Midkiff, 1992; L. A. P. Kohn et al., 1993; Püschel et al., 2020), it precludes the examination of biological affinities among modified individuals and comparative populations (García Velasco, 2019, p. 124). Therefore, in this study, I use phenotypic variation in cervicometric tooth dimensions (Hillson et al., 2005; Stojanowski, 2007), which are robust to cultural body modifications, to examine biological distances between Non-Grid 4 individuals and antecedent and contemporaneous Mesoamerican populations to discern potential source populations for the Non-Grid 4 migrants.

Materials and Methods

A total of 333 individuals from Non-Grid 4 and comparative Classic and Epiclassic sites throughout Mexico were analyzed in this study (Table 4). Most potential regions of origin are represented in the comparative Mesoamerican sample, including central, southern, and northern Mexico, as well as the Bajío and Malpaso Valley-La Quemada settlement system regions (Fig 10). Although many sites included in the analysis have occupations preceding or postdating the Classic and Epiclassic periods, only burials dating to these two periods were included in the comparative sample. While precise chronologies are not available for the northern Mexican sites of Cusihuiriachi, Sierra de la Fragua, and Charcas, they are believed to be from the late pre-Hispanic period are included in the analysis to ensure an important potential source of Epiclassic migrants was represented in the analysis.

Table 4. Sites and sample sizes of individuals included in the study.

Site (Abbreviation)	**N**	**Time period**	**Region**	**Location[a]**
Teotihuacan, Mexico State				
La Ventilla B (Teo-LVB)	51	Classic	Central Mexico	INAH-DAF
Tlajinga 33 (Teo-TLJ)	28	Classic	Central Mexico	ASU TRL
Cuevas del Pirul y de las Varillas (Teo-CUE)	3	Epiclassic	Central Mexico	UNAM
Non-Grid 4, Mexico State (NG4)	115	Epiclassic	Central Mexico	UNAM
Tula, Hidalgo (TUL)	7	Epiclassic	Central Mexico	INAH-DAF
Cholula, Puebla (CHL)	19	Epiclassic	Central Mexico	INAH-DAF
Los Pilarillos, Zacatecas (PIL)	14	Epiclassic	Malpaso Valley	LQMVAP
El Ocote, Aguascalientes (OCO)	10	Epiclassic	Bajío	INAH-Aguascalientes
Monte Albán, Oaxaca (MAB)	55	Epiclassic	Southern Mexico	INAH-DAF
Cusihuiriachi, Chihuahua (CHI)	17	Epiclassic-Postclassic	Northern Mexico	NMNH
Sierra de la Fragua, Coahuila (COH)	8	Epiclassic-Postclassic	Northern Mexico	NMNH
Charcas, San Luis Potosí (SLP)	6	Epiclassic-Postclassic	Northern Mexico	NMNH

[a] INAH-DAF=Instituto Nacional de Antropología e Historia-Dirección de Antropología Física, Mexico City; ASU TRL = Arizona State University Teotihuacan Research Laboratory, San Juan Teotihuacan; UNAM=Universidad Nacional Autónoma de México, Mexico City; LQMVAP=La Quemada Malpaso Valley Archaeological Project, Zacatecas; NMNH=National Museum of Natural History, Washington D.C

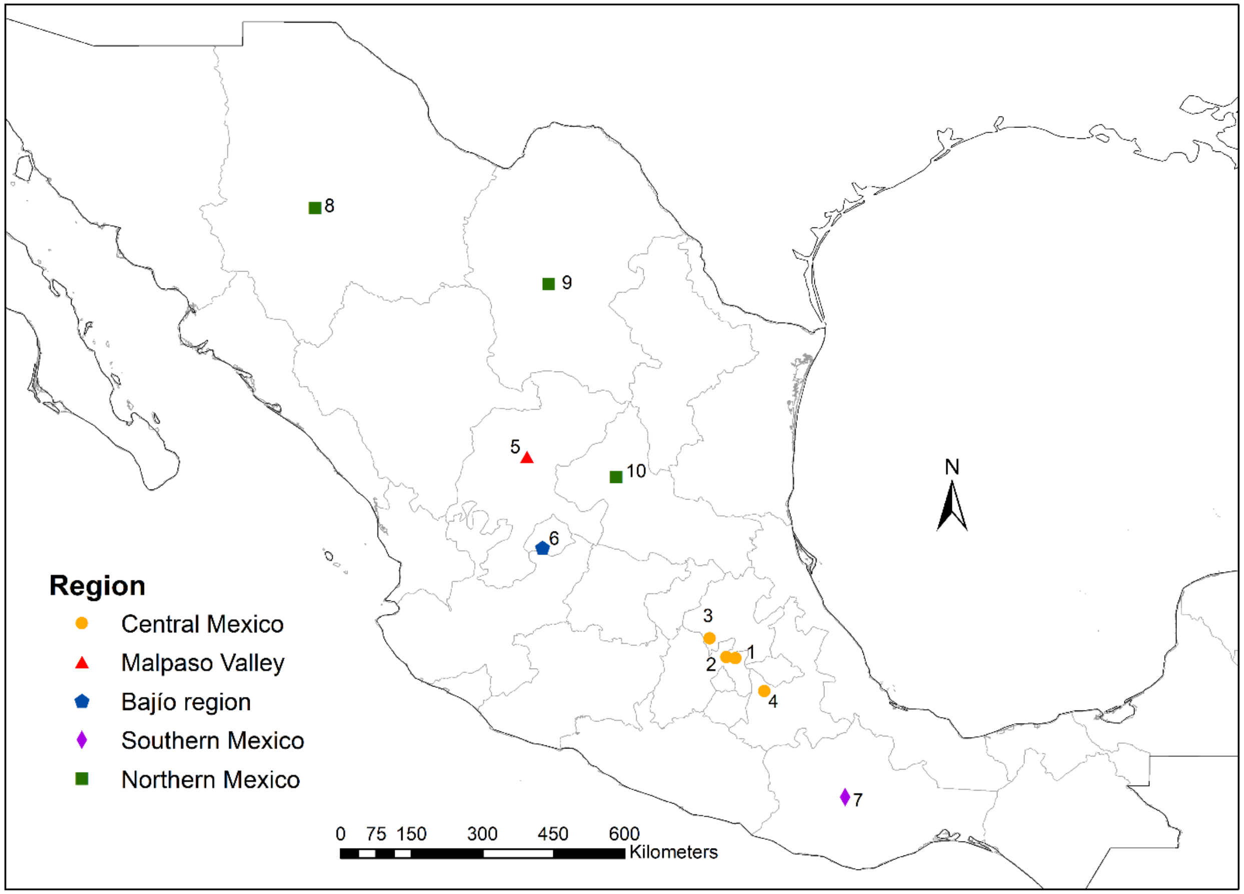

Figure 10. Sites and regions included in the analysis. 1=TEO, 2=NG4, 3=TUL; 4=CHL, 5=PIL, 6=OCO, 7=MAB, 8=CHI, 9=COH, 10=SLP.

Moreover, burials from the central Mexican site of Teotihuacan were treated as three separate contexts for the purposes of the analysis. Epiclassic period Pirul and Varillas cave burials were segregated from Classic period burials, as they represent a temporally distinct occupation (Manzanilla et al., 1996). Similarly, Classic period burials were divided into two groups—those from the elite residential compound of La Ventilla B (Cabrera Castro & Gómez Chavez, 2008) and those from the craft specialist residential compound Tlajinga 33 (Widmer, 1987). Various studies show Teotihuacan residential compounds were predominantly occupied by kin groups of consanguinal and affinal relatives (Millon, 1976; Spence, 1974, 1994; Storey, 1992), indicating that these two populations were unlikely to have engaged in mate exchange and were thus effectively two distinct biological populations.

Cervicometric mesio-distal and bucco-lingual dimensions were collected from all individuals, following Hillson and colleagues (2005), with updates in premolar and molar caliper placement following Aubry (2014). All measurements were taken on the left side, using antimere substitution for unobservable or missing teeth. Cervicometric dimensions are highly correlated with crown dimensions, exhibiting similar degrees of phenotypic variability and producing similar patterns of biological affinity as crown measurements (Hillson et al., 2005; Stojanowski, 2007). In addition to being more resistant to dental attrition, cervicometric dimensions are typically unaffected by cultural practices of body modification including cranial and dental modification, both of which occur among Non-Grid 4 individuals.

Collected cervicometric variables exhibiting high intra-observer error were eliminated (Utermohle & Zegura, 1982). Missing data were minimized through antimere substitution, and cases and variables with high levels of missing data were removed to produce a data matrix with less than 40% missing data. Examination of margin plots of missing data distributions suggests that most values were missing at random. I used multiple imputation to create and analyze 10 multiply imputed datasets (*m*=10; Fig 11). Multiple imputation improves accuracy and statistical power relative to other missing data imputation techniques by accounting for the missing data uncertainty (Schafer, 1999; Schafer & Olsen, 1998; van Buuren, 2018). Missing values were imputed under fully conditional specification, using the random forest settings of the mice 3.0 package in R (R Core Team, 2016; van Buuren & Groothuis-Oudshoorn, 2011). The random forest imputation method is a machine learning technique that can accommodate nonlinearities and interactions and does not require a particular regression model to be specified. This method has been shown to perform well in the imputation of complex data sets where some individuals have missing data and the data do not conform to a normal distribution (Shah et al., 2014). Parameters of interest were estimated separately for each imputed dataset and pooled following Rubin (1987).

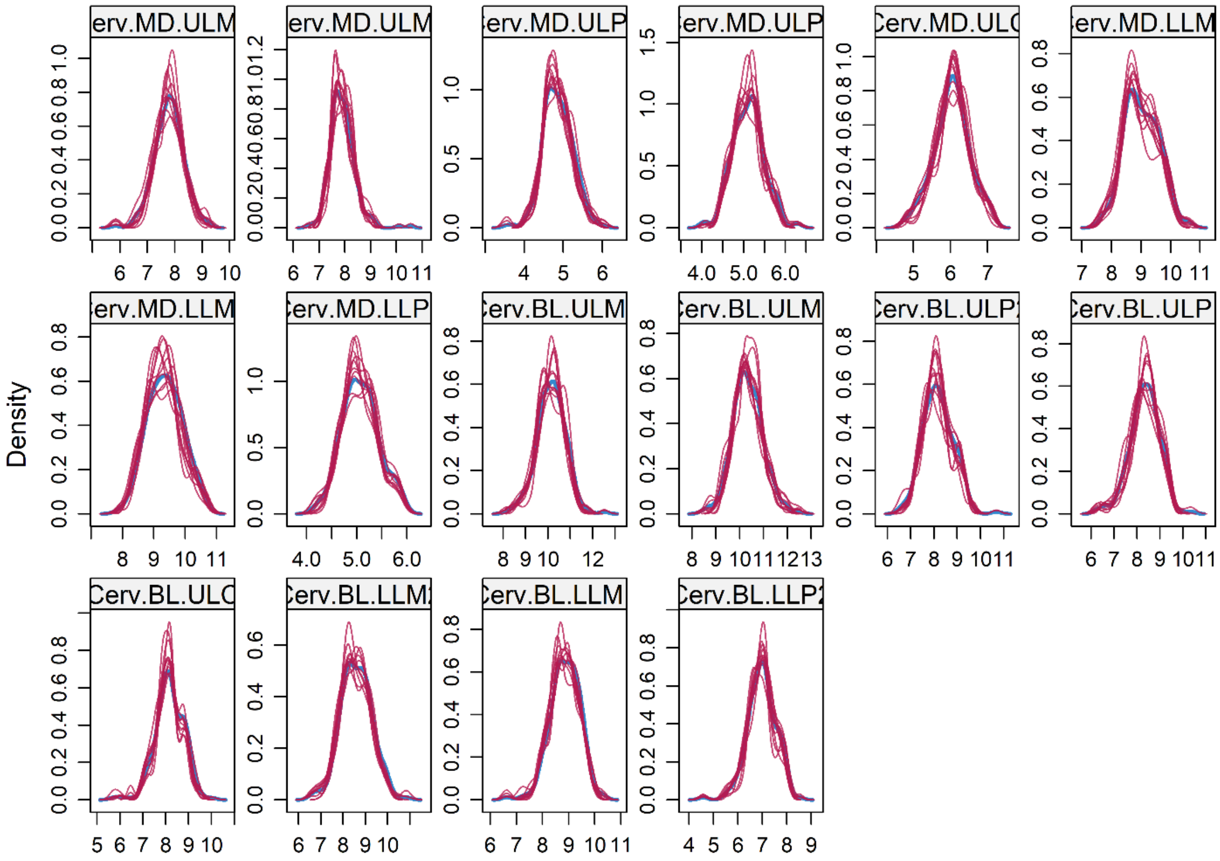

Figure 11. Density plots of imputed data by variable. Imputed data (red) conform to the same distribution of the observed data (blue). Matching distributions indicate the imputed values are plausible value.

Imputed data sets were subjected to pre-analysis data treatments. Size differences due to sexual dimorphism and allometric effects were minimized through a Q-mode correction (Corruccini, 1973). I then used a principal components analysis to generate uncorrelated variables from Q-mode corrected cervicometric data to eliminate redundancy in the phenotypic data. Resulting uncorrelated eigenvectors were used in all further analyses.

Finite Mixture Analysis at Non-Grid 4

Previous geometric morphometric analysis by García Velasco (2019) found three morphologically distinct groups among Non-Grid 4 individuals, one of which isolated individuals exhibiting cranial modification. The presence of two groups among unmodified individuals indicates that there is greater phenotypic—and therefore likely greater genetic—diversity at Non-Grid 4 than would normally be expected from a single population of consanguinal and affinal relatives. García Velasco's identification of at least two biological groups, in conjunction with biogeochemical results indicating the presence of a handful of local individuals as well as non-local individuals from multiple geologically distinct regions (Pacheco-Forés, Morehart, et al., in preparation), suggests that Non-Grid 4 individuals likely originated from multiple distinct sources. I therefore used finite mixture analysis to reveal latent biological population structure among Non-Grid 4 individuals to further refine my ability to pinpoint potential migrant source populations.

Finite mixture models provide powerful but flexible tools to detect the presence of multiple biological groups within a larger sample (McLachlan & Peel, 2000). This analysis assumes no prior knowledge of the number of groups presence, or individuals' sex or group affiliation (Algee-Hewitt, 2016). Instead, the model iteratively selects the most likely number of groups present in the sample via maximum likelihood estimation using the expectation-maximization algorithm (McLachlan & Krishnan, 1997). Additionally, the analysis generates estimated posterior probabilities of group membership for each individual for *k* groups. I performed a finite mixture analysis on all observable Non-Grid 4 individuals (*n*=115) in R using the MCLUST 4.3 mixture clustering package (Fraley & Raftery, 2002, 2012). I used estimated posterior probabilities to assign individuals to *k* groups for subsequent analysis.

Relationship (R) matrix analysis

I used each imputed dataset (*m*=10; *n*=333), including Non-Grid 4 *k* groups, to conduct a relationship (R) matrix analysis in RMET 5.0. R-matrix analysis evaluates the extent of regional differential external gene flow, as well as the average genetic differentiation among populations (Harpending & Ward, 1982; Relethford, 2003; Relethford et al., 1997; Relethford & Blangero, 1990). The analysis produces two parameters of interest. The first, the F_{ST} statistic, ranges between 0 and 1 and represents overall levels of genetic variation within a regional mating network. Values closer to 0 indicate high levels of mate exchange between populations, while values closer to 1 indicate very limited mate exchange and increased genetic isolation. The second parameter of interest is estimated genetic distance matrix between individual populations. Using equal population size weighting schemes and an average heritability of $h^2=0.62$ for odontometric traits following Stojanowski (2005a, 2005b), I generated inter-site genetic distance matrices for each imputed dataset. Distance matrices, unbiased F_{ST} statistics, and their respective standard errors for *m* imputations were then averaged into a pooled set of results. This method combines the results from *m* imputations into a single set of results that reflects the statistical uncertainty due to missing data (Rubin, 1987). The pooled distance matrix was visualized using multidimensional scaling and the ggplot2 package in R (Wickham, 2009).

Results

Top estimated *BIC* values for finite mixture candidate models for all Non-Grid 4 imputed datasets was *k*=2 (Table 5). Non-Grid 4 individuals were thus classified into two groups for each iterated dataset based on generated cluster membership posterior probabilities for best fitting models. Final sample sizes for each Non-Grid 4 group (designated as Non-Grid 4 A and Non-Grid 4 B) are reported in Table 5.

Table 5. Finite mixture analysis top *BIC* values and *k* group solutions for *m* imputed datasets.

m	**Top model *BIC***	***k***	**Non-Grid 4 A (*n*)**	**Non-Grid 4 B (*n*)**
1	-4345.3	2	45	70
2	-4342.2	2	69	46
3	-4459.7	2	53	62
4	-4409.2	2	98	17
5	-4470.3	2	37	78
6	-4390.1	2	53	62
7	-4539.8	2	95	20
8	-4273.0	2	83	32
9	-4409.0	2	51	64
10	-4413.8	2	44	71

The unbiased pooled average genetic differentiation among all populations was F_{ST}=0.05. This statistic differed significantly from 0 (*se*=0.01; *t*=4.69, *p*<.001). Pooled estimated genetic distance values between populations and their associated standard errors are presented in Table 6. Z-distribution tests were used to determine if inter-site estimated genetic distances were statistically significant (Table 7). Many calculated *p*-values of intersite estimated genetic distances do not fall under the α=0.05 threshold, indicating they are not statistically significantly different from 0. This is likely due to small sample sizes among many of the reference populations. I discuss them below regardless, as they are suggestive of trends, even if not statistically significant.

Table 6. Pooled inter-site estimated genetic distances[a] (upper triangle) and associated standard errors (lower triangle).

Site[b]	Teo-LVB	Teo-TLJ	Teo-CUE	NG4A	NG4B	TUL	CHL	PIL	OCO	MAB	CHI	COH	SLP
Teo-LVB	-	**0.06**	**0.26**	**0.10**	**0.12**	0.07	**0.08**	0.04	0.05	0.02	0.04	0.08	0.12
Teo-TLJ	0.02	-	0.05	**0.07**	**0.09**	0.12	0.05	0.02	0.07	**0.04**	0.03	0.11	0.05
Teo-CUE	0.13	0.10	-	0.18	0.20	0.31	0.10	0.09	0.31	0.22	0.15	0.22	0.17
NG4A	0.02	0.02	0.12	-	**0.16**	**0.12**	**0.09**	**0.10**	**0.13**	**0.07**	**0.08**	**0.14**	0.13
NG4B	0.03	0.03	0.12	0.03	-	**0.17**	**0.13**	**0.08**	**0.15**	**0.09**	**0.11**	**0.16**	**0.17**
TUL	0.05	0.06	0.17	0.06	0.07	-	0.12	0.13	0.08	0.09	0.11	0.18	0.16
CHL	0.03	0.03	0.11	0.03	0.04	0.07	-	0.07	0.11	**0.06**	0.08	0.12	0.13
PIL	0.03	0.03	0.12	0.04	0.04	0.08	0.04	-	0.06	0.05	0.02	0.09	0.07
OCO	0.04	0.04	0.16	0.05	0.05	0.07	0.06	0.05	-	0.04	0.04	0.11	0.08
MAB	0.01	0.02	0.13	0.02	0.02	0.05	0.03	0.03	0.04	-	0.04	0.08	0.10
CHI	0.03	0.03	0.12	0.03	0.04	0.07	0.04	0.03	0.04	0.03	-	0.13	0.06
COH	0.05	0.06	0.15	0.06	0.06	0.10	0.06	0.06	0.07	0.05	0.07	-	**0.21**
SLP	0.07	0.06	0.15	0.07	0.07	0.10	0.08	0.07	0.08	0.06	0.06	0.11	-

[a] D^2 values with significant associated *p*-values bolded.

[b] Abbreviations based on those in Table 4.

Table 7. Z-scores of inter-site estimated genetic distances (upper triangle) and associated *p*-values[a] (lower triangle).

Site[b]	**Teo_LVB**	**Teo_TLJ**	**Teo_CUE**	**NG4A**	**NG4B**	**TUL**	**CHL**	**PIL**	**OCO**	**MAB**	**CHI**	**COH**	**SLP**
Teo_LVB	-	2.65	1.98	4.39	4.49	1.37	2.57	1.43	1.32	1.58	1.63	1.61	1.78
Teo_TLJ	0.01	-	0.54	3.07	3.35	1.82	1.71	0.83	1.48	1.97	1.00	1.92	0.86
Teo_CUE	0.05	0.59	-	1.49	1.63	1.81	0.87	0.81	1.93	1.74	1.21	1.45	1.11
NG4A	0.00	0.00	0.13	-	5.48	2.01	2.95	2.65	2.68	3.61	2.62	2.42	1.94
NG4B	0.00	0.00	0.10	0.00	-	2.46	3.35	2.26	2.88	4.04	2.99	2.59	2.28
TUL	0.17	0.07	0.07	0.04	0.01	-	1.73	1.77	1.09	1.62	1.62	1.86	1.58
CHL	0.01	0.09	0.38	0.00	0.00	0.08	-	1.61	1.93	2.11	1.94	1.81	1.72
PIL	0.15	0.41	0.42	0.01	0.02	0.08	0.11	-	1.19	1.56	0.44	1.41	0.99
OCO	0.19	0.14	0.05	0.01	0.00	0.28	0.05	0.23	-	1.16	0.86	1.50	1.01
MAB	0.11	0.05	0.08	0.00	0.00	0.11	0.03	0.12	0.25	-	1.49	1.60	1.55
CHI	0.10	0.32	0.23	0.01	0.00	0.11	0.05	0.66	0.39	0.14	-	1.94	0.85
COH	0.11	0.05	0.15	0.02	0.01	0.06	0.07	0.16	0.13	0.11	0.05	-	1.97
SLP	0.08	0.39	0.27	0.05	0.02	0.11	0.09	0.32	0.31	0.12	0.40	0.05	-

[a] A significant *p*-value indicates that the D^2 value (Table 6) is statistically different from 0.

[b] Abbreviations based on those in Table 4.

Inter-site estimated genetic distances are visualized in Fig 12. While the ordination plot gives a good overall summary of genetic variation among analyzed populations, it compresses genetic variation within central Mexican populations and thus does not exactly reflect estimated genetic distances (Table 6). For example, while Non-Grid 4 B should plot most closely to Pilarillos ($D^2=0.08$, $p=0.023$) populations from the Malpaso Valley-La Quemada settlement system region, followed by Tlajinga 33 ($D^2=0.09$, $p<0.001$) in central Mexico, and Monte Albán ($D^2=0.09$, $p<0.001$) in southern Mexico based on estimated genetic distances, the central Mexican sites of Cholula ($D^2=0.13$, $p<0.001$) and Non-Grid 4 A ($D^2=0.16$, $p<0.001$) appear to be among its nearest neighbors on the ordination plot. For this reason, all subsequent discussion of inter-site genetic distances will focus on the values reported in Table 6 rather than on the ordination plot.

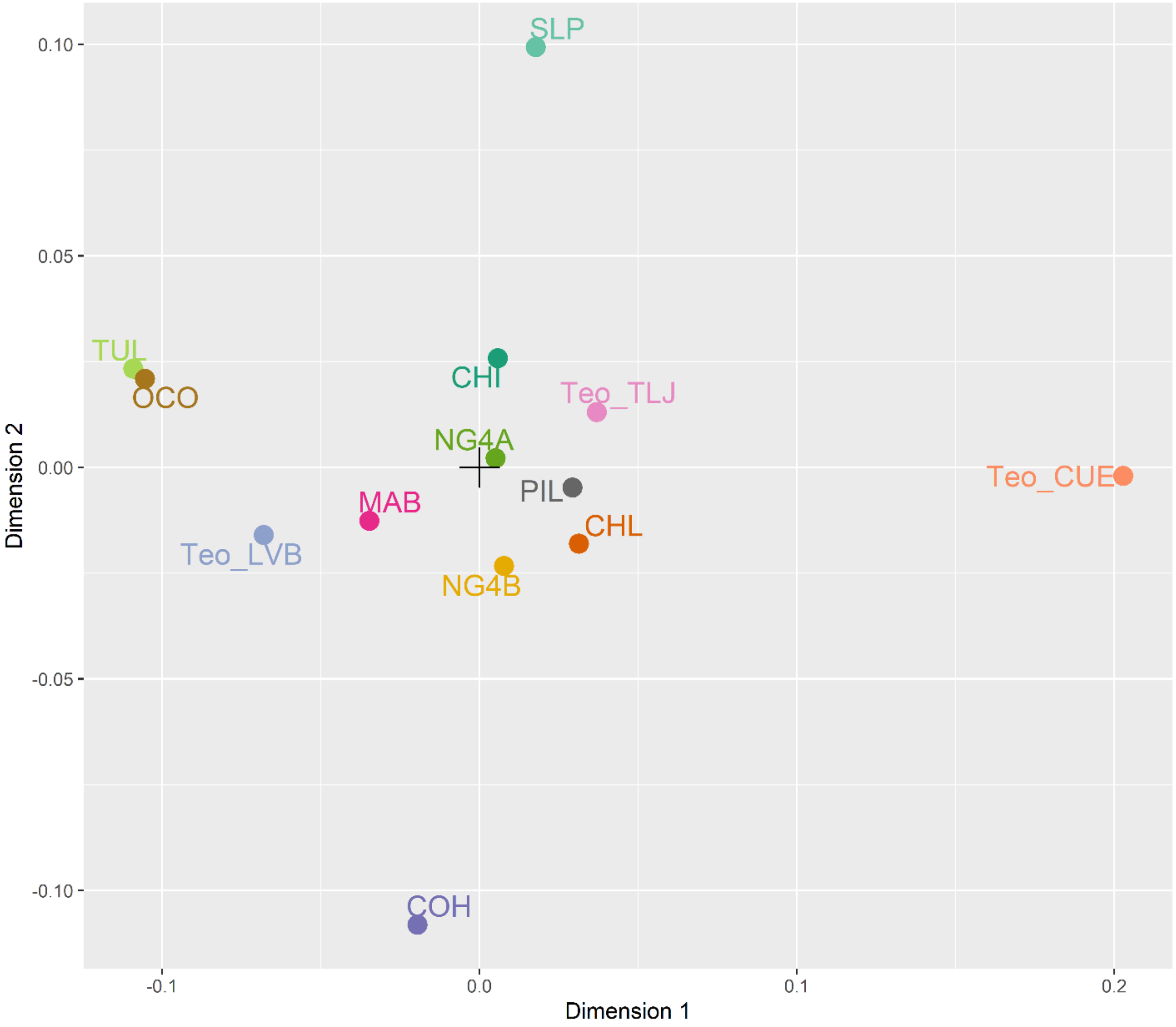

Figure 12. Multidimensional scaling of inter-site estimated genetic distances. Site abbreviations in Table 4. Note that the ordination compresses variation among central Mexican sites, making them appear more similar than estimated genetic distances indicate.

Discussion

The pooled average genetic differentiation among populations of F_{ST}=0.05 indicates that analyzed Classic and Epiclassic Mesoamerican populations are significantly different. The low magnitude of the statistic, however, suggests that there are high levels of gene flow between populations. When considered alongside biodistance and mtDNA studies finding that cultural differences—more so than geography or time period—best explain patterns of biological differentiation in ancient Mesoamerica (Morales-Arce et al., 2019; Willermet et al., 2013), this result provides some support to archaeological and bioarchaeological models of Epiclassic migrations within Mesoamerica. Greater mate exchange between populations implies greater movement of peoples.

Nevertheless, the F_{ST} is not necessarily meaningful in isolation. Instead, it establishes a baseline level of diversity among sampled populations. An examination of changes in overall levels of genetic variation over time (see Stojanowski, 2009) could better characterize changes in levels of inter-populational mate exchange from the Classic to the Epiclassic periods, bolstering support for Epiclassic migration hypotheses. Unfortunately, such an analysis is limited here by a lack of sufficient Classic-period samples.

Consideration of Non-Grid 4 variation at the intra-site level indicates that at least two biologically distinct populations were interred at the site. Finite mixture analysis results dividing Non-Grid 4 individuals into two distinct groups further clarify García Velasco’s (2019) finding that phenotypic diversity at Non-Grid 4 was likely indicative of multiple biological populations. This is further supported by the relatively large estimated genetic distance between the two Non-Grid 4 groups (D^2=0.16, *p*<.001), which was greater than 80% of all estimated genetic distances in the analysis. By dividing Non-Grid

4 individuals into two groups, this analysis reveals important biological variation within the Non-Grid 4 sample.

Continuity or replacement in Epiclassic Central Mexico?

Archaeological discussions of migration are often polarized between binary models of cultural and biological continuity or replacement. Inter-site estimated genetic distances between the five Epiclassic central Mexican groups (Non-Grid 4 A and B, the Teotihuacan Cuevas burials, Tula, and Cholula) and previous Classic period central Mexican populations (the Teotihuacan La Ventilla B and Tlajinga 33 burials), however, demonstrate that central Mexican population structure during the Classic-Epiclassic transition was far more complex. The three Cuevas individuals are the most genetically isolated group of any considered in the R-matrix analysis (Fig 12). When considering Classic-Epiclassic biological relationships, the Cuevas-La Ventilla B genetic distance is among the largest in the analysis ($D^2=0.26$, $p=.047$). Although the Cuevas-Tlajinga 33 distance is among the smallest ($D^2=0.05$, $p=.592$), it was not statistically significant different from 0, likely due to small sample size. Price and colleagues' (2000) biogeochemical identification of at least three migrants among the Cuevas individuals, however, further supports the finding that the Cuevas individuals were indeed biologically distinct from at least some Classic period populations at Teotihuacan.

Other Epiclassic central Mexican populations range from being relatively genetically distinct from Classic central Mexican populations (Non-Grid 4 B-La Ventilla B, $D^2=0.12$, $p<.001$; Tula-Tlajinga 33, $D^2=0.12$, $p=.068$) to sharing a greater genetic affinity with them (Cholula-Tlajinga 33, D^2=0.05, p=.087; Non-Grid 4 A-Tlajinga 33, D^2=0.07, p=.002; Tula-La Ventilla B, D^2=0.07, p=.171). This again suggests some level of biological continuity within Epiclassic central Mexico, while also providing evidence of external gene flow—and an accompanying influx of migrants—into the region during the Classic-Epiclassic transition. However, I again note the need for greater representation of Classic period central Mexican samples in future analyses, as I have here only a limited representation of regional Classic period biological diversity.

These results contradict previous archaeological models dismissing the influence of migrants on central Mexican sociopolitical development (e.g., Sanders, 1986, 2006; Sugiura Yamamoto, 2006). Similarly, they also do not support prior models of complete population replacement (e.g., Rattray, 1966, 1996, 2006). The results suggest that rather than assessing Epiclassic central Mexico population structure through polarized models of biological continuity or replacement, a perspective of biological admixture may be more appropriate.

Epiclassic migrant origins at Non-Grid 4 and beyond

Interestingly, results show that Epiclassic central Mexican groups are generally more biologically distinct from each other than they are from Classic central Mexican populations at Teotihuacan. The Cuevas group is particularly divergent from other Epiclassic central Mexican groups (Cuevas-Tula, D^2=0.31, p=.070; Cuevas-Non-Grid 4 B, D^2=0.20, p=.103; Cuevas-Non-Grid 4 A, D^2=0.18, p=.135). Similarly, Non-Grid 4 B is genetically distinct from Tula (D^2=0.17, p=.014), and as previously discussed, the two

Non-Grid 4 groups are biologically distinct from each other. This suggests that although increased biological diversity into central Mexico is likely consistent with an influx of migrants, these migrants do not represent a biological monolith. Biogeochemical analyses of both Cuevas and Non-Grid 4 individuals support this finding, as identified migrants from both sites exhibit clear differences in isotopic values reflective of several geologically distinct geographic origin locales (Pacheco-Forés, Morehart, et al., in preparation; Price et al., 2000). Instead, migrants appear to be arriving in central Mexico from multiple distinct biological source populations.

Inter-site estimated genetic distances also provide valuable insight when considering possible source populations for Epiclassic migrants into central Mexico. Cuevas individuals share the greatest biological affinity with individuals from Los Pilarillos in the Malpaso Valley-La Quemada settlement system region of north-central Mexico ($D^2=0.09$, $p=.053$). Non-Grid 4 A individuals are most biologically similar to groups from Monte Albán in southern Mexico ($D^2=0.07$, $p<.001$) and Cusihuiriachi in northern Mexico ($D^2=0.08$, $p=.009$). Non-Grid 4 B individuals are most genetically similar to those from Los Pilarillos ($D^2=0.08$, $p=.024$) and Monte Albán ($D^2=0.09$, $p<.001$). Although I focus on sites where biogeochemical analyses have confirmed the presence of migrants (Cuevas and Non-Grid 4), it is interesting to note that Epiclassic individuals at Tula are most similar to those from El Ocote in the Bajío region of north-central Mexico ($D^2=0.08$, $p=.276$), and individuals at Cholula share the greatest biological affinity with Monte Albán ($D^2=0.06$, $p=.035$).

The biological distances discerned here reflect possible source populations for Epiclassic migrants in central Mexico. While these results further support archaeological and bioarchaeological models suggesting Epiclassic migrants came from northern Mexico, including the Bajío and Malpaso Valley-La Quemada settlement system regions, they also suggest potential Epiclassic migration sources not previously considered by archaeologists.

For example, although migration from southern Mexico is rarely included in discussions of central Mexican Epiclassic migrations, individuals from Non-Grid 4 (both A and B) and Cholula all shared close biological affinities with individuals from Epiclassic Monte Albán. Material evidence at Non-Grid 4 further supports this finding. Excavations of the Non-Grid 4 shrine recovered numerous matte finish gray ladle ceramic censers (Morehart et al., 2012). Such censers are uncommon within Classic period central Mexican ceramic assemblages, but strongly resemble Epiclassic period Xoo phase ceramics found at Monte Albán and throughout the Oaxaca Valley in southern Mexico (Martínez López et al., 2000).

The presence of Oaxacan migrants is well documented at the Classic period Teotihuacan residential compound of Tlailotlacan (Price et al., 2000; Spence et al., 2005; White, Spence, et al., 2004), as well as at Teotihuacan-established colonies to the north in the Tula region (Healan & Cobean, 2019; Spence, 2005). Additionally, Xoo phase ceramics recovered from other Epiclassic sites within central Mexico were interpreted as evidence of a southern Mexican merchant enclave (Smith & Lind, 2005). The biological and cultural evidence thus not only suggest that Oaxaca may indeed have been a source of migrants into central Mexico during the Epiclassic period, but also that Oaxacan diaspora networks persisted in some form throughout the Classic/Epiclassic transition.

These analyses therefore indicate that Epiclassic migrants in central Mexico may have originated in the Bajío or Malpaso Valley-La Quemada settlement system regions of northern Mexico or in the Oaxaca Valley in southern Mexico. However, it is also possible that close genetic distances between these groups reflect limitations in the analyzed sample, which include small sample sizes from northern Mexico and a lack of samples from western Mexico—an important hypothesized source of Epiclassic migrants (e.g, Beekman & Christensen, 2003; Gómez-Valdés et al., 2008). Thus, while the analyses have clarified certain aspects of the role of migration during the Classic-Epiclassic transition in central Mexico, more work remains to be done.

Conclusion

The biodistance analyses presented here demonstrate the complexities of central Mexican population structure during the Classic-Epiclassic transition. Analyses indicate some degree of biological continuity within central Mexico during this transition, while also showing support for an influx of migrants. Thus, rather than supporting archaeological models of biological continuity or replacement within central Mexico, I find support for population admixture during the Epiclassic period.

Furthermore, I find that Epiclassic populations within central Mexico were themselves biologically diverse, indicating that purported Epiclassic migrants originated from various source populations throughout Mesoamerica. While findings support archaeological and bioarchaeological models positing a northern Mexican origin for these migrants, including the Bajío and Malpaso Valley-La Quemada settlement system regions, they also find evidence of migration from the Oaxaca Valley in southern Mexico. Future work would benefit greatly from further examination of central Mexican connections with southern Mexico during the Epiclassic, as well as the inclusion of western Mexican Epiclassic skeletal samples and more samples from northern Mexico.

REFERENCES

Aguirre-Samudio, A., González-Sobrino, B. Z., Álvarez-Sandoval, B. A., Montiel, R., Serrano-Sánchez, C., & Meza-Peñaloza, A. (2017). Genetic history of Classic period Teotihuacan burials in central Mexico. Revista Argentina de Antropología Biológica, 19, 7–20.

Algee-Hewitt, B. F. B. (2016). Population inference from contemporary American craniometrics. American Journal of Physical Anthropology, 160(4), 604–624. https://doi.org/10.1002/ajpa.22959

Álvarez-Sandoval, B. A., Manzanilla, L. R., González-Ruiz, M., Malgosa, A., & Montiel, R. (2015). Genetic evidence supports the multiethnic character of Teopancazco, a neighborhood center of Teotihuacan, Mexico (AD 200-600). PLOS ONE, 10(7), e0132371. https://doi.org/10.1371/journal.pone.0132371

Anderson, J. H., Healan, D. M., & Cobean, R. H. (2016). Collapse, regeneration, and the origins of Tula and the Toltec state. In R. K. Faulseit (Ed.), Beyond collapse: archaeological perspectives on resilience, revitalization, and transformation in complex societies (pp. 431–458). Carbondale, Illinois: Southern Illinois University Press.

Anton, S. C. (1989). Intentional cranial vault deformation and induced changes of the cranial base and face. American Journal of Physical Anthropology, 79(2), 253–267.

Aubry, B. S. (2009). Population structure and interregional interaction in prehispanic Mesoamerica: a biodistance study (Ph.D. dissertation). Ohio State University, Columbus, OH.

Aubry, B. S. (2014). Cervical dimensions for in situ and loose teeth: a critique of the Hillson et al. (2005) method. American Journal of Physical Anthropology, 154, 159–164. https://doi.org/10.1002/ajpa.22475

Beekman, C. S. (2015). Causes and consequences of migration in Epiclassic northern Mesoamerica. In B. J. Baker & T. Tsuda (Eds.), Migration and disruptions: toward a unifying theory of ancient and contemporary migrations (pp. 73–96). Gainesville, FL: University Press of Florida.

Beekman, C. S., & Christensen, A. F. (2003). Controlling for doubt and uncertainty through multiple lines of evidence: a new look at the Mesoamerican Nahua migrations. Journal of Archaeological Method and Theory, 10(2), 111–164. https://doi.org/10.1023/A:1024519712257

Beekman, C. S., & Christensen, A. F. (2011). Power, agency, and identity: migration and aftermath in the Mezquital area of north-central Mexico. In G. S. Cabana & J. J. Clark (Eds.), Rethinking anthropological perspectives on migration. Retrieved from https://muse.jhu.edu/book/17953

Braniff, B. (2005). Los chichimecas a la caída de Teotihuacan y durante la conformación de la Tula de Hidalgo. In L. R. Manzanilla (Ed.), Reacomodos demográficos del clásico al posclásico en el centro de México (pp. 45–56). Mexico City: Universidad Nacional Autónoma de México Instituto de Investigaciones Antropológicas.

Buckley, G., Storey, R., Hirth, K. G., Kennett, D. J., & Culleton, B. J. (2016). Geographical isotopes, migration, and the Tlajinga District of Teotihuacan. Presented at the 81st Annual Meeting of the Society for American Archaeology, Orlando, FL.

Buikstra, J. E. (1980). Epigenetic distance: a study of biological variability in the Lower Illinois River region. In D. Browman (Ed.), Early Native Americans (pp. 271–300). New York: Mouton.

Buikstra, J. E., Frankenberg, S. R., & Konigsberg, L. W. (1990). Skeletal biological distance studies in American physical anthropology: recent trends. American Journal of Physical Anthropology, 82(1), 1–7. https://doi.org/10.1002/ajpa.1330820102

Cabrera Castro, R., & Gómez Chavez, S. (2008). La Ventilla: a model for a barrio in the urban structure of Teotihuacan. In A. G. Mastache, R. H. Cobean, A. García Cook, & K. G. Hirth (Eds.), El urbanismo en Mesoamérica/Urbanism in Mesoamerica (Vol. 2, pp. 37–83). University Park, PA: Instituto Nacional de Antropología e Historia and Pennsylvannia State University.

Carballo, D. M. (2011). Obsidian and the Teotihuacan State: weaponry and ritual production at the Moon Pyramid/La obsidiana y el Estado Teotihuacano: la producción militar y ritual en la Pirámide de la Luna. Pittsburgh and Mexico City: University of Pittsburgh Center for Comparative Archaeology and the Instituto de Investigaciones Antropológicas, Universidad Nacional Autónoma de México.

Cheverud, J. M. (1988). A comparison of genetic and phenotypic correlations. Evolution, 42(5), 958. https://doi.org/10.2307/2408911

Cheverud, J. M., Kohn, L. A., Konigsberg, L. W., & Leigh, S. R. (1992). Effects of fronto-occipital artificial cranial vault modification on the cranial base and face. American Journal of Physical Anthropology, 88(3), 323–345.

Cheverud, J. M., & Midkiff, J. E. (1992). The effects of fronto-occipital cranial reshaping on mandibular form. American Journal of Physical Anthropology, 87, 167–171.

Christensen, A. F. (1997). Cranial non-metric variation in north and central Mexico. Anthropologischer Anzeiger, 55(1), 15–32.

Cobean, R. H., & Mastache, A. G. (1989). The Late Classic and Early Postclassic chronology of the Tula region. In D. M. Healan (Ed.), Tula of the Toltecs: excavation and survey (pp. 34–48). Iowa City, IO: University of Iowa Press.

Corruccini, R. S. (1973). Size and shape in similarity coefficients based on metric characters. American Journal of Physical Anthropology, 38(3), 743–753. https://doi.org/10.1002/ajpa.1330380313

Cowgill, G. L. (2013). Possible migrations and shifting identities in the central Mexican Epiclassic. Ancient Mesoamerica, 24(01), 131–149. https://doi.org/10.1017/S0956536113000060

Cowgill, G. L. (2015a). Ancient Teotihuacan: early urbanism in central Mexico. Cambridge, U.K.: Cambridge University Press.

Cowgill, G. L. (2015b). The debated role of migration in the fall of ancient Teotihuacan in central Mexico. In B. J. Baker & T. Tsuda (Eds.), Migration and disruptions: toward a unifying theory of ancient and contemporary migrations (pp. 97–122). Gainesville, FL: University Press of Florida.

Crider, D. L. (2011). Epiclassic and early Postclassic interaction in central Mexico as evidenced by decorated pottery (Ph.D. dissertation). Arizona State University, Tempe, AZ.

Crider, D. L. (2013). Shifting alliances: Epiclassic and early Postclassic interactions at Cerro Portezuelo. Ancient Mesoamerica, 24(01), 107–130. https://doi.org/10.1017/S0956536113000047

Cyphers, A. (2000). Cultural identity and interregional interaction during the Gobernador Phase: a ceramic perspective. In K. G. Hirth (Ed.), Archaeological research at Xochicalco (Vol. 2, pp. 102–135). Salt Lake City, UT: University of Utah Press.

Diehl, R. A., & Berlo, J. C. (Eds.). (1989). Mesoamerica after the decline of Teotihuacan AD 700-900. Washington, D.C: Dumbarton Oaks.

Faure, G., & Powell, J. L. (1972). Strontium isotope geology. New York, NY: Springer-Verlag.

Fournier, P., & Bolaños, V. (2007). The Epiclassic in the Tula region beyond Tula Chico. In C. Kristan-Graham & J. Kowalski (Eds.), Twin Tollans: Chichén Itzá, Tula, and the epiclassic to early postclassic Mesoamerican world (pp. 481–529). Washington, D.C.: Dumbarton Oaks.

Fournier, P., & Vargas Sanders, R. (2002). En busca de los" dueños del silencio": cosmovisión y ADN antiguo de las poblaciones otomíes epiclásicas de la región de Tula. Revista de Estudios Otopames, 3, 37–75.

Fraley, C., & Raftery, A. E. (2002). Model-based clustering, discriminant analysis and density estimation. Journal of the American Statistical Association, 97, 611–631.

Fraley, C., & Raftery, A. E. (2012). mclust version 4 for R: normal mixture modeling for model-based clustering, classification, and density estimation (Technical Report No. 597). Seattle, WA: Department of Statistics, University of Washington.

García Velasco, M. (2019). Estudio craneológico de un conjunto de individuos sacrificados en Xaltocan en el periodo epiclásico (Ph.D. dissertation). Universidad Nacional Autónoma de México, Mexico City.

Gat, J. R. (1996). Oxygen and hydrogen isotopes in the hydrologic cycle. Annual Review of Earth and Planetary Sciences, 24(1), 225–262. https://doi.org/10.1146/annurev.earth.24.1.225

Gaxiola González, M. (2006). Tradición y estilo en el estudio de la variabilidad cerámica del Epiclásico en el centro de México. In L. Solar Valverde (Ed.), El fenómeno Coyotlatelco en el centro de México: tiempo, espacio y significado (pp. 31–54). Mexico City: Instituto Nacional de Antropología e Historia.

Gómez-Valdés, J. A., Bautista Martínez, J. B., Pompa y Padilla, J. A., Talavera González, A., & Castrejón-Caballero, J. L. (2008). Continuidad genética entre el Occidente y la Mesoamérica nuclear: hipótesis morfológica dental. Arqueología, (37), 23–34.

González-José, R., Martínez-Abadías, N., González-Martín, A., Bautista-Martínez, J., Gómez-Valdés, J., Quinto, M., & Hernández, M. (2007). Detection of a population replacement at the Classic–Postclassic transition in Mexico. Proceedings of the Royal Society B: Biological Sciences, 274(1610), 681–688. https://doi.org/10.1098/rspb.2006.0151

Harpending, H. C., & Jenkins, T. (1973). Genetic distance among southern African populations. In M. H. Crawford & P. L. Workman (Eds.), Methods and theories of anthropological genetics (pp. 177–199). Albuquerque, NM: University of New Mexico Press.

Harpending, H. C., & Ward, R. H. (1982). Chemical systematics and human evolution. In M. Nitecki (Ed.), Biochemical aspects of evolutionary biology (pp. 213–256). Chicago, IL: University of Chicago Press.

Healan, D. M. (1997). Pre-Hispanic quarrying in the Ucareo-Zinapecuaro obdisidian source area. Ancient Mesoamerica, 8(1), 77–100. Retrieved from JSTOR.

Healan, D. M. (2012). The archaeology of Tula, Hidalgo, Mexico. Journal of Archaeological Research, 20(1), 53–115. https://doi.org/10.1007/s10814-011-9052-3

Healan, D. M., & Cobean, R. H. (2019). Three migration case studies from the Tula region. In C. S. Beekman (Ed.), Migrations in late Mesoamerica (pp. 66–87). Gainesville, FL: University Press of Florida.

Hernández, C. L. (2016). Ceramic evidence of Teotihuacan contact linking the Basin of Mexico, the Bajío, and southern Hidalgo. In E. Williams & B. Maldonado (Eds.), Cultural dynamics and production activities in ancient western Mexico (pp. 215–238). Oxford: Archaeopress.

Hernández, C. L., & Healan, D. M. (2019). Migration and the Coyotlatelco ceramic tradition: evidence from El Bajío. In C. S. Beekman (Ed.), Migrations in late Mesoamerica (pp. 88–108). Gainesville, FL: University Press of Florida.

Hillson, S., FitzGerald, C., & Flinn, H. (2005). Alternative dental measurements: proposals and relationships with other measurements. American Journal of Physical Anthropology, 126(4), 413–426. https://doi.org/10.1002/ajpa.10430

Hopkins, N. A. (1984). Otomanguean linguistic prehistory. In J. K. Josserand, M. Winter, & N. A. Hopkins (Eds.), Essays in Otomanguean culture history (pp. 25–64). Nashville, TN: Vanderbilt University.

Kaufman, T. (2001). The history of the Nawa language group from the earliest times to the sixteenth century: some intial results. Retrieved from https://www.albany.edu/anthro/maldp/Nawa.pdf

Kohn, L. A. P., Leigh, S. R., Jacobs, S. C., & Cheverud, J. M. (1993). Effects of annular cranial vault modification on the cranial base and face. American Journal of Physical Anthropology, 90(2), 147–168.

Larsen, C. S. (1999). Historical dimensions of skeletal variation: tracing genetic relationships. In Bioarchaeology: interpreting behavior from the human skeleton (pp. 302–332). Cambridge: Cambridge University Press.

Manzanilla, L. R. (2005). Migrantes epiclásicos en Teotihuacan: propuesta metodológica para análisis de migraciones del clásico al posclásico. In L. R. Manzanilla (Ed.), Reacomodos demográficos del clásico al posclásico en el centro de México (pp. 261–274). Mexico City: Universidad Nacional Autónoma de México Instituto de Investigaciones Antropológicas.

Manzanilla, L. R., López, C., & Freter, A. (1996). Dating results from excavations in quarry tunnels behind the Pyramid of the Sun at Teotihuacan. Ancient Mesoamerica, 7(02), 245–266. https://doi.org/10.1017/S0956536100001450

Martínez López, C., Markens, R., Winter, M. C., & Lind, M. D. (2000). Cerámica de la fase Xoo (época Monte Albán IIIB-IV) del Valle de Oaxaca. Oaxaca: Proyecto Especial Monte Albán, Centro Instituto Nacional de Anthropología e Historia.

Mastache, A. G., Cobean, R. H., & Healan, D. M. (2002). Ancient Tollan: Tula and the Toltec heartland. Boulder, CO: University Press of Colorado.

McLachlan, G. J., & Krishnan, T. (1997). The EM algorithm and extensions. New York: Wiley.

McLachlan, G. J., & Peel, D. (2000). Finite mixture models. New York: Wiley-Interscience.

Meza-Peñaloza, A., Zertuche, F., García-Velasco, M., & Morehart, C. (2019). A non-metric traits study of skulls from Epiclassic Xaltocan in relation to other Mesoamerican cultures. Journal of Archaeological Science: Reports, 23, 559–566. https://doi.org/10.1016/j.jasrep.2018.11.031

Miller, W. R. (1983). Uto-Aztecan languages. In A. Ortiz (Ed.), Handbook of North American indians, vol. 10: Southwest (pp. 13–24). Washington, D.C.: Smithsonian Institution Press.

Millon, R. (1976). Social relations in ancient Teotihuacan. In E. R. Wolf (Ed.), The Valley of Mexico: studies in pre-Hispanic ecology and society (pp. 205–248). Albuquerque, NM: University of New Mexico Press.

Morales-Arce, A. Y., McCafferty, G., Hand, J., Schmill, N., McGrath, K., & Speller, C. (2019). Ancient mitochondrial DNA and population dynamics in postclassic Central Mexico: Tlatelolco (ad 1325–1520) and Cholula (ad 900–1350). Archaeological and Anthropological Sciences. https://doi.org/10.1007/s12520-018-00771-7

Morehart, C. T., Peñaloza, A. M., Sánchez, C. S., de Tapia, E. M., & Morales, E. I. (2012). Human sacrifice during the Epiclassic period in the northern Basin of Mexico. Latin American Antiquity, 23(4), 426–448.

Nado, K. L. (2017). Dietary practices, socioeconomic status, and social mobility at Teotihuacan, Mexico (Ph.D. dissertation). Arizona State University, Tempe, AZ.

Nelson, B. A., & Crider, D. L. (2005). Posibles pasajes migratorios en el norte de México y el suroeste de los Estados Unidos durante el epiclásico y el posclásico. In L. R. Manzanilla (Ed.), Reacomodos demográficos del clásico al posclásico en el centro de México (pp. 75–102). Mexico City: Universidad Nacional Autónoma de México Instituto de Investigaciones Antropológicas.

Nelson, Z. (2009). Obsidian biface production at Teotihuacan: reexamining a Coyotlatelco phase workshop from Hacienda Metepec. Ancient Mesoamerica, 20(1), 149–162. Retrieved from JSTOR.

Pacheco-Forés, S. I., Morehart, C. T., & Knudson, K. J. (in preparation). Migration, violence, and the “other”: a biogeochemical approach to identity-based violence and human sacrifice in the Epiclassic Basin of Mexico. Journal of Anthropological Archaeology.

Parsons, J. R., Gorenflo, L. J., Parsons, M. H., & Wilson, D. J. (2008). Prehispanic settlement patterns in the northwestern Valley of Mexico: the Zumpango region. Ann Arbor, MI: Museum of Anthropology, University of Michigan.

Parsons, J. R., & Sugiura, Y. (2012). Teotihuacan and the Epiclassic in central Mexico. In D. L. Nichols & C. A. Pool (Eds.), The Oxford handbook of Mesoamerican archaeology (pp. 309–323). Oxford: Oxford University Press.

Price, T. D., Manzanilla, L. R., & Middleton, W. D. (2000). Immigration and the ancient city of Teotihuacan in Mexico: a study using strontium isotope ratios in human bone and teeth. Journal of Archaeological Science, 27(10), 903–913. https://doi.org/10.1006/jasc.1999.0504

Püschel, T. A., Friess, M., & Manríquez, G. (2020). Morphological consequences of artificial cranial deformation: Modularity and integration. PLOS ONE, 15(1), e0227362. https://doi.org/10.1371/journal.pone.0227362

R Core Team. (2016). R: a language and environment for statistical computing. Vienna, Austria: R Foundation for Statistical Computing.

Ragsdale, C. S., & Edgar, H. J. H. (2018). Population continuity and replacement in the pre-contact Valley of Mexico. In C. Willermet & A. Cucina (Eds.), Bioarchaeology of pre-Columbian Mesoamerica: an interdisciplinary approach (pp. 37–69). Gainesville, FL: University Press of Florida.

Rattray, E. C. (1966). An archaeological and stylistic study of Coyotlatelco pottery. Mesoamerican Notes, 7–8, 87–211.

Rattray, E. C. (1987). La producción y la distribución de obdisidana en el periodo Coyotlatelco en Teotihuacan: un estudio preliminar. In E. McClung de Tapia & E. C. Rattray (Eds.), Teotihuacan: nuevos datos, nuevas síntesis, nuevos problemas (pp. 451–463). Mexico City: Instituto de Investigaciones Antropológicas, Universidad Nacional Autónoma de México.

Rattray, E. C. (1996). A regional perspective on the Epiclassic period in central Mexico. In A. G. Mastache, J. R. Parsons, R. S. Santley, & M. C. Serra Puche (Eds.), Arqueología mesoamericana: homenaje a William T. Sanders (pp. 213–231). Mexico City: Instituto Nacional de Antropología e Historia.

Rattray, E. C. (2006). El Epiclásico de Teotihuacan y Azcapotzalco. In L. Solar Valverde (Ed.), El fenómeno Coyotlatelco en el centro de México: tiempo, espacio y significado (pp. 201–214). Mexico City: Instituto Nacional de Antropología e Historia.

Relethford, J. H. (2003). Anthropometric data and population history. In D. A. Herring & A. C. Swedlund (Eds.), Human biologists in the archives: demography, health, nutrition, and genetics in historical populations (pp. 32–52). Cambridge: Cambridge University Press.

Relethford, J. H., & Blangero, J. (1990). Detection of differential gene flow from patterns of quantitative variation. Human Biology, 62(1), 5–25.

Relethford, J. H., Crawford, M. H., & Blangero, J. (1997). Genetic drift and gene flow in post-famine Ireland. Human Biology, 69(4), 443–465.

Rubin, D. B. (1987). Multiple imputation for nonresponse in surveys. New York, NY: Wiley.

Sanders, W. T. (Ed.). (1986). The Teotihuacan Valley Project, Final Report, Volume 4: the Toltec period occupation. University Park, PA: Department of Anthropology, Pennsylvania State University.

Sanders, W. T. (1989). The Epiclassic as a stage in Mesoamerican prehistory: an evaluation. In R. A. Diehl & J. C. Berlo (Eds.), Mesoamerica after the decline of Teotihuacan, A.D. 700-900 (pp. 211–218). Washington, D.C.: Dumbarton Oaks.

Sanders, W. T. (2006). Late Xolalpan-Metepec/Oxtotipac-Coyotlatelco: ethnic succession or changing patterns of political economy, a reevaluation. In L. Solar Valverde (Ed.), El fenómeno Coyotlatelco en el centro de México: tiempo, espacio y significado (pp. 183–200). Mexico City: Instituto Nacional de Antropología e Historia.

Sanders, W. T., Parsons, J. R., & Santley, R. S. (1979). The Basin of Mexico: ecological processes in the evolution of a civilization. New York: Academic Press.

Schaaf, P., Solís, G., Manzanilla, L. R., Hernández, T., Lailson, B., & Horn, P. (2012). Isótopos de estroncio aplicados a estudios de migración humana en el centro de barrio de Teopancazco, Teotihuacan. In L. R. Manzanilla (Ed.), Estudios arqueométricos del centro de barrio de Teopancazco en Teotihuacan (pp. 425–448). Mexico City: Instituto de Investigaciones Antropológicas, Universidad Nacional Autónoma de México.

Schafer, J. L. (1999). Multiple imputation: a primer. Statistical Methods in Medical Research, 8(1), 3–15. https://doi.org/10.1177/096228029900800102

Schafer, J. L., & Olsen, M. K. (1998). Multiple imputation for multivariate missing-data problems: a data analyst’s perspective. Multivariate Behavioral Research, 33(4), 545–571. https://doi.org/10.1207/s15327906mbr3304_5

Shah, A. D., Bartlett, J. W., Carpenter, J., Nicholas, O., & Hemingway, H. (2014). Comparison of random forest and parametric imputation models for imputing missing data using MICE: a CALIBER study. American Journal of Epidemiology, 179(6), 764–774. https://doi.org/10.1093/aje/kwt312

Smith, M. E., & Lind, M. D. (2005). Xoo-phase ceramics from Oaxaca found at Calixtlahuaca in central Mexico. Ancient Mesoamerica, 16(2), 169–177. Retrieved from JSTOR.

Solar Valverde, L. (Ed.). (2006). El fenómeno Coyotlatelco en el centro de México: tiempo, espacio y significado. México D.F.: Instituto Nacional de Antropología e Historia.

Solís Pichardo, G., Schaaf, P., Hernández Treviño, T., Lailson, B., Manzanilla, L. R., & Horn, P. (2017). Migrants in Teopancazco: evidence from strontium isotopic studies. In L. R. Manzanilla (Ed.), Multiethnicity and migration at Teopancazco: investigations of a Teotihuacan neighborhood center (pp. 143–163). Gainesville, FL: University Press of Florida.

Spence, M. W. (1974). Residential practices and the distribution of skeletal traits in Teotihuacan, Mexico. Man, 9(2), 262. https://doi.org/10.2307/2800077

Spence, M. W. (1994). Human skeletal material from Teotihuacan. In M. L. Sempowski & M. W. Spence (Eds.), Mortuary practices and skeletal remains at Teotihuacan (pp. 315–427). Salt Lake City: University of Utah Press.

Spence, M. W. (2005). A Zapotec diaspora network in Classic-period central Mexico. In G. J. Stein (Ed.), The archaeology of colonial encounters: comparative perspectives (pp. 173–206). Santa Fe, NM: School of American Research Press.

Spence, M. W., White, C., Rattray, E. C., & Longstaffe, F. J. (2005). Past lives in different places: the origins and relationships of Teotihuacan's foreign residents. In R. E. Blanton (Ed.), Settlement, subsistence and social complexity: essays honoring the legacy of Jeffrey Parsons. Los Angeles, CA: Costen Institute of Archaeology, University of California, Los Angeles.

Stojanowski, C. M. (2005a). Biocultural histories in La Florida: a bioarchaeological perspective. Tuscaloosa, AL: University of Alabama Press.

Stojanowski, C. M. (2005b). The bioarchaeology of identity in Spanish colonial Florida: social and evolutionary transformation before, during, and after demographic collapse. American Anthropologist, 107(3), 417–431.

Stojanowski, C. M. (2007). Comment on "Alternative dental measurements" by Hillson et al. American Journal of Physical Anthropology, 132(2), 234–237. https://doi.org/10.1002/ajpa.20400

Stojanowski, C. M. (2009). Bridging histories: the bioarchaeology of identity in Postcontact Florida. In K. J. Knudson & C. M. Stojanowski (Eds.), Bioarchaeology and identity in the Americas (pp. 59–81). Gainesville, FL: University Press of Florida.

Stojanowski, C. M., & Schillaci, M. A. (2006). Phenotypic approaches for understanding patterns of intracemetery biological variation. American Journal of Physical Anthropology, 131(S43), 49–88. https://doi.org/10.1002/ajpa.20517

Storey, R. (1992). Life and death in the ancient city of Teotihuacan: a modern paleodemographic synthesis. Retrieved from http://site.ebrary.com/lib/alltitles/docDetail.action?docID=10527765

Sugiura Yamamoto, Y. (2006). ¿Cambio gradual o discontinuidad en la cerámica?: discusión acerca del paso del Clásico al Epiclásico, visto desde el Valle de Toluca. In L. Solar Valverde (Ed.), El fenómeno Coyotlatelco en el centro de México: tiempo, espacio y significado (pp. 127–162). Mexico City: Instituto Nacional de Antropología e Historia.

Tozzer, A. M. (1921). Excavations of a site at Santiago Ahuitzotla City, Mexico. Washington, D.C.: Bureau of American Ethnology.

Tsuda, T., Baker, B. J., Eder, J. F., Knudson, K. J., Maupin, J., Meierotto, L., & Scott, R. E. (2015). Unifying themes in studies of ancient and contemporary migrations. In B. J. Baker & T. Tsuda (Eds.), Migration and disruptions: toward a unifying theory of ancient and contemporary migrations (pp. 15–30). Gainesville: University Press of Florida.

Utermohle, C. J., & Zegura, S. L. (1982). Intra- and interobserver error in craniometry: a cautionary tale. American Journal of Physical Anthropology, 57(3), 303–310. https://doi.org/10.1002/ajpa.1330570307

van Buuren, S. (2018). Flexible imputation of missing data (2nd ed.). Retrieved from https://stefvanbuuren.name/fimd/

van Buuren, S., & Groothuis-Oudshoorn, K. (2011). mice: multivariate imputation by chained equations in R. Journal of Statistical Software, 45(3), 1–67.

White, C. D., Spence, M. W., Longstaffe, F. J., & Law, K. R. (2004). Demography and ethnic continuity in the Tlailotlacan enclave of Teotihuacan: the evidence from stable oxygen isotopes. Journal of Anthropological Archaeology, 23(4), 385–403. https://doi.org/10.1016/j.jaa.2004.08.002

White, C. D., Spence, M. W., Longstaffe, F. J., Stuart-Williams, H., & Law, K. R. (2002). Geographic identities of the sacrificial victims from the Feathered Serpent Pyramid, Teotihuacan: implications for the nature of state power. Latin American Antiquity, 13(2), 217–236.

White, C. D., Spence, M. W., Stuart-Williams, H. L. Q., & Schwarcz, H. P. (1998). Oxygen isotopes and the identification of geographical origins: the Valley of Oaxaca versus the Valley of Mexico. Journal of Archaeological Science, 25(7), 643–655. https://doi.org/10.1006/jasc.1997.0259

White, C. D., Storey, R., Longstaffe, F. J., & Spence, M. W. (2004). Immigration, assimilation, and status in the ancient city of Teotihuacan: stable isotopic evidence from Tlajinga 33. Latin American Antiquity, 15(2(June)), 176–198.

Wickham, H. (2009). ggplot2: elegant graphics for data analysis. New York: Springer-Verlag.

Widmer, R. (1987). The evolution of form and function in a Teotihuacan apartment compound. In E. McClung de Tapia & E. C. Rattray (Eds.), Teotihuacán: nuevos datos, nuevas síntesis, nuevos problemas (pp. 317–368). Mexico City: Universidad Autónoma de México.

Willermet, C., Edgar, H. J. H., Ragsdale, C., & Aubry, B. S. (2013). Biodistances among Mexica, Maya, Toltec, and Totonac groups of central and coastal Mexicio. Chungará, Revista de Antropología Chilena, 45, 447–459.

CHAPTER 5

CONCLUSION

The preceding chapters build upon a persistent theme in interpreting the prehistory of ancient Mesoamerica: migration has long been a subject of archaeological research within central Mexico. The vast majority of research has focused on discerning the role of migration in the dramatic social, political, and cultural changes that swept central Mexico during the Epiclassic period. Migration has been implicated in the declining regional political and economic dominance of the Teotihuacan state to varying degrees (Cowgill, 2013, 2015a; Manzanilla, 2015), as well as in the emergence of new polities within the region (Beekman, 2015; Beekman & Christensen, 2011; Healan & Cobean, 2019).

Scholars have sought to reconstruct evidence for Epiclassic central migrations using material correlates in the archaeological record. Central among these is the appearance of the Coyotlatelco ceramic industry in central Mexico during the Epiclassic period (Crider, 2011; Solar Valverde, 2006; Tozzer, 1921). Most authors agree that these ceramics bear little resemblance to antecedent ceramic industries in central Mexico (Cowgill, 2013; Crider, 2013; Rattray, 1966, 1996, 2006), although countervailing opinions do exist (Fournier & Bolaños, 2007; Sanders, 1986, 2006; Sugiura Yamamoto, 2006). Instead, Coyotlatelco ceramics strongly resemble older ceramic industries from outside of central Mexico. Scholars have posited possible origins for Coyotlatelco in the Bajío (Beekman & Christensen, 2003, 2011; Healan, 2012; Hernández, 2016; Hernández

& Healan, 2019) and Malpaso Valley-La Quemada settlement system (Mastache et al., 2002; B. A. Nelson & Crider, 2005) regions of northwestern Mexico.

Archaeologists have also noted other changes in material culture coincident with the appearance of Coyotlatelco ceramics. The Epiclassic also saw the advent of new forms of lithic production throughout central Mexico (Carballo, 2011; Z. Nelson, 2009; Rattray, 1987). These techniques produced projectile points that were distinct from previous Classic period artifacts (Cowgill, 2015a, p. 111). Additionally, central Mexican Epiclassic sites with large numbers of Coyotlatelco ceramics also appeared to be exploiting obsidian sources distinct from those preferred during the Classic period (Healan, 1997). Interestingly, Ucareo-Zinapécuaro, the obsidian source dominating these assemblages, is located in the Bajío region, coinciding with one of the proposed origins of Coyotlatelco ceramics (Hernández & Healan, 2019). Scholars have thus hypothesized that these combined shifts in material culture patterns make up an intrusive material culture complex suggestive of migration into Epiclassic central Mexico (Cowgill, 2013, 2015a; Hernández & Healan, 2019).

Cognizant of critiques of cultural-historical archaeology and its oversimplified approach to migration, however (see Cabana, 2011), many researchers have been hesitant to equate changes in ceramic forms with the incursion of new peoples into central Mexico (Cowgill, 2013; Crider, 2013). Such changes could also be explained by the local emulation of foreign material forms, as well as by an intentional social, political, or moral distancing from previous material forms that may have fallen out of vogue with

Teotihuacan’s declining regional political and economic influence during the Epiclassic (Cowgill, 2013). Distinguishing the subtle differences between the introduction of a foreign style by migrants and local emulation of a foreign style, however, is difficult to discern archaeologically and little work has been done on the topic to date.

As such, archaeologists have sought to incorporate additional lines of evidence to further support Epiclassic migration hypotheses. Extensive regional survey data reveal stark discontinuities between Classic and Epiclassic settlement patterns in central Mexico. While the majority of Classic period settlements were located in clusters on the alluvial plain, most Epiclassic settlements are found on dispersed hilltops (Healan, 2012; Healan & Cobean, 2019; Mastache et al., 2002; Parsons et al., 2008; Sanders et al., 1979). Many Classic period settlements were abandoned during the Epiclassic, including sectors of Teotihuacan itself (Cabrera Castro & Gómez Chavez, 2008; Healan & Cobean, 2019; Rattray, 2006). Of the Classic settlements that persisted, few show evidence of interaction with new Epiclassic sites, as inferred through the lack of appreciable amounts of Coyotlatelco ceramics (Healan & Cobean, 2019). The association of new settlement patterns with the introduction of novel forms of material culture thus also suggested the arrival of a migrant population.

Art historical evidence further supports Epiclassic migration hypotheses. Public monumental art during the Epiclassic period is characterized primarily by its hybridity and eclecticism. In particular, murals and public monuments at Epiclassic sites in central Mexico have been described as stylistically foreign. This eclecticism has been attributed to emulation of foreign art styles (Nagao, 1989, 2014), and it has also been held up as an additional line of evidence supporting Epiclassic migration hypotheses within central Mexico (Turner, 2019).

While these data strongly suggest of substantial migration into central Mexico during the Epiclassic period, George Cowgill noted that “the most decisive evidence about migrations will probably eventually come through bioarchaeological methods” (2013, p. 143). To date, one biogeochemical study has directly identified three Epiclassic migrant individuals interred at Teotihuacan (Price et al., 2000). Interestingly, although ancient DNA (Morales-Arce et al., 2019) and biodistance analyses (Aubry, 2009; Beekman & Christensen, 2003; Christensen, 1997; Gómez-Valdés et al., 2008; González-José et al., 2007; Ragsdale & Edgar, 2018) have produced results that also indicate biological discontinuity between Classic and Postclassic period central Mexican peoples and likely population replacement due to migration, few have examined Epiclassic individuals directly (but see Manzanilla, 2005a). This is due to the rarity of Epiclassic skeletal remains recovered from central Mexican sites.

The discovery and excavation of a minimum of 180 individuals who were sacrificed and interred at the Epiclassic Non-Grid 4 shrine site in the northern Basin of Mexico (Morehart et al., 2012) thus provide a wealth of data for central Mexican migration studies. Biodistance analyses suggests that the individuals represented multiple biological kinship groups (García Velasco, 2019) who were also biologically distinct from previous central Mexican populations (Meza-Peñaloza et al., 2019).

In addition to providing much needed bioarchaeological data on migration in populations living in Epiclassic central Mexico, the Non-Grid 4 individuals also provide a unique opportunity to examine the consequences of such population movements on the migrants themselves. Thus, the goals of this dissertation were threefold:

1. To develop a theoretical framework for investigating identity-based violence in the past using bioarchaeological methods (Chapter 3). Bioarchaeological studies are highly successful in accessing multivalent past social identities, but applications of social identity theory to contexts of violence to understand who is targeted for violence are rare (but see Kurin, 2014, 2016).
2. To identify first-generation immigrants at Non-Grid 4 by reconstructing individuals' residential histories using biogeochemical methods. This involves creating a radiogenic strontium isotope baseline for central Mexico (Chapter 2) in addition to analyzing hard tissue samples from Non-Grid 4 using radiogenic strontium ($^{87}Sr/^{86}Sr$) and stable oxygen ($\delta^{18}O$) isotopic systems (Chapter 3).
3. To characterize patterns of biological affinity at Non-Grid 4 using multi-scalar biodistance analyses to evaluate archaeological models of migration and population dynamics in Classic-Epiclassic central Mexico and Mesoamerica (Chapter 4).

Summary of Results

Chapter 2 creates a baseline of bioavailable radiogenic strontium values for central Mexico. A total of 63 plant and water samples collected from 13 sites across central Mexico are analyzed for $^{87}Sr/^{86}Sr$ on a Thermo-Finnigan Neptune multi-collector inductively couple plasma mass spectrometer (MC-ICP-MS). These data are analyzed alongside 16 previously published soil and faunal bone $^{87}Sr/^{86}Sr$ values from two additional central Mexican sites. A five-cluster k-means model is generated to determine which regions of central Mexico can and cannot be distinguished isotopically using $^{87}Sr/^{86}Sr$ values.

Results demonstrate that although the two clusters falling within the Basin of Mexico within central Mexico overlap in their expected local $^{87}Sr/^{86}Sr$ ranges, many locations within the Basin are distinguishable using site-specific $^{87}Sr/^{86}Sr$ local ranges. In the context of central Mexican migration studies, the use of cluster or site-specific $^{87}Sr/^{86}Sr$ local ranges should thus be determined by the research question and the scale of mobility to be examined. This study contributes to central Mexican paleomobility studies by expanding knowledge of strontium isotope variability within the region, ultimately allowing researchers to detect intra-regional residential mobility and gain a greater understanding of the sociopolitical interactions within and between central Mexico and other regions of Mesoamerica.

Chapter 3 introduces a theoretical framework for examining identity-based violence in the past. It explores how during periods of scarcity and heightened intergroup competition, universally observed social dynamics like in-group favoritism and out-group bias can coalesce around specific salient social identities and escalate into identity-based violence. This framework is then applied to understand identity-based violence at Non-Grid 4.

Ethnohistoric and archaeological data indicate that geographic origin was a culturally significant indicator of social difference in pre-Hispanic Mesoamerica. Biogeochemical analyses of $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ isotopes, along with the biogeochemical $^{87}Sr/^{86}Sr$ developed in Chapter 2 are therefore used to reconstruct a sample (n=73) of sacrificial victims' residential histories to examine whether residential mobility predisposed individuals to suffer violence. Results find that 80% of sacrificed individuals at Non-Grid 4 were born outside of the Basin of Mexico. Furthermore 39 of these foreign-born individuals (53% of the total sample) are identified as first-generation immigrants. In contrast, only 6% of sampled individuals are identified as having lived locally within the Basin of Mexico their whole lives. Although there are no normative central Mexican Epiclassic burial contexts against which to compare these percentages, the overwhelming majority of foreign-born individuals strongly suggests individuals' divergent geographic origins and residential histories predisposed them to be targeted for ritual violence.

This work expands knowledge of migration processes in Epiclassic central Mexico. It uses biogeochemical methods to directly identify a large group of Epiclassic immigrants into central Mexico, providing decisive support for Epiclassic migration models. Furthermore, through the development of a theoretical framework within which to examine identity-based violence bioarchaeologically, it refocuses the central Mexican

Epiclassic migration debate on the migrants themselves, exploring the human impact of population movement and individual residential mobility, which included an increased vulnerability to suffer ritual violence.

Chapter 4 reconstructs patterns of biological affinity among Non-Grid 4 sacrificial victims (*n*=115) and a comparative sample of Classic (*n*=79) and Epiclassic (*n*=139) Mesoamerican populations. It uses multi-scalar biodistance analyses to characterize central Mexican population structure and dynamics during the Epiclassic period. Finite mixture analysis of Non-Grid 4 individuals reveals latent biological population structure within the sample indicating that two biologically distinct kinship groups are represented among the sacrificial victims. When considered alongside biogeochemical results presented in Chapter 3 finding a wide range of non-local $^{87}Sr/^{86}Sr$ values in identified migrant individuals, this suggests that migrants at Non-Grid 4 came from multiple origin communities.

Relationship (R) matrix analysis of Non-Grid 4 subpopulations and comparative Classic and Epiclassic Mesoamerican populations reveal a complex picture of population structure in Epiclassic central Mexico. Archaeological models of Epiclassic migration into the region are divided between those that emphasize biological continuity and dismiss the influence of migrants and those that posit complete population replacement of Classic central Mexican populations with Epiclassic migrants. Estimated genetic distances between Classic and Epiclassic central Mexican populations, however, demonstrate that the biological reality of Epiclassic central Mexico was far more complex, with some support for migration as well as for biological continuity. Thus, rather than assessing Epiclassic central Mexico through the polarized lens of biological continuity or replacement, it is best understood from the perspective of biological admixture.

Additionally, R matrix analysis results point to potential origin communities for central Mexican Epiclassic migrants. Estimated genetic distances support archaeological models suggesting Epiclassic populations in central Mexico originated from the Bajío and Malpaso Valley-La Quemada settlement system regions in northwestern Mexico. However, they also indicate migration from the Oaxaca Valley in southern Mexico may have taken place during the Epiclassic—a somewhat unexpected result. This indicates that Oaxacan migration and diaspora networks may have persisted beyond archaeologically well documented ethnic enclaves dating to the Classic period (e.g., Spence, 2005) into the Epiclassic period and beyond.

Final Thoughts and Future Directions

This dissertation reconstructs patterns of Epiclassic central Mexican migration through paleomobility and biodistance analyses of individuals ritually sacrificed and interred at the Non-Grid 4 shrine site in central Mexico. Additionally, it examines the interaction between perceptions of social difference and ritual violence to determine whether individuals with distinct categorical social identities were at greater risk of suffering violence during the Epiclassic period, a period of dramatic socio-political upheaval and reorganization.

This study reaffirms the efficacy and importance of employing multiple lines of evidence to investigate past migrations. The biogeochemical and biodistance results presented here provide direct support for Epiclassic central Mexican migration models. Not only are migrants directly identified using biogeochemical techniques, but their potential places of origin are proposed using R matrix analysis. Similarly, the integration of archaeological data in these analyses is essential, further clarifying and contextualizing results. For example, in the absence of archaeological data, unexpected results such as the presence of southern Mexican migrants within Epiclassic central Mexico, may have been dismissed as an artifact of small sample size or a non-representative sample. Instead, these results are now an exciting direction for future research.

Moreover, this study demonstrates the promise of identity-based violence as a subject of bioarchaeological inquiry. Although a growing body of anthropological and broader social science research indicates that the perception of social difference can motivate instances of violence today (e.g., Bowman, 1994; Bush & Keyman, 1997; Schmidt & Schröder, 2001), little work has been done to examine such identity-based violence in the past (but see Kurin, 2014, 2016). This project thus provides a theoretical framework within which to examine identity-based violence in the past, allowing bioarchaeologists to understand who was most vulnerable to violence in past societies.

Additionally, examining identity-based violence in the past provides a deep time perspective to social scientists seeking to understand the topic today. For example, although the research presented here investigates the complex relationship between political instability, migration, and violence in ancient Mesoamerica, many of these processes are increasingly relevant to today's world. Similarly volatile social processes are increasingly evident in the United States and around the world, manifest in the rising tides of nationalism, xenophobia, and violence in response to increasing globalization, demographic change, and mass migration (Bogel-Burroughs, 2019; Cai et al., 2019; Cai & Landon, 2019; Kulish, 2011). By understanding the causes and consequences of identity-based violence in the past, I can connect the past to the present to understand patterns of marginalization and violence through time. This allows researchers to recognize the persistence of identity-based violence as well as the profound challenges to be met in altering patterned violent behaviors.

More importantly, recognizing past instances of identity-based violence shows that although such violence did exist in the past, it is rare in the archaeological record. This dissertation highlights numerous examples of multi-ethnic societies within ancient Mesoamerica that benefitted greatly from sustained migration (e.g., Healan & Cobean, 2019; Manzanilla, 2015; Nichols, 2016; Winter, 1998). When examined within this broader context of migration, it becomes clear that identity-based violence at Non-Grid 4 was a response to a particular set of circumstances that included migration as well as political fragmentation and increased competition for access to resources and land. Identity-based violence is therefore neither ubiquitous nor an inevitable outcome of diverse human interaction in the past, present, or future.

REFERENCES

Abascal, R., Harbottle, G., & Sayre, E. (1974). Correlation between terra cotta figurines and pottery from the Valley of Mexico and source clays by activation analysis. In C. Beck (Ed.), *Archaeological chemistry* (pp. 81–99). Chemical Society.

Aguirre-Samudio, A., González-Sobrino, B. Z., Álvarez-Sandoval, B. A., Montiel, R., Serrano-Sánchez, C., & Meza-Peñaloza, A. (2017). Genetic history of Classic period Teotihuacan burials in central Mexico. *Revista Argentina de Antropología Biológica*, *19*, 7–20.

Akademische Druck (Ed.). (1979). *Codex Vaticanus A (Codex Ríos)*. Akademische Druck und Verlagsanstalt.

Algee-Hewitt, B. F. B. (2016). Population inference from contemporary American craniometrics. *American Journal of Physical Anthropology*, *160*(4), 604–624. https://doi.org/10.1002/ajpa.22959

Álvarez-Sandoval, B. A., Manzanilla, L. R., González-Ruiz, M., Malgosa, A., & Montiel, R. (2015). Genetic evidence supports the multiethnic character of Teopancazco, a neighborhood center of Teotihuacan, Mexico (AD 200-600). *PLOS ONE*, *10*(7), e0132371. https://doi.org/10.1371/journal.pone.0132371

Anderson, J. H., Healan, D. M., & Cobean, R. H. (2016). Collapse, regeneration, and the origins of Tula and the Toltec state. In R. K. Faulseit (Ed.), *Beyond collapse: Archaeological perspectives on resilience, revitalization, and transformation in complex societies* (pp. 431–458). Southern Illinois University Press.

Andrews, A. P. (1983). *Maya salt production and trade*. The University of Arizona Press.

Andrushko, V. A., & Torres, E. C. (2011). Skeletal evidence for Inca warfare from the Cuzco region of Peru. *American Journal of Physical Anthropology*, *146*(3), 361–372. https://doi.org/10.1002/ajpa.21574

Anthony, D. W. (1990). Migration in archeology: The baby and the bathwater. *American Anthropologist*, *92*(4), 895–914. https://doi.org/10.1525/aa.1990.92.4.02a00030

Anton, S. C. (1989). Intentional cranial vault deformation and induced changes of the cranial base and face. *American Journal of Physical Anthropology*, *79*(2), 253–267.

Arkush, E., & Tung, T. A. (2013). Patterns of war in the Andes from the Archaic to the Late Horizon: Insights from settlement patterns and cranial trauma. *Journal of Archaeological Research*, *21*(4), 307–369. https://doi.org/10.1007/s10814-013-9065-1

Ashburn-Nardo, L., Voils, C. I., & Monteith, M. J. (2001). Implicit associations as the seeds of intergroup bias: How easily do they take root? *Journal of Personality and Social Psychology*, *81*(5), 789–799. http://dx.doi.org.ezproxy1.lib.asu.edu/10.1037/0022-3514.81.5.789

Aubert, D., Probst, A., Stille, P., & Viville, D. (2002). Evidence of hydrological control of Sr behavior in stream water (Strengbach catchment, Vosges mountains, France). *Applied Geochemistry*, *17*(3), 285–300. https://doi.org/10.1016/S0883-2927(01)00080-4

Aubry, B. S. (2009). *Population structure and interregional interaction in prehispanic Mesoamerica: A biodistance study* [Ph.D. dissertation]. Ohio State University.

Aubry, B. S. (2014). Cervical dimensions for in situ and loose teeth: A critique of the Hillson et al. (2005) method. *American Journal of Physical Anthropology*, *154*, 159–164. https://doi.org/10.1002/ajpa.22475

Baird, E. T. (1989). Stars and war at Cacaxtla. In R. A. Diehl & J. C. Berlo (Eds.), *Mesoamerica after the decline of Teotihuacan A.D. 700-900* (pp. 105–122). Dumbarton Oaks.

Baker, B. J., & Tsuda, T. (Eds.). (2015). *Migration and disruptions: Toward a unifying theory of ancient and contemporary migrations*. University Press of Florida.

Balcaen, L., Schrijver, I. D., Moens, L., & Vanhaecke, F. (2005). Determination of the 87Sr/86Sr isotope ratio in USGS silicate reference materials by multi-collector ICP–mass spectrometry. *International Journal of Mass Spectrometry*, *242*(2–3), 251–255. https://doi.org/10.1016/j.ijms.2004.10.025

Barba, L., Blancas, J., Manzanilla, L. R., Ortiz, A., Barca, D., Crisci, G. M., Miriello, D., & Pecci, A. (2009). Provenance of the limestone used in Teotihuacan (Mexico): A methodological approach. *Archaeometry*, *51*(4), 525–545. https://doi.org/10.1111/j.1475-4754.2008.00430.x

Barba Pingarrón, L. (2013). El uso de la cal en el mundo prehispánico mesoamericano. In L. Barba Pingarrón & I. Villaseñor (Eds.), *La cal: Historia, propiedades y usos* (pp. 19–46). Universidad Nacional Autónoma de México Instituto de Investigaciones Antropológicas.

Barth, F. (1969). Introduction: Ethnic groups and boundaries. In F. Barth (Ed.), *Ethnic groups and boundaries: The social organization of culture difference* (pp. 9–38). Waveland Press.

Beekman, C. S. (2015). Causes and consequences of migration in Epiclassic northern Mesoamerica. In B. J. Baker & T. Tsuda (Eds.), *Migration and disruptions: Toward a unifying theory of ancient and contemporary migrations* (pp. 73–96). University Press of Florida.

Beekman, C. S. (Ed.). (2019). *Migrations in late Mesoamerica*. University Press of Florida.

Beekman, C. S., & Christensen, A. F. (2003). Controlling for doubt and uncertainty through multiple lines of evidence: A new look at the Mesoamerican Nahua migrations. *Journal of Archaeological Method and Theory*, *10*(2), 111–164. https://doi.org/10.1023/A:1024519712257

Beekman, C. S., & Christensen, A. F. (2011). Power, agency, and identity: Migration and aftermath in the Mezquital area of north-central Mexico. In G. S. Cabana & J. J. Clark (Eds.), *Rethinking anthropological perspectives on migration*. University Press of Florida. https://muse.jhu.edu/book/17953

Begun, E. M. (2013). *Detecting ethnicity at Teotihuacan through archaeology: The West Mexican presence at Structure N1W5:19* [Ph.D. dissertation]. University of Iowa.

Bentley, J. H. (1993). *Old World encounters: Cross-cultural contacts and exchanges in pre-modern times*. Oxford University Press.

Bentley, R. A. (2006). Strontium isotopes from the earth to the archaeological skeleton: A review. *Journal of Archaeological Method and Theory*, *13*(3), 135–187. https://doi.org/10.1007/s10816-006-9009-x

Bentley, R. A., Price, T. D., & Stephan, E. (2004). Determining the 'local' 87Sr/86Sr range for archaeological skeletons: A case study from Neolithic Europe. *Journal of Archaeological Science*, *31*(4), 365–375. https://doi.org/10.1016/j.jas.2003.09.003

Berdan, F., & Anawalt, P. R. (Eds.). (1997). *The essential Codex Mendoza*. University of California Press.

Bigler, R. S., Jones, L. C., & Lobliner, D. B. (1997). Social categorization and the formation of intergroup attitudes in children. *Child Development*, *68*(3), 530–543. https://doi.org/10.1111/j.1467-8624.1997.tb01956.x

Blum, J. D., Taliaferro, E. H., Weisse, M. T., & Holmes, R. T. (2000). Changes in Sr/Ca, Ba/Ca and 87Sr/86Sr ratios between trophic levels in two forest ecosystems in the northeastern U.S.A. *Biogeochemistry*, *49,* 87–101.

Bobo, L. (1983). Whites' opposition to busing: Symbolic racism or realistic group conflict? *Journal of Personality and Social Psychology*, *45*(6), 1196–1210. http://dx.doi.org.ezproxy1.lib.asu.edu/10.1037/0022-3514.45.6.1196

Bogel-Burroughs, N. (2019, August 9). 'I'm the shooter': El Paso suspect confessed to targeting Mexicans, police say. *The New York Times*. https://www.nytimes.com/2019/08/09/us/el-paso-suspect-confession.html

Böhm, R., Rusch, H., & Gürerk, Ö. (2016). What makes people go to war? Defensive intentions motivate retaliatory and preemptive intergroup aggression. *Evolution and Human Behavior*, *37*(1), 29–34. https://doi.org/10.1016/j.evolhumbehav.2015.06.005

Bowen, G. J., Wassenaar, L. I., & Hobson, K. A. (2005). Global application of stable hydrogen and oxygen isotopes to wildlife forensics. *Oecologia*, *143*(3), 337–348.

Bowman, G. (1994). Xenophobia, fantasy, and the nation: The logic of ethnic violence in Former Yugoslavia. In V. Goddard, L. Josep, & C. Shore (Eds.), *Anthropology of Europe: Identity and boundaries in conflict* (pp. 143–171). Berg Press.

Bowman, G. (2001). The violence in identity. In *Anthropology of violence and conflict* (pp. 25–46). Routledge.

Braniff, B. (2005). Los chichimecas a la caída de Teotihuacan y durante la conformación de la Tula de Hidalgo. In L. R. Manzanilla (Ed.), *Reacomodos demográficos del clásico al posclásico en el centro de México* (pp. 45–56). Universidad Nacional Autónoma de México Instituto de Investigaciones Antropológicas.

Brettell, R., Montgomery, J., & Evans, J. (2012). Brewing and stewing: The effect of culturally mediated behaviour on the oxygen isotope composition of ingested fluids and the implications for human provenance studies. *Journal of Analytical Atomic Spectrometry*, *27*(5), 778. https://doi.org/10.1039/c2ja10335d

Brubaker, R., & Cooper, F. (2000). Beyond “identity.” *Theory and Society*, *29*(1), 1–47. https://doi.org/10.1023/A:1007068714468

Buckley, G., Storey, R., Hirth, K. G., Kennett, D. J., & Culleton, B. J. (2016). *Geographical isotopes, migration, and the Tlajinga District of Teotihuacan*. 81st Annual Meeting of the Society for American Archaeology, Orlando, FL.

Budd, P., Montgomery, J., Barreiro, B., & Thomas, R. G. (2000). Differential diagenesis of strontium in archaeological human dental tissues. *Applied Geochemistry*, *15*(5), 687–694. https://doi.org/10.1016/S0883-2927(99)00069-4

Buikstra, J. E. (1980). Epigenetic distance: A study of biological variability in the Lower Illinois River region. In D. Browman (Ed.), *Early Native Americans* (pp. 271–300). Mouton.

Buikstra, J. E., Frankenberg, S. R., & Konigsberg, L. W. (1990). Skeletal biological distance studies in American physical anthropology: Recent trends. *American Journal of Physical Anthropology*, *82*(1), 1–7. https://doi.org/10.1002/ajpa.1330820102

Buikstra, J. E., & Scott, R. E. (2009). Key concepts in identity studies. In K. J. Knudson & C. M. Stojanowski (Eds.), *Bioarchaeology and identity in the Americas* (pp. 24–55). University Press of Florida.

Buikstra, J. E., & Ubelaker, D. H. (Eds.). (1994). *Standards for data collection from human skeletal remains: Proceedings of a seminar at the Field Museum of Natural History, organized by Jonathan Haas*. Arkansas Archaeological Survey.

Burmeister, S. (2000). Archaeology and migration: Approaches to an archaeological proof of migration. *Current Anthropology*, *41*, 539–553.

Burton, J. H., & Price, T. D. (2002). The use and abuse of trace elements for paleodietary research. In *Biogeochemical approaches to paleodietary analysis* (pp. 159–171). Springer. http://link.springer.com/chapter/10.1007/0-306-47194-9_8

Bush, K. D., & Keyman, E. F. (1997). Identity-based conflict: Rethinking security in a post–Cold War world. *Global Governance*, *3*(3), 311–328.

Buzon, M. R., Conlee, C. A., & Bowen, G. J. (2011). Refining oxygen isotope analysis in the Nasca region of Peru: An investigation of water sources and archaeological samples. *International Journal of Osteoarchaeology*, *21*(4), 446–455. https://doi.org/10.1002/oa.1151

Cabana, G. S. (2011). The problematic relationship between migration and culture change. In G. S. Cabana & J. J. Clark (Eds.), *Rethinking anthropological perspectives on migration* (pp. 16–28). University Press of Florida.

Cabana, G. S., & Clark, J. J. (Eds.). (2011). *Rethinking anthropological perspectives on migration*. University Press of Florida.

Cabrera Castro, R. (1998). Teotihuacan: Nuevos datos para el estudio de las rutas de comunicación. In E. C. Rattray (Ed.), *Rutas de intercambio en Mesoamérica: III Coloquio Pedro Bosch Gimpera* (pp. 57–75). Universidad Nacional Autónoma de México.

Cabrera Castro, R., & Gómez Chavez, S. (2008). La Ventilla: A model for a barrio in the urban structure of Teotihuacan. In A. G. Mastache, R. H. Cobean, A. García Cook, & K. G. Hirth (Eds.), *El urbanismo en Mesoamérica/Urbanism in Mesoamerica* (Vol. 2, pp. 37–83). Instituto Nacional de Antropología e Historia and Pennsylvannia State University.

Cai, W., Griggs, T., Kao, J., Love, J., & Ward, J. (2019). White extremist ideology drives many deadly shootings. *The New York Times*, 5.

Cai, W., & Landon, S. (2019, April 3). Attacks by white extremists are growing. So are their connections. *The New York Times*.

Cameron, C. M. (2013). How people moved among ancient societies: Broadening the view. *American Anthropologist*, *115*(2), 218–231. https://doi.org/10.1111/aman.12005

Campbell, B. C., & Barone, L. (2012). Evolutionary basis of human migration. In M. H. Crawford & B. C. Campbell (Eds.), *Causes and consequences of human migration: An evolutionary perspective* (pp. 45–64). Cambridge University Press.

Campbell, B. C., & Crawford, M. H. (2012). Perspectives on human migration: Introduction. In B. C. Campbell & M. H. Crawford (Eds.), *Causes and consequences of human migration: An evolutionary perspective* (pp. 1–8). Cambridge University Press.

Campbell, D. T. (1965). Ethnocentric and other altruistic motives. In D. Levine (Ed.), *Nebraska symposium on motivation* (pp. 283–311). University of Nebraska Press.

Carballo, D. M. (2011). *Obsidian and the Teotihuacan State: Weaponry and ritual production at the Moon Pyramid/La obsidiana y el Estado Teotihuacano: La producción militar y ritual en la Pirámide de la Luna*. University of Pittsburgh Center for Comparative Archaeology and the Instituto de Investigaciones Antropológicas, Universidad Nacional Autónoma de México.

Castañeda de la Paz, M. (2013). Dos parcialidades étnicas en Azcapotzalco: Mexicapan y Tepanecapan. *Estudios de Cultura Náhuatl*, *46*, 223–248.

Cheverud, J. M. (1988). A comparison of genetic and phenotypic correlations. *Evolution*, *42*(5), 958. https://doi.org/10.2307/2408911

Cheverud, J. M., Kohn, L. A. P., Konigsberg, L. W., & Leigh, S. R. (1992). Effects of fronto-occipital artificial cranial vault modification on the cranial base and face. *American Journal of Physical Anthropology*, *88*(3), 323–345.

Cheverud, J. M., & Midkiff, J. E. (1992). The effects of fronto-occipital cranial reshaping on mandibular form. *American Journal of Physical Anthropology*, *87*, 167–171.

Christensen, A. F. (1997). Cranial non-metric variation in north and central Mexico. *Anthropologischer Anzeiger*, *55*(1), 15–32.

Clark, J. J. (2001). *Tracking prehistoric migrations: Pueblo settlers among the Tonto Basin Hohokam*. University of Arizona Press.

Clark, J. J., Birch, J. A., Hegmon, M., Mills, B. J., Glowacki, D. M., Ortman, S. G., Dean, J. S., Gauthier, R., Lyons, P. D., Peeples, M. A., Borck, L., & Ware, J. A. (2019). Resolving the migrant paradox: Two pathways to coalescence in the late precontact U.S. Southwest. *Journal of Anthropological Archaeology*, *53*, 262–287. https://doi.org/10.1016/j.jaa.2018.09.004

Cobean, R. H., & Mastache, A. G. (1989). The Late Classic and Early Postclassic chronology of the Tula region. In D. M. Healan (Ed.), *Tula of the Toltecs: Excavation and survey* (pp. 34–48). University of Iowa Press.

Codex Azcatitlan. (1949). Societé des Americanistes.

Codex Boturini: Tira de la peregrinación mexica. (1944). Librería Anticuaria.

Códice Aubin: Manuscrito azteca de la Biblioteca Real de Berlín. (1963). Ediciones José Porrúa Turanzas.

Collins, P. H. (2015). Intersectionality's definitional dilemmas. *Annual Review of Sociology*, *41*(1), 1–20. https://doi.org/10.1146/annurev-soc-073014-112142

Coplen, T. B., Kendall, C., & Hopple, J. (1983). Comparison of stable isotope reference samples. *Nature*, *302*, 236–238.

Corruccini, R. S. (1973). Size and shape in similarity coefficients based on metric characters. *American Journal of Physical Anthropology*, *38*(3), 743–753. https://doi.org/10.1002/ajpa.1330380313

Cowgill, G. L. (2013). Possible migrations and shifting identities in the central Mexican Epiclassic. *Ancient Mesoamerica*, *24*(01), 131–149. https://doi.org/10.1017/S0956536113000060

Cowgill, G. L. (2015a). The debated role of migration in the fall of ancient Teotihuacan in central Mexico. In B. J. Baker & T. Tsuda (Eds.), *Migration and disruptions: Toward a unifying theory of ancient and contemporary migrations* (pp. 97–122). University Press of Florida.

Cowgill, G. L. (2015b). *Ancient Teotihuacan: Early urbanism in central Mexico*. Cambridge University Press.

Craig, H. (1957). Isotopic standards for carbon and oxygen and correction factors for mass-spectrometric analysis of carbon dioxide. *Geochimica et Cosmochimica Acta*, *12*(1), 133–149. https://doi.org/10.1016/0016-7037(57)90024-8

Craig, H. (1961). Standard for reporting concentrations of deuterium and oxygen-18 in natural waters. *Science*, *133*(3467), 1833–1834. https://doi.org/10.1126/science.133.3467.1833

Crandall, J. J., & Thompson, J. L. (2014). Beyond victims: Exploring the identity of sacrificed infants and children at La Cueva de los Muertos Chiquitos, Durango, Mexico (AD 571-1168). In *Tracing childhood: Bioarchaeological investigations of early lives in antiquity* (pp. 36–57). University Press of Florida.

Crawford, M. H., & Campbell, B. C. (Eds.). (2012). *Causes and consequences of human migration: An evolutionary perspective*. Cambridge University Press.

Crider, D. L. (2011). *Epiclassic and early Postclassic interaction in central Mexico as evidenced by decorated pottery* [Ph.D. dissertation]. Arizona State University.

Crider, D. L. (2013). Shifting alliances: Epiclassic and early Postclassic interactions at Cerro Portezuelo. *Ancient Mesoamerica*, *24*(01), 107–130. https://doi.org/10.1017/S0956536113000047

Cyphers, A. (2000). Cultural identity and interregional interaction during the Gobernador Phase: A ceramic perspective. In K. G. Hirth (Ed.), *Archaeological research at Xochicalco* (Vol. 2, pp. 102–135). University of Utah Press.

D'Altroy, T. N. (1992). *Provincial power in the Inka empire*. Smithsonian Institution Press.

Dansgaard, W. (1964). Stable isotopes in precipitation. *Tellus*, *16*(4), 436–468. https://doi.org/10.1111/j.2153-3490.1964.tb00181.x

Dasch, E. J. (1969). Strontium isotopes in weathering profiles, deep-sea sediments, and sedimentary rocks. *Geochimica et Cosmochimica Acta*, *33*(12), 1521–1552.

Daux, V., Lécuyer, C., Héran, M.-A., Amiot, R., Simon, L., Fourel, F., Martineau, F., Lynnerup, N., Reychler, H., & Escarguel, G. (2008). Oxygen isotope fractionation between human phosphate and water revisited. *Journal of Human Evolution*, *55*(6), 1138–1147. https://doi.org/10.1016/j.jhevol.2008.06.006

de Cserna, Z. (1989). An outline of the geology of Mexico. In A. W. Bally & A. R. Palmer (Eds.), *The geology of North America—An overview: Vol. A* (pp. 233–264). Geological Society of America.

De La Cruz, I., González-Oliver, A., Kemp, B. M., Román Berrelleza, J. A., Smith, D. G., & Torre-Blanco, A. (2008). Sex identification of children sacrificed to the ancient Aztec rain gods in Tlatelolco. *Current Anthropology*, *49*(3), 519–526. https://doi.org/10.1086/587642

Demant, A. (1981). Interpretación geodinámica del volcanismo del Eje Neovolcánico Transmexicano. *Revista Mexicana de Ciencias Geológicas*, *5*(2), 217–222.

Diehl, R. A., & Berlo, J. C. (Eds.). (1989). *Mesoamerica after the decline of Teotihuacan AD 700-900*. Dumbarton Oaks.

Dillehay, T. D. (2002). Archaeology: Climate and human migrations. *Science*, *298*(5594), 764–765. https://doi.org/10.1126/science.1078163

Duncan, W. N. (2005). *The bioarchaeology of ritual violence in Postclassic El Peten, Guatemala (AD 950—1524)* [Ph.D.]. Southern Illinois University at Carbondale.

Duncan, W. N. (2011). Bioarchaeological analysis of sacrificial victims from a postclassic Maya temple from Ixlu, El Peten, Guatemala. *Latin American Antiquity*, *22*(4), 549–572.

Duncan, W. N. (2012). Biological distance analyses in contexts of ritual violence. In D. L. Martin, R. P. Harrod, & V. R. Pérez (Eds.), *The bioarchaeology of violence: Bioarchaeological interpretations of the human past: Local, regional, and global perspectives* (pp. 251–275). University Press of Florida.

Dunham, Y., & Emory, J. (2014). Of affect and ambiguity: The emergence of preference for arbitrary ingroups. *Journal of Social Issues*, *70*(1), 81–98. https://doi.org/10.1111/josi.12048

Dunham Yarrow, Baron Andrew Scott, & Carey Susan. (2011). Consequences of “minimal” group affiliations in children. *Child Development*, *82*(3), 793–811. https://doi.org/10.1111/j.1467-8624.2011.01577.x

Durán, D. (1867). *Historia de las Indias de Nueva España y islas de tierra firme* (J. F. Ramirez, Ed.; Vol. 1–2). J. M. Andrade y F. Escalante.

Durazo, J., & Farvolden, R. N. (1989). The groundwater regime of the Valley of Mexico from historic evidence and field observations. *Journal of Hydrology*, *112*(1–2), 171–190. https://doi.org/10.1016/0022-1694(89)90187-X

Efferson, C., Lalive, R., & Fehr, E. (2008). The coevolution of cultural groups and ingroup favoritism. *Science*, *321*(5897), 1844–1849. https://doi.org/10.1126/science.1155805

Ehleringer, J. R., Bowen, G. J., Chesson, L. A., West, A. G., Podlesak, D. W., & Cerling, T. E. (2008). Hydrogen and oxygen isotope ratios in human hair are related to geography. *Proceedings of the National Academy of Sciences*, *105*(8), 2788–2793.

Elliott, M., Fisher, C. T., Nelson, B. A., Molina Garza, R. S., Collins, S. K., & Pearsall, D. M. (2010). Climate, agriculture, and cycles of human occupation over the last 4000yr in southern Zacatecas, Mexico. *Quaternary Research*, *74*(1), 26–35. https://doi.org/10.1016/j.yqres.2010.04.001

Ericson, J. E. (1985). Strontium isotope characterization in the study of prehistoric human ecology. *Journal of Human Evolution*, *14*(5), 503–514.

Esses, V. M., Dovidio, J. F., Jackson, L. M., & Armstrong, T. L. (2001). The immigration dilemma: The role of perceived group competition, ethnic prejudice, and national identity. *Journal of Social Issues*, *57*(3), 389–412. https://doi.org/10.1111/0022-4537.00220

Evans, J. A., & Tatham, S. (2004). Defining 'local signature' in terms of Sr isotope composition using a tenth- to twelfth-century Anglo-Saxon population living on a Jurassic clay-carbonate terrain, Rutland, UK. *Geological Society, London, Special Publications*, *232*(1), 237–248. https://doi.org/10.1144/GSL.SP.2004.232.01.21

Everett, J. A. C., Faber, N. S., & Crockett, M. (2015). Preferences and beliefs in ingroup favoritism. *Frontiers in Behavioral Neuroscience*, *9*, 1–21. https://doi.org/10.3389/fnbeh.2015.00015

Faure, G. (1998). *Principles and applications of geochemistry: A comprehensive textbook for geology students*. Prentice Hall.

Faure, G., & Powell, J. L. (1972). *Strontium isotope geology*. Springer-Verlag.

Feinman, G. M., & Nicholas, L. M. (2013). Settlement patterns of the Ejutla Valley, Oaxaca, Mexico: A diachronic macroscale perspective. *Fieldiana. Anthropology*, *43*, 1–330. JSTOR.

Feliciano Velázquez, P. (Ed.). (1975). *Codex Chimalpopoca: Anales de Cuauhtitlan y leyenda de los soles*. Universidad Nacional Autónoma de México Instituto de Investigaciones Históricas.

Fenner, J. N., & Wright, L. E. (2014). Revisiting the strontium contribution of sea salt in the human diet. *Journal of Archaeological Science*, *44*, 99–103. https://doi.org/10.1016/j.jas.2014.01.020

Ferrusquía-Villafranca, I. (1993). Geology of Mexico: A synopsis. In T. P. Ramamoorthy, R. Bye, A. Lot, & J. Fa (Eds.), *Biological diversity of Mexico: Origins and distribution* (pp. 3–107). Oxford University Press.

Finegold, A. (2012). *Dramatic renditions: Battle murals and the struggle for elite legitimacy in Epiclassic Mesoamerica* [Ph.D.]. Columbia University.

Flockhart, D. T. T., Kyser, T. K., Chipley, D., Miller, N. G., & Norris, D. R. (2015). Experimental evidence shows no fractionation of strontium isotopes (87Sr/86Sr) among soil, plants, and herbivores: Implications for tracking wildlife and forensic science. *Isotopes in Environmental and Health Studies*, *51*(3), 372–381. https://doi.org/10.1080/10256016.2015.1021345

Foster, M. S. (1999). The Aztatlán tradition of west and northwest Mexico and Casas Grandes: Speculations on the Medio period florescence. In F. Schaafsma & C. L. Riley (Eds.), *The Casas Grandes world* (pp. 149–163). University of Utah Press.

Fournier, P., & Bolaños, V. (2007). The Epiclassic in the Tula region beyond Tula Chico. In C. Kristan-Graham & J. Kowalski (Eds.), *Twin Tollans: Chichén Itzá, Tula, and the epiclassic to early postclassic Mesoamerican world* (pp. 481–529). Dumbarton Oaks.

Fournier, P., & Vargas Sanders, R. (2002). En busca de los" dueños del silencio": Cosmovisión y ADN antiguo de las poblaciones otomíes epiclásicas de la región de Tula. *Revista de Estudios Otopames*, *3*, 37–75.

Fowler, J. H., & Kam, C. D. (2007). Beyond the self: Social identity, altruism, and political participation. *Journal of Politics*, *69*(3), 813–827. https://doi.org/10.1111/j.1468-2508.2007.00577.x

Fraley, C., & Raftery, A. E. (2002). Model-based clustering, discriminant analysis and density estimation. *Journal of the American Statistical Association*, *97*, 611–631.

Fraley, C., & Raftery, A. E. (2012). *Mclust version 4 for R: normal mixture modeling for model-based clustering, classification, and density estimation* (Technical Report No. 597). Department of Statistics, University of Washington.

Frederick, C. D., & Cordova, C. E. (2018). Prehispanic and colonial landscape change and fluvial dynamics in the Chalco Region, Mexico. *Geomorphology*. https://doi.org/10.1016/j.geomorph.2018.10.009

Friedman, I., O'Neil, J., & Cebula, G. (1982). Two new carbonate stable isotope standards. *Geostandards Newsletter, 6*, 11–12.

Fries, Jr., C. (1958). *Geology of the state of Morelos and contiguous areas in south-central Mexico* [Ph.D. dissertation]. University of Arizona.

Gagnon, C. M., Andrus, C. F. T., Ida, J., & Richardson, N. (2015). Local water source variation and experimental chicha de maíz brewing: Implications for interpreting human hydroxyapatite δ18O values in the Andes. *Journal of Archaeological Science: Reports*, *4*, 174–181. https://doi.org/10.1016/j.jasrep.2015.09.008

Galler, P., Limbeck, A., Boulyga, S. F., Stingeder, G., Hirata, T., & Prohaska, T. (2007). Development of an on-line flow injection Sr/matrix separation method for accurate, high-throughput determination of Sr isotope ratios by multiple collector-inductively coupled plasma-mass spectrometry. *Analytical Chemistry*, *79*(13), 5023–5029. https://doi.org/10.1021/ac070307h

Galtung, J. (2013). Cultural violence. In J. Galtung & D. Fischer (Eds.), *Johan Galtung: Pioneer of peace research* (pp. 41–58). Springer.

García Cook, A. (2013). El Epiclásico en la región poblano-tlaxcalteca. In *The Olmeca-Xicallanca of Teotihuacan, Cacaxtla, and Cholula: An archaeological, ethnohistorical, and linguistic synthesis* (pp. 1–54). Archaeopress.

García Velasco, M. (2014). *Estudio de un contexto sacrifical en Xaltocan (Estado de México)* [M.A. thesis]. Universidad Nacional Autónoma de México.

García Velasco, M. (2019). *Estudio craneológico de un conjunto de individuos sacrificados en Xaltocan en el periodo epiclásico* [Ph.D. dissertation]. Universidad Nacional Autónoma de México.

Gat, J. R. (1996). Oxygen and hydrogen isotopes in the hydrologic cycle. *Annual Review of Earth and Planetary Sciences*, *24*(1), 225–262. https://doi.org/10.1146/annurev.earth.24.1.225

Gaxiola González, M. (2006). Tradición y estilo en el estudio de la variabilidad cerámica del Epiclásico en el centro de México. In L. Solar Valverde (Ed.), *El fenómeno Coyotlatelco en el centro de México: Tiempo, espacio y significado* (pp. 31–54). Instituto Nacional de Antropología e Historia.

Gómez Chavez, S. (1998). Nuevos datos sobre la relación de Teotihuacan y el Occidente de México. In *Antropología e historia del Occidente de México* (pp. 1461–1493). Sociedad Mexicana de Antropología, Universidad Nacional Autónoma de México.

Gómez Chavez, S. (2002). Presencia del Occidente de México en Teotihuacán: Aproximaciones a la política exterior del estado Teotihuacano. In M. E. Ruiz Gallut (Ed.), *Ideología y política a través de materiales, imágenes y símbolos* (pp. 563–625). Universidad Nacional Autónoma de México Instituto de Investigaciones Antropológicas.

Gómez, J. M., Verdú, M., González-Megías, A., & Méndez, M. (2016). The phylogenetic roots of human lethal violence. *Nature*, *538*, 233–237. https://doi.org/10.1038/nature19758

Gómez-Valdés, J. A., Bautista Martínez, J. B., Pompa y Padilla, J. A., Talavera González, A., & Castrejón-Caballero, J. L. (2008). Continuidad genética entre el Occidente y la Mesoamérica nuclear: Hipótesis morfológica dental. *Arqueología*, *37*, 23–34.

González, S., Pastrana, A., Siebe, C., & Duller, G. (2000). Timing of the prehistoric eruption of Xitle volcano and the abandonment of Cuicuilco pyramid, souther Valley of Mexico. In B. McGuire, D. Griffiths, & I. Stewarts (Eds.), *The archaeology of geological catastrophes* (pp. 205–224). Geological Society of London.

González-José, R., Martínez-Abadías, N., González-Martín, A., Bautista-Martínez, J., Gómez-Valdés, J., Quinto, M., & Hernández, M. (2007). Detection of a population replacement at the Classic–Postclassic transition in Mexico. *Proceedings of the Royal Society B: Biological Sciences*, *274*(1610), 681–688. https://doi.org/10.1098/rspb.2006.0151

Gorenflo, L. J., & Sanders, W. T. (2007). *Archaeological settlement pattern data from the Cuautitlan, Temascalapa, and Teotihuacan regions, Mexico*. Department of Anthropology, Pennsylvania State University.

Graulich, M. (2006). Aztec human sacrifice as expiation. In J. N. Bremmer (Ed.), *The strange world of human sacrifice* (pp. 9–30). Peeters Publishers.

Grimstead, D. N., Nugent, S., & Whipple, J. (2017). Why a standardization of strontium isotope baseline environmental data is needed and recommendations for methodology. *Advances in Archaeological Practice*, *5*(02), 184–195. https://doi.org/10.1017/aap.2017.6

Gulson, B. L., Jameson, W. W., & Gillings, B. R. (1997). Stable lead isotopes in teeth as indicators of past domicile-a potential new tool in forensic science? *Journal of Forensic Sciences*, *42*, 787–791.

Haken, N., Messner, J. J., Hendry, K., Taft, P., Lawrence, K., Brisard, L., & Umaña, F. (2014). *Fragile states index 2014*. The Fund for Peace.

Hamnett, M. P. (1985). Precontact movement among Eivo and Simeku speakers in central Bougainville. In M. Chapman & R. M. Prothero (Eds.), *Circulation in* *population movement: Substance and concepts from the Melanesian case* (pp. 39–56). Routledge & Kegan Paul.

Harmon, B. G., Becker, D. E., Jensen, A. H., & Baker, D. H. (1969). Nutrient composition of corn and soybean meal. *Journal of Animal Science, 28,* 459–464.

Harpending, H. C., & Jenkins, T. (1973). Genetic distance among southern African populations. In M. H. Crawford & P. L. Workman (Eds.), *Methods and theories of anthropological genetics* (pp. 177–199). University of New Mexico Press.

Harpending, H. C., & Ward, R. H. (1982). Chemical systematics and human evolution. In M. Nitecki (Ed.), *Biochemical aspects of evolutionary biology* (pp. 213–256). University of Chicago Press.

Healan, D. M. (1997). Pre-Hispanic quarrying in the Ucareo-Zinapecuaro obdisidian source area. *Ancient Mesoamerica*, *8*(1), 77–100. JSTOR.

Healan, D. M. (2012). The archaeology of Tula, Hidalgo, Mexico. *Journal of Archaeological Research*, *20*(1), 53–115. https://doi.org/10.1007/s10814-011-9052-3

Healan, D. M., & Cobean, R. H. (2019). Three migration case studies from the Tula region. In C. S. Beekman (Ed.), *Migrations in late Mesoamerica* (pp. 66–87). University Press of Florida.

Hernández, C. L. (2016). Ceramic evidence of Teotihuacan contact linking the Basin of Mexico, the Bajío, and southern Hidalgo. In E. Williams & B. Maldonado (Eds.), *Cultural dynamics and production activities in ancient western Mexico* (pp. 215–238). Archaeopress.

Hernández, C. L., & Healan, D. M. (2019). Migration and the Coyotlatelco ceramic tradition: Evidence from El Bajío. In C. S. Beekman (Ed.), *Migrations in late Mesoamerica* (pp. 88–108). University Press of Florida.

Herring, D. A., Saunders, S. R., & Katzenberg, M. A. (1998). Investigating the weaning process in past populations. *American Journal of Physical Anthropology*, *105*(4), 425–439. https://doi.org/10.1002/(SICI)1096-8644(199804)105:4<425::AID-AJPA3>3.0.CO;2-N

Hills, C. (2015). The Anglo-Saxon migration: An archaeological case study of disruption. In B. J. Baker & T. Tsuda (Eds.), *Migration and disruptions: Toward a unifying* *theory of ancient and contemporary migrations* (pp. 33–51). University Press of Florida.

Hillson, S. (1996). *Dental anthropology*. Cambridge University Press.

Hillson, S., FitzGerald, C., & Flinn, H. (2005). Alternative dental measurements: Proposals and relationships with other measurements. *American Journal of Physical Anthropology*, *126*(4), 413–426. https://doi.org/10.1002/ajpa.10430

Hirth, K. G. (1989). Militarism and social organization at Xochicalco, Morelos. In R. A. Diehl & J. C. Berlo (Eds.), *Mesoamerica after the decline of Teotihuacan A.D. 700-900* (pp. 69–82). Dumbarton Oaks.

Hirth, K. G. (2000). *Archaeological research at Xochicalco*. University of Utah Press.

Hodell, D. A., Quinn, R. L., Brenner, M., & Kamenov, G. (2004). Spatial variation of strontium isotopes (87Sr/86Sr) in the Maya region: A tool for tracking ancient human migration. *Journal of Archaeological Science*, *31*(5), 585–601. https://doi.org/10.1016/j.jas.2003.10.009

Hoffmeister, K., & Wright, L. E. (2016). *The origins and identities of the Colha Skull Pit skeletal remains*. 81st Annual Meeting of the Society for American Archaeology, Orlando, FL.

Hoggarth, J. A., Restall, M., Wood, J. W., & Kennett, D. J. (2017). Drought and its demographic effects in the Maya lowlands. *Current Anthropology*, 000–000. https://doi.org/10.1086/690046

Holt Mehta, H. (2018). More than an enclave? Ethnic identity and cultural affiliations at El Tesoro, a Classic period Zapotec site in the Tula area. In R. K. Faulseit, N. Xiuhtecutli, & H. Holt Mehta (Eds.), *City, craft, and residence in Mesoamerica: Research papers presented in honor of Dan M. Healan* (pp. 125–134). Middle American Research Institute, Tulane Univesity.

Hoogewerff, J., Papesch, W., Kralik, M., Berner, M., Vroon, P., Miesbauer, H., Gaber, O., Künzel, K.-H., & Kleinjans, J. (2001). The last domicile of the Iceman from Hauslabjoch: A geochemical approach using Sr, C and O isotopes and trace element signatures. *Journal of Archaeological Science*, *28*(9), 983–989.

Hopkins, N. A. (1984). Otomanguean linguistic prehistory. In J. K. Josserand, M. Winter, & N. A. Hopkins (Eds.), *Essays in Otomanguean culture history* (pp. 25–64). Vanderbilt University.

Howard, T. (2014). *Failed states and the origins of violence: A comparative analysis of state failure as a root cause of terrorism and political violence*. Ashgate Publishing Company.

Hut, G. (1987). *Consultants' group meeting on stable isotope reference samples for geochemical and hydrological investigations* (Report to the Director General). International Atomic Energy Agency.

Iacumin, P., Bocherens, H., Mariotti, A., & Longinelli, A. (1996). Oxygen isotope analyses of co-existing carbonate and phosphate in biogenic apatite: A way to monitor diagenetic alteration of bone phosphate? *Earth and Planetary Science Letters*, *142*(1), 1–6. https://doi.org/10.1016/0012-821X(96)00093-3

IAEA. (1992). *Statistical treatment of data on environmental isotopes in precipitation*. International Atomic Energy Agency (IAEA).

Inomata, T. (2003). War, destruction, and abandonment: The fall of the Classic Maya center of Aguateca, Guatemala. In T. Inomata & R. W. Webb (Eds.), *The archaeology of settlement abandonment in Middle America* (pp. 43–60). University of Utah Press.

Inomata, T. (2014). Fire intensity assessment through the analysis of artifacts and building materials: Burning and abandonment at the Classic Maya sites of Aguateca and Ceibal, Guatemala. *Advances in Archaeological Practice*, *2*(1), 50–63. https://doi.org/10.7183/2326-3768.2.1.50

Issar, A., Quijano, J. L., Gat, J. R., & Castro, M. (1984). The isotope hydrology of the groundwaters of central Mexico. *Journal of Hydrology*, *71*(3–4), 201–224. https://doi.org/10.1016/0022-1694(84)90097-0

Jackson, J. W. (1993). Realistic group conflict theory: A review and evaluation of the theoretical and empirical literature. *The Psychological Record*, *43*, 395–414.

Jenkins, R. (2004). *Social identity* (2nd edition). Routledge.

Johnson, E. S., & Marston, J. M. (2020). The experimental identification of nixtamalized maize through starch spherulites. *Journal of Archaeological Science*, *113*, 105056. https://doi.org/10.1016/j.jas.2019.105056

Kamenov, G. D., Lofaro, E. M., Goad, G., & Krigbaum, J. (2018). Trace elements in modern and archaeological human teeth: Implications for human metal exposure and enamel diagenetic changes. *Journal of Archaeological Science*, *99*, 27–34. https://doi.org/10.1016/j.jas.2018.09.002

Katzenberg, M. A. (2008). Stable isotope analysis: A tool for studying past diet, demography, and life history. In M. A. Katzenberg & S. R. Saunders (Eds.), *Biological anthropology of the human skeleton* (pp. 413–442). Wiley-Liss.

Kaufman, T. (2001). *The history of the Nawa language group from the earliest times to the sixteenth century: Some intial results*. https://www.albany.edu/anthro/maldp/Nawa.pdf

Kelley, J. C. (2000). The Aztatlán mercantile system: Mobile trades and the northwestward expansion of Mesoamerican civilization. In M. S. Foster & S. Gorenstein (Eds.), *Greater Mesoamerica: The archaeology of west and northwest Mexico* (pp. 137–154). University of Utah Press.

Kelly, D. J., Quinn, P. C., Slater, A. M., Lee, K., Gibson, A., Smith, M., Ge, L., & Pascalis, O. (2005). Three-month-olds, but not newborns, prefer own-race faces. *Developmental Science*, *8*(6), F31–F36. https://doi.org/10.1111/j.1467-7687.2005.0434a.x

Kemp, B. M., Reséndez, A., Román Berrelleza, J. A., Malhi, R. S., & Smith, D. G. (2005). An analysis of ancient Aztec mtDNA from Tlatelolco: Pre-Columbian relations and the spread of Uto-Aztecan. In D. M. Reed (Ed.), *Biomolecular archaeology: Genetic approaches to the past* (pp. 22–46). Southern Illinois University Press.

Kieffer, C. L. (2017). Sacrifice of the social outcasts: Two cases of Klippel–Feil syndrome at Midnight Terror Cave, Belize. *International Journal of Osteoarchaeology*, *27*, 45–55. https://doi.org/10.1002/oa.2456

Kintigh, K. W. (1990). Intrasite spatial analysis: A commentary on major methods. In A. Voorrips (Ed.), *Mathematics and information science in archaeology: A flexible framework* (pp. 165–200). Holos.

Kintigh, K. W., & Ammerman, A. J. (1982). Heuristic approaches to spatial analysis in archaeology. *American Antiquity*, *47*(1), 31–63. https://doi.org/10.2307/280052

Kinzler, K. D., Corriveau, K. H., & Harris, P. L. (2011). Children’s selective trust in native-accented speakers. *Developmental Science*, *14*(1), 106–111. https://doi.org/10.1111/j.1467-7687.2010.00965.x

Kirchhoff, P., Odena Güemes, L., & Reyes García, L. (Eds.). (1976). *Historia tolteca-chichimeca*. Fondo de Cultura Económica, CIESAS.

Knudson, K. J. (2009). Oxygen isotope analysis in a land of environmental extremes: The complexities of isotopic work in the Andes. *International Journal of Osteoarchaeology*, *19*(2), 171–191. https://doi.org/10.1002/oa.1042

Knudson, K. J., Goldstein, P. S., Dahlstedt, A., Somerville, A., & Schoeninger, M. J. (2014). Paleomobility in the Tiwanaku diaspora: Biogeochemical analyses at Rio Muerto, Moquegua, Peru. *American Journal of Physical Anthropology*, *155*(3), 405–421. https://doi.org/10.1002/ajpa.22584

Knudson, K. J., O'Donnabhain, B., Carver, C., Cleland, R., & Price, T. D. (2012). Migration and Viking Dublin: Paleomobility and paleodiet through isotopic analyses. *Journal of Archaeological Science*, *39*(2), 308–320. https://doi.org/10.1016/j.jas.2011.09.014

Knudson, K. J., & Price, T. D. (2007). Utility of multiple chemical techniques in archaeological residential mobility studies: Case studies from Tiwanaku- and Chiribaya-affiliated sites in the Andes. *American Journal of Physical Anthropology*, *132*(1), 25–39. https://doi.org/10.1002/ajpa.20480

Knudson, K. J., Stanish, C., Lozada Cerna, M. C., Faull, K. F., & Tantaleán, H. (2016). Intra-individual variability and strontium isotope measurements: A methodological study using 87Sr/86Sr data from Pampa de los Gentiles, Chincha Valley, Peru. *Journal of Archaeological Science: Reports*, *5*, 590–597. https://doi.org/10.1016/j.jasrep.2016.01.016

Knudson, K. J., & Stojanowski, C. M. (2008). New directions in bioarchaeology: Recent contributions to the study of human social identities. *Journal of Archaeological Research*, *16*(4), 397–432. https://doi.org/10.1007/s10814-008-9024-4

Knudson, K. J., & Stojanowski, C. M. (Eds.). (2009). *The bioarchaeology of identity in the Americas*. University Press of Florida.

Knudson, K. J., & Torres-Rouff, C. (2015). Migration as a response to environmental and political disruption: The Middle Horizona and Late Intermediate periods in the south-central Andes. In B. J. Baker & T. Tsuda (Eds.), *Migration and disruptions: Toward a unifying theory of ancient and contemporary migrations* (pp. 123–141). University Press of Florida.

Knudson, K. J., Webb, E., White, C., & Longstaffe, F. J. (2014). Baseline data for Andean paleomobility research: A radiogenic strontium isotope study of modern Peruvian agricultural soils. *Archaeological and Anthropological Sciences*, *6*(3), 205–219. https://doi.org/10.1007/s12520-013-0148-1

Koch, P. L., Tuross, N., & Fogel, M. L. (1997). The effects of sample treatment and diagenesis on the isotopic integrity of carbonate in biogenic hydroxylapatite. *Journal of Archaeological Science*, *24*(5), 417–429. https://doi.org/10.1006/jasc.1996.0126

Kohn, L. A. P., Leigh, S. R., Jacobs, S. C., & Cheverud, J. M. (1993). Effects of annular cranial vault modification on the cranial base and face. *American Journal of Physical Anthropology*, *90*(2), 147–168.

Kohn, M. J. (1996). Predicting animal δ 18 O: Accounting for diet and physiological adaptation. *Geochimica et Cosmochimica Acta*, *60*(23), 4811–4829.

Koontz, R. A. (1994). *The iconography of El Tajín, Veracruz, Mexico* [Ph.D. dissertation]. University of Texas.

Kulish, N. (2011, July 23). Norway attacks put spotlight on rise of right-wing sentiment in Europe. *The New York Times*. https://www.nytimes.com/2011/07/24/world/europe/24europe.html

Kurin, D. S. (2014). Cranial trauma and cranial modification in post-imperial Andahuaylas, Peru. In D. L. Martin & C. P. Anderson (Eds.), *Bioarchaeological and forensic perspectives on violence: How violent death is interpreted from skeletal remains* (pp. 236–260). Cambridge University Press.

Kurin, D. S. (2016). *The bioarchaeology of societal collapse and regeneration in ancient Peru*. Springer.

Lachniet, M. S., Asmerom, Y., Polyak, V., & Bernal, J. P. (2017). Two millennia of Mesoamerican monsoon variability driven by Pacific and Atlantic synergistic forcing. *Quaternary Science Reviews*, *155*, 100–113. https://doi.org/10.1016/j.quascirev.2016.11.012

Lachniet, M. S., Bernal, J. P., Asmerom, Y., Polyak, V., & Piperno, D. (2012). A 2400 yr Mesoamerican rainfall reconstruction links climate and cultural change. *Geology*, *40*(3), 259–262. https://doi.org/10.1130/G32471.1

Larsen, C. S. (1999). Historical dimensions of skeletal variation: Tracing genetic relationships. In *Bioarchaeology: Interpreting behavior from the human skeleton* (pp. 302–332). Cambridge University Press.

Locksley, A., Ortiz, V., & Hepburn, C. (1980). Social categorization and discriminatory behavior: Extinguishing the minimal intergroup discrimination effect. *Journal of Personality and Social Psychology*, *39*(5), 773–783. https://doi.org/10.1037/0022-3514.39.5.773

Longinelli, A. (1984). Oxygen isotopes in mammal bone phosphate: A new tool for paleohydrological and paleoclimatological research? *Geochimica et Cosmochimica Acta*, *48*(2), 385–390. https://doi.org/10.1016/0016-7037(84)90259-X

López Luján, L., Chávez Balderas, X., Valentín, N., & Montúfar, A. (2010). Huitzilopochtli y el sacrificio de niños en el Templo Mayor de Tenochtitlan. In *El sacrificio humano en la tradición religiosa mesoamericana* (pp. 367–394). Instituto Nacional de Antropología e Historia.

López Luján, L., & Olivier, G. (Eds.). (2010). *El sacrificio humano en la tradición religiosa mesoamericana*. Instituto Nacional de Antropología e Historia, Universidad Nacional Autónoma de México.

Lorenz, S., Marks, N., & Brady, J. (2016). *Geographic origins of child sacrifices: Radiogenic strontium isotope analyses from Midnight Terror Cave, Belize* [Paper]. 81st Annual Meeting of the Society for American Archaeology, Orlando, FL.

Luz, B., & Kolodny, Y. (1989). Oxygen isotope variation in bone phosphate. *Applied Geochemistry*, *4*(3), 317–323. https://doi.org/10.1016/0883-2927(89)90035-8

Luz, B., Kolodny, Y., & Horowitz, M. (1984). Fractionation of oxygen isotopes between mammalian bone-phosphate and environmental drinking water. *Geochimica et Cosmochimica Acta*, *48*(8), 1689–1693. https://doi.org/10.1016/0016-7037(84)90338-7

Ma, J., Wei, G., Liu, Y., Ren, Z., Xu, Y., & Yang, Y. (2013). Precise measurement of stable (δ 88/86Sr) and radiogenic (87Sr/86Sr) strontium isotope ratios in geological standard reference materials using MC-ICP-MS. *Chinese Science Bulletin*, *58*(25), 3111–3118. https://doi.org/10.1007/s11434-013-5803-5

Maechler, M., Rousseeuw, P., Struyf, A., Hubert, M., & Hornik, K. (2017). *cluster: Cluster analysis basics and extensions*. R package version 2.0.6. https://cran.r-project.org/web/packages/cluster/cluster.pdf

Mamdani, M. (2002). *When victims become killers: Colonialism, nativism, and the genocide in Rwanda* (3. print., and 1. paperback print). Princeton Univ. Press.

Manahan, T. K. (2004). The way things fall apart: Social organization and the Classic Maya collapse of Copan. *Ancient Mesoamerica*, *15*(01), 107–125. https://doi.org/10.1017/S0956536104151092

Manning, P. (2006). Cross-community migration: A distinctive human pattern. *Social Evolution & History*, *5*(2), 24–54.

Manzanilla, L. R. (2003). The abandonment of Teotihuacan. In T. Inomata & R. Webb (Eds.), *The archaeology of settlement abandonment in Middle America* (pp. 91–101). University of Utah Press.

Manzanilla, L. R. (2005a). Migrantes epiclásicos en Teotihuacan: Propuesta metodológica para análisis de migraciones del clásico al posclásico. In L. R. Manzanilla (Ed.), *Reacomodos demográficos del clásico al posclásico en el centro de México* (pp. 261–274). Universidad Nacional Autónoma de México Instituto de Investigaciones Antropológicas.

Manzanilla, L. R. (Ed.). (2005b). *Reacomodos demográficos del clásico al posclásico en el centro de México*. Universidad Nacional Autónoma de México Instituto de Investigaciones Antropológicas.

Manzanilla, L. R. (2007). Las “casas” nobles de los barrios de Teotihuacan: Estructuras exclusionistas en un entorno corporativo. In *Memoria 2007* (pp. 453–470). El Colegio Nacional.

Manzanilla, L. R. (2015). Cooperation and tensions in multiethnic corporate societies using Teotihuacan, Central Mexico, as a case study. *Proceedings of the National Academy of Sciences, 112*(30), 9210–9215. https://doi.org/10.1073/pnas.1419881112

Manzanilla, L. R. (Ed.). (2017). *Multiethnicity and migration at Teopancazco: Investigations of a Teotihuacan neighborhood center*. University Press of Florida.

Manzanilla, L. R., López, C., & Freter, A. (1996). Dating results from excavations in quarry tunnels behind the Pyramid of the Sun at Teotihuacan. *Ancient Mesoamerica*, *7*(02), 245–266. https://doi.org/10.1017/S0956536100001450

Manzanilla, L. R., Mejía, G., Jiménez, G., Schaaf, P., Lailson, B., Solís, G., Morales Puente, P., & Cienfuegos Alvarado, E. (2012). Caracterización de la población multiétnica de Teopancazco por isótopos estables, isótopos de estroncio y elementos traza. In L. R. Manzanilla (Ed.), *Estudios arqueométricos del centro de barrio de Teopancazco en Teotihuacan* (pp. 449–465). Instituto de Investigaciones Antropológicas, Universidad Nacional Autónoma de México.

Martínez López, C., Markens, R., Winter, M. C., & Lind, M. D. (2000). *Cerámica de la fase Xoo (época Monte Albán IIIB-IV) del Valle de Oaxaca*. Proyecto Especial Monte Albán, Centro Instituto Nacional de Anthropología e Historia.

Mastache, A. G., Cobean, R. H., & Healan, D. M. (2002). *Ancient Tollan: Tula and the Toltec heartland*. University Press of Colorado.

McAnany, P. A., & Yoffee, N. (2012). *Questioning collapse: Human resilience, ecological vulnerability, and the aftermath of empire*. Cambridge University Press.

McLachlan, G. J., & Krishnan, T. (1997). *The EM algorithm and extensions*. Wiley.

McLachlan, G. J., & Peel, D. (2000). *Finite mixture models*. Wiley-Interscience.

McVicker, D. (1985). The “Mayanized” Mexicans. *American Antiquity*, *50*(1), 82–101. https://doi.org/10.2307/280635

McVicker, D. (2007). Images of violence in Mesoamerican mural art. In R. J. Chacon & R. G. Mendoza (Eds.), *Latin American indigenous warfare and ritual violence* (pp. 73–90). University of Arizona Press.

Mendoza, R. G. (1992). *Conquest polities of the Mesoamerican Epiclassic: Circum-Basin regionalism, A.D. 550-850* [Ph.D. dissertation]. The University of Arizona.

Messner, J. J., Taft, P., Moges, D., Quinn, A., Bhambani, R., Fiertz, C., Blyth, H., Murphy, C., Obike, K., Merriman, C., Haken, N., Maglo, M., Wilson, W., Meyer, K., & Onyekwere, I. (2019). *Fragile States Index annual report 2019* (p. 43). The Fund for Peace. https://fundforpeace.org/wp-content/uploads/2019/04/9511904-fragilestatesindex.pdf

Meza Peñaloza, A. (2015). *Afinidades biológicas y contextos culturales en los antiguos teotihuacanos*. Universidad Nacional Autónoma de México, Instituto de Investigaciones Antropológicas.

Meza-Peñaloza, A., Zertuche, F., García-Velasco, M., & Morehart, C. (2019). A non-metric traits study of skulls from Epiclassic Xaltocan in relation to other Mesoamerican cultures. *Journal of Archaeological Science: Reports*, *23*, 559–566. https://doi.org/10.1016/j.jasrep.2018.11.031

Miller, K. A. (2015). *Family, 'foreigners', and fictive kinship: A bioarchaeological approach to social organization at Late Classic Copan* [Ph.D. dissertation]. Arizona State University.

Miller, W. R. (1983). Uto-Aztecan languages. In A. Ortiz (Ed.), *Handbook of North American indians, vol. 10: Southwest* (pp. 13–24). Smithsonian Institution Press.

Miller Wolf, K. A., & Freiwald, C. (2018). Re-interpreting ancient Maya mobility: A strontium isotope baseline for western Honduras. *Journal of Archaeological Science: Reports*, *20*, 799–807. https://doi.org/10.1016/j.jasrep.2018.04.023

Millon, R. (1973). *Urbanization at Teotihuacan, Mexico*. University of Texas Press.

Millon, R. (1976). Social relations in ancient Teotihuacan. In E. R. Wolf (Ed.), *The Valley of Mexico: Studies in pre-Hispanic ecology and society* (pp. 205–248). University of New Mexico Press.

Miriello, D., Barca, D., Crisci, G. M., Barba, L., Blancas, J., Ortíz, A., Pecci, A., & Luján, L. L. (2011). Characterization and provenance of lime plasters from the Templo Mayor of Tenochtitlan (Mexico City). *Archaeometry*, *53*(6), 1119–1141. https://doi.org/10.1111/j.1475-4754.2011.00603.x

Mock, S. B. (1994). Destruction and denouement during the Late-Terminal Classic: The Colha skull pit. In T. Hester, H. Shafer, & J. Eaton (Eds.), *Continuing archaeology at Colha, Belize* (pp. 221–231). Texas Archaeological Research Laboratory, University of Texas, Austin.

Moorbath, S., Thorpe, R. S., & Gibson, I. L. (1978). Strontium isotope evidence for petrogenesis of Mexican andesites. *Nature*, *271*(5644), 437–439. https://doi.org/10.1038/271437a0

Mooser, F. (1975). Historia geológica de la cuenca de México. In *Memoria de las obras del sistema de drenaje profundo del Distrito Federal* (Vol. 1, pp. 7–38). Departamento del Distrito Federal.

Morales-Arce, A. Y., McCafferty, G., Hand, J., Schmill, N., McGrath, K., & Speller, C. (2019). Ancient mitochondrial DNA and population dynamics in postclassic Central Mexico: Tlatelolco (ad 1325–1520) and Cholula (ad 900–1350). *Archaeological and Anthropological Sciences*. https://doi.org/10.1007/s12520-018-00771-7

Morán-Zenteno, D. (1994). *The geology of the Mexican republic* (J. L. Wilson & L. Sanchez-Barreda, Trans.). American Association of Petroleum Geologists.

Morehart, C. T. (2010). *The archaeology of farmscapes: Production, place, and the materiality of landscape at Xaltocan, Mexico* [Ph.D.]. Northwestern University.

Morehart, C. T. (2012). Mapping ancient chinampa landscapes in the Basin of Mexico: A remote sensing and GIS approach. *Journal of Archaeological Science*, *39*(7), 2541–2551. https://doi.org/10.1016/j.jas.2012.03.001

Morehart, C. T. (2016a). *Proyecto de ecología histórica del norte de la cuenca de México: Informe de la temporada de campo 2015* [Annual excavation report]. Instituto Nacional de Antropología e Historia.

Morehart, C. T. (2016b). Let the earth forever remain! Landscape legacies and the materiality of history in the northern Basin of Mexico. *Journal of the Royal Anthropological Institute*, *22*, 939–961. https://doi.org/10.1111/1467-9655.12498

Morehart, C. T. (Ed.). (2017a). *Proyecto de ecología histórica del norte de la Cuenca de México: Informe de la temporada de campo 2016*. Instituto Nacional de Antropología e Historia.

Morehart, C. T. (2017b). Ritual time: The struggle to pinpoint the temporality of ritual practice using archaeobotanical data. In M. P. Sayre & M. C. Bruno (Eds.), *Social perspectives on ancient lives from paleoethnobotanical data* (pp. 145–158). Springer International Publishing. https://doi.org/10.1007/978-3-319-52849-6_7

Morehart, C. T., Peñaloza, A. M., Sánchez, C. S., de Tapia, E. M., & Morales, E. I. (2012). Human sacrifice during the Epiclassic period in the northern Basin of Mexico. *Latin American Antiquity*, *23*(4), 426–448.

Moreira, G., F, J., Bavel, V., J, J., & Telzer, E. H. (2017). The neural development of ‘us and them.’ *Social Cognitive and Affective Neuroscience*, *12*(2), 184–196. https://doi.org/10.1093/scan/nsw134

Moreiras Reynaga, D. (2019). *The life histories of Aztec sacrifices: A stable isotope study (C, N, and O) of offerings from Tlatelolco and the Templo Mayor of Tenochtitlan* [Ph.D. dissertation, University of Western Ontario]. https://ir.lib.uwo.ca/etd/6448

Moya, C. (2013). Evolved priors for ethnolinguistic categorization: A case study from the Quechua–Aymara boundary in the Peruvian Altiplano. *Evolution and Human Behavior : Official Journal of the Human Behavior and Evolution Society*, *34*(4), 265–272. https://doi.org/10.1016/j.evolhumbehav.2013.03.004

Moya, C., & Boyd, R. (2015). Different selection pressures give rise to distinct ethnic phenomena: A functionalist framework with illustrations from the Peruvian Altiplano. *Human Nature*, *26*(1), 1–27. https://doi.org/10.1007/s12110-015-9224-9

Mullen, B., Brown, R., & Smith, C. (1992). Ingroup bias as a function of salience, relevance, and status: An integration. *European Journal of Social Psychology*, *22*(2), 103–122. https://doi.org/10.1002/ejsp.2420220202

Nado, K. L. (2017). *Dietary practices, socioeconomic status, and social mobility at Teotihuacan, Mexico* [Ph.D. dissertation]. Arizona State University.

Nado, K. L., Zolotova, N., & Knudson, K. J. (2016). Paleodietary analysis of the sacrificial victims from the Feathered Serpent Pyramid, Teotihuacan. *Archaeological and Anthropological Sciences*, 1–16. https://doi.org/10.1007/s12520-016-0416-y

Nagao, D. (1989). Public proclamation in the art of Cacaxtla and Xochicalco. In R. A. Diehl & J. C. Berlo (Eds.), *Mesoamerica after the decline of Teotihuacan A.D. 700-900* (pp. 83–104). Dumbarton Oaks.

Nagao, D. (2014). *An interconnected world? Evidence of interaction in the arts of Epiclassic Cacaxtla and Xochicalco, Mexico* [Ph.D. dissertation]. Columbia University.

Natural Earth. (n.d.). Retrieved February 3, 2020, from https://www.naturalearthdata.com/

Négrel, Ph., Petelet-Giraud, E., Barbier, J., & Gautier, E. (2003). Surface water–groundwater interactions in an alluvial plain: Chemical and isotopic systematics. *Journal of Hydrology*, *277*(3–4), 248–267. https://doi.org/10.1016/S0022-1694(03)00125-2

Nelson, B. A., & Crider, D. L. (2005). Posibles pasajes migratorios en el norte de México y el suroeste de los Estados Unidos durante el epiclásico y el posclásico. In L. R. Manzanilla (Ed.), *Reacomodos demográficos del clásico al posclásico en el centro de México* (pp. 75–102). Universidad Nacional Autónoma de México Instituto de Investigaciones Antropológicas.

Nelson, Z. (2009). Obsidian biface production at Teotihuacan: Reexamining a Coyotlatelco phase workshop from Hacienda Metepec. *Ancient Mesoamerica, 20*(1), 149–162. JSTOR.

Nesdale, D., Griffiths, J. A., Durkin, K., & Maass, A. (2007). Effects of group membership, intergroup competition and out-group ethnicity on children's ratings of in-group and out-group similarity and positivity. *British Journal of Developmental Psychology*, *25*(3), 359–373. https://doi.org/10.1348/026151006X150382

Nichols, D. L. (2016). Teotihuacan. *Journal of Archaeological Research*, *24*(1), 1–74. https://doi.org/10.1007/s10814-015-9085-0

Offenbecker, A. M. (2018). *Geographic origins, status, and identity at Paquimé, northwest Chihuahua, Mexico* [Ph.D. dissertation]. University of Calgary.

Ohmoto, H., Hart, S. R., & Holland, H. D. (1966). Studies in the Providencia area, Mexico, II, K-Ar and Rb-Sr ages of intrusive rocks and hydrothermal minerals. *Economic Geology*, *61*, 1205–1213.

Ortega-Guerrero, A., Cherry, J. A., & Aravena, R. (1997). Origin of pore water and salinity in the lacustrine aquitard overlying the regional aquifer of Mexico City. *Journal of Hydrology*, *197*(1–4), 47–69. https://doi.org/10.1016/S0022-1694(96)03280-5

Otten, S., & Wentura, D. (1999). About the impact of automaticity in the minimal group paradigm: Evidence from affective priming tasks. *European Journal of Social Psychology*, *29*(8), 1049–1071. https://doi.org/10.1002/(SICI)1099-0992(199912)29:8<1049::AID-EJSP985>3.0.CO;2-Q

Overholtzer, L., & De Lucia, K. (2016). A multiscalar approach to migration and social change at Middle Postclassic Xaltocan. *Ancient Mesoamerica*, *27*(1), 163–182. https://doi.org/10.1017/S0956536116000110

Pacheco-Forés, S. I. (2016). Investigaciones preliminares de biodistancia e isótopos en los restos humanos de Non-Grid 4, Xaltocan, México. In C. T. Morehart (Ed.), *Proyecto de ecología histórica del norte de la Cuenca de México: Informe de la temporada de campo 2015* (pp. 117–133).

Pacheco-Forés, S. I. (2017). Análisis exploratorio de afinidad biológica entre los individuos sacrificados en No-Cuadrícula 4, Xaltocan, Edo. De México. In C. T. Morehart (Ed.), *Proyecto de ecología histórica del norte de la Cuenca de México: Informe de la temporada de campo 2016* (pp. 145–153). Instituto Nacional de Antropología e Historia.

Pacheco-Forés, S. I., Carpenter, L., & Knudson, K. J. (in preparation). Radiogenic strontium isotope variability in the Oaxaca Valley: A baseline for paleomobility studies. *Journal of Archaeological Science: Reports*.

Pacheco-Forés, S. I., Gordon, G. W., & Knudson, K. J. (2020). Expanding radiogenic strontium isotope baseline data for central Mexican paleomobility studies. *PLOS ONE, 15*(2), e0229687. https://doi.org/10.1371/journal.pone.0229687

Pacheco-Forés, S. I., Morehart, C. T., & Knudson, K. J. (in preparation). Migration, violence, and the “other”: A biogeochemical approach to identity-based violence and human sacrifice in the Epiclassic Basin of Mexico. *Journal of Anthropological Archaeology*.

Palmer, M. R., & Edmond, J. M. (1992). Controls over the strontium isotope composition of river water. *Geochimica et Cosmochimica Acta*, *56*(5), 2099–2111. https://doi.org/10.1016/0016-7037(92)90332-D

Parsons, J. R. (2001). *The last saltmakers of Nexquipayac, Mexico: An archaeological ethnography*. Museum of Anthropology, University of Michigan.

Parsons, J. R. (2008). Beyond Santley and Rose (1979): The role of aquatic resources in the prehispanic economy of the Basin of Mexico. *Journal of Anthropological Research*, *64*(3), 351–366. https://doi.org/10.3998/jar.0521004.0064.303

Parsons, J. R., & Gorenflo, L. J. (2008). The patterning of settlement. In J. R. Parsons, L. J. Gorenflo, M. H. Parsons, & D. J. Wilson (Eds.), *Prehispanic settlement* *patterns in the northwestern Valleyof Mexico: The Zumpango region* (pp. 61–99). Museum of Anthropology, University of Michigan.

Parsons, J. R., Gorenflo, L. J., Parsons, M. H., & Wilson, D. J. (2008). *Prehispanic settlement patterns in the northwestern Valley of Mexico: The Zumpango region*. Museum of Anthropology, University of Michigan.

Parsons, J. R., & Sugiura, Y. (2012). Teotihuacan and the Epiclassic in central Mexico. In D. L. Nichols & C. A. Pool (Eds.), *The Oxford handbook of Mesoamerican archaeology* (pp. 309–323). Oxford University Press.

Pate, F. D. (1994). Bone chemistry and paleodiet. *Journal of Archaeological Method and Theory*, *1*(2), 161–209.

Pellegrini, M., Lee-Thorp, J. A., & Donahue, R. E. (2011). Exploring the variation of the δ18Op and δ18Oc relationship in enamel increments. *Palaeogeography, Palaeoclimatology, Palaeoecology*, *310*(1–2), 71–83. https://doi.org/10.1016/j.palaeo.2011.02.023

Pestle, W. J., Crowley, B. E., & Weirauch, M. T. (2014). Quantifying inter-laboratory variability in stable isotope analysis of ancient skeletal remains. *PLoS ONE*, *9*(7), e102844. https://doi.org/10.1371/journal.pone.0102844

Pestle, W. J., Simonetti, A., & Curet, L. A. (2013). 87Sr/86Sr variability in Puerto Rico: Geological complexity and the study of paleomobility. *Journal of Archaeological Science*, *40*(5), 2561–2569. https://doi.org/10.1016/j.jas.2013.01.020

Plunket, P., & Uruñuela, G. (2006). Social and cultural consequences of a late Holocene eruption of Popocatépetl in central Mexico. *Quaternary International*, *151*(1), 19–28. https://doi.org/10.1016/j.quaint.2006.01.012

Pollard, A. M., Pellegrini, M., & Lee-Thorp, J. A. (2011). Technical note: Some observations on the conversion of dental enamel δ18op values to δ18ow to determine human mobility. *American Journal of Physical Anthropology*, *145*(3), 499–504. https://doi.org/10.1002/ajpa.21524

Price, T. D., Blitz, J., Burton, J., & Ezzo, J. A. (1992). Diagenesis in prehistoric bone: Problems and solutions. *Journal of Archaeological Science*, *19*(5), 513–529. https://doi.org/10.1016/0305-4403(92)90026-Y

Price, T. D., Burton, J. H., & Bentley, R. A. (2002). The characterization of biologically available strontium isotope ratios for the study of prehistoric migration. *Archaeometry*, *44*(1), 117–135. https://doi.org/10.1111/1475-4754.00047

Price, T. D., Burton, J. H., Cucina, A., Zabala, P., Frei, R., Tykot, Robert H., & Tiesler, V. (2012). Isotopic studies of human skeletal remains from a sixteenth to seventeenth century AD churchyard in Campeche, Mexico: Diet, place of origin, and age. *Current Anthropology*, *53*(4), 396–433. https://doi.org/10.1086/666492

Price, T. D., Burton, J. H., Fullagar, P. D., Wright, L. E., Buikstra, J. E., & Tiesler, V. (2008). Strontium isotopes and the study of human mobility in ancient Mesoamerica. *Latin American Antiquity*, *19*(2), 167–180. https://doi.org/10.2307/25478222

Price, T. D., Burton, J. H., Fullagar, P. D., Wright, L. E., Buikstra, J. E., & Tiesler, V. (2015). Strontium isotopes and the study of human mobility among the ancient Maya. In A. Cucina (Ed.), *Archaeology and Bioarchaeology of Population Movement among the Prehispanic Maya* (pp. 119–132). Springer International Publishing. https://doi.org/10.1007/978-3-319-10858-2_11

Price, T. D., Burton, J. H., Sharer, R. J., Buikstra, J. E., Wright, L. E., Traxler, L. P., & Miller, K. A. (2010). Kings and commoners at Copan: Isotopic evidence for origins and movement in the Classic Maya period. *Journal of Anthropological Archaeology*, *29*(1), 15–32. https://doi.org/10.1016/j.jaa.2009.10.001

Price, T. D., Burton, J. H., Wright, L. E., White, C. D., & Longstaffe, F. J. (2007). Victims of sacrifice: Isotopic evidence for place of origin. In V. Tiesler & A. Cucina (Eds.), *Human sacrifice and ritual body treatments in ancient Maya society* (pp. 263–292). Springer.

Price, T. D., Johnson, C. M., Ezzo, J. A., Ericson, J., & Burton, J. H. (1994). Residential mobility in the prehistoric southwest United States: A preliminary study using strontium isotope analysis. *Journal of Archaeological Science*, *21*(3), 315–330.

Price, T. D., Manzanilla, L. R., & Middleton, W. D. (2000). Immigration and the ancient city of Teotihuacan in Mexico: A study using strontium isotope ratios in human bone and teeth. *Journal of Archaeological Science*, *27*(10), 903–913. https://doi.org/10.1006/jasc.1999.0504

Price, T. D., Nakamura, S., Suzuki, S., Burton, J. H., & Tiesler, V. (2014). New isotope data on Maya mobility and enclaves at Classic Copan, Honduras. *Journal of*

Anthropological Archaeology, *36*, 32–47. https://doi.org/10.1016/j.jaa.2014.02.003

Price, T. D., Tiesler, V., & Burton, J. H. (2006). Early African diaspora in colonial Campeche, Mexico: Strontium isotopic evidence. *American Journal of Physical Anthropology*, *130*(4), 485–490. https://doi.org/10.1002/ajpa.20390

Price, T. D., Tiesler, V., Folan, W. J., & Tykot, R. H. (2018). Calakmul as a central place: Isotopic insights on urban Maya mobility and diet during the first millenium AD. *Latin American Antiquity*, *29*(3), 439–454. https://doi.org/10.1017/laq.2018.31

Purnell, T., Idsardi, W., & Baugh, J. (1999). Perceptual and phonetic experiments on American English dialect identification. *Journal of Language and Social Psychology*, *18*(1), 10–30. https://doi.org/10.1177/0261927X99018001002

Püschel, T. A., Friess, M., & Manríquez, G. (2020). Morphological consequences of artificial cranial deformation: Modularity and integration. *PLOS ONE*, *15*(1), e0227362. https://doi.org/10.1371/journal.pone.0227362

R Core Team. (2016). *R: a language and environment for statistical computing*. R Foundation for Statistical Computing.

Ragsdale, C. S. (2017). Regional population structure in Postclassic Mexico. *Ancient Mesoamerica*, 1–13. https://doi.org/10.1017/S0956536117000013

Ragsdale, C. S., & Edgar, H. J. H. (2018). Population continuity and replacement in the pre-contact Valley of Mexico. In C. Willermet & A. Cucina (Eds.), *Bioarchaeology of pre-Columbian Mesoamerica: An interdisciplinary approach* (pp. 37–69). University Press of Florida.

Rand, D. G., Pfeiffer, T., Dreber, A., Sheketoff, R. W., Wernerfelt, N. C., & Benkler, Y. (2009). Dynamic remodeling of in-group bias during the 2008 presidential election. *Proceedings of the National Academy of Sciences*, *106*(15), 6187–6191. https://doi.org/10.1073/pnas.0811552106

Rattray, E. C. (1966). An archaeological and stylistic study of Coyotlatelco pottery. *Mesoamerican Notes*, *7–8*, 87–211.

Rattray, E. C. (1987). La producción y la distribución de obdisidana en el periodo Coyotlatelco en Teotihuacan: Un estudio preliminar. In E. McClung de Tapia & E. C. Rattray (Eds.), *Teotihuacan: Nuevos datos, nuevas síntesis, nuevos* *problemas* (pp. 451–463). Instituto de Investigaciones Antropológicas, Universidad Nacional Autónoma de México.

Rattray, E. C. (1989). El barrio de los comerciantes y el conjunto Tlamimilolpa: Un estudio comparativo. *Arqueología, 5*, 105–129.

Rattray, E. C. (1996). A regional perspective on the Epiclassic period in central Mexico. In A. G. Mastache, J. R. Parsons, R. S. Santley, & M. C. Serra Puche (Eds.), *Arqueología mesoamericana: Homenaje a William T. Sanders* (pp. 213–231). Instituto Nacional de Antropología e Historia.

Rattray, E. C. (2006). El Epiclásico de Teotihuacan y Azcapotzalco. In L. Solar Valverde (Ed.), *El fenómeno Coyotlatelco en el centro de México: Tiempo, espacio y significado* (pp. 201–214). Instituto Nacional de Antropología e Historia.

Relethford, J. H. (2003). Anthropometric data and population history. In D. A. Herring & A. C. Swedlund (Eds.), *Human biologists in the archives: Demography, health, nutrition, and genetics in historical populations* (pp. 32–52). Cambridge University Press.

Relethford, J. H., & Blangero, J. (1990). Detection of differential gene flow from patterns of quantitative variation. *Human Biology, 62*(1), 5–25.

Relethford, J. H., Crawford, M. H., & Blangero, J. (1997). Genetic drift and gene flow in post-famine Ireland. *Human Biology, 69*(4), 443–465.

Reynolds, A. C., Quade, J., & Betancourt, J. L. (2012). Strontium isotopes and nutrient sourcing in a semi-arid woodland. *Geoderma, 189–190*, 574–584. https://doi.org/10.1016/j.geoderma.2012.06.029

Riek, B. M., Mania, E. W., & Gaertner, S. L. (2006). Intergroup threat and outgroup attitudes: A meta-analytic review. *Personality and Social Psychology Review, 10*(4), 336–353. https://doi.org/10.1207/s15327957pspr1004_4

Ringle, W. M., Negrón, T. G., & Bey, G. J. (1998). The return of Quetzalcoatl: Evidence for the spread of a world religion during the Epiclassic period. *Ancient Mesoamerica*, *9*(02), 183–232. https://doi.org/10.1017/S0956536100001954

Rodríguez Galicia, B., & Valadez Azúa, R. (2013). Vestigios del recurso costero en el sitio arqueológico de Teopancazco, Teotihuacan, Estado de México. *Revista Española de Antropología Americana*, *43*(1), 9–29. https://doi.org/10.5209/rev_REAA.2013.v43.n1.42294

Román Berrelleza, J. A. (2010). El papel de los infantes en las prácticas sacrificiales Mexicas. In L. López Luján & G. Olivier (Eds.), *El sacrificio humano en la tradición religiosa mesoamericana* (pp. 345–366). Instituto Nacional de Antropología e Historia.

Romaniello, S. J., Field, M. P., Smith, H. B., Gordon, G. W., Kim, M. H., & Anbar, A. D. (2015). Fully automated chromatographic purification of Sr and Ca for isotopic analysis. *Journal of Analytical Atomic Spectrometry*, *30*(9), 1906–1912. https://doi.org/10.1039/C5JA00205B

Rubin, D. B. (1987). *Multiple imputation for nonresponse in surveys*. Wiley.

Runia, Lex. T. (1987). Strontium and calcium distribution in plants: Effect on palaeodietary studies. *Journal of Archaeological Science*, *14*(6), 599–608. https://doi.org/10.1016/0305-4403(87)90078-1

Sahagún, B. de. (1951). *Florentine codex, general history of the things of New Spain: Book II - the ceremonies* (A. J. O. Anderson & C. E. Dibble, Trans.; Vol. 2). School of American Research Press.

Sahagún, B. de. (1961). *Florentine codex, general history of the things of New Spain: Book X - the people* (A. J. O. Anderson & C. E. Dibble, Trans.; Vol. 10). School of American Research Press.

Sahagún, B. de. (1963). *Florentine codex, general history of the things of New Spain: Book XI - earthly things* (A. J. O. Anderson & C. E. Dibble, Trans.). School of American Research Press.

Salinas Prieto, J. C., Montiel Escobar, J., Sánchez Rojas, E., Díaz Salgado, C., de la Calleja, A., Barajas Nigoche, D., Dorantes Salgado, E., Jiménez Gonzaga, A., & Amezcua Torres, N. (2007). *Carta geológica de México* (6 ed.) [Map]. Servicio Geológico Mexicano.

Sánchez, J. E. (2013). *Para comprender el Epiclásico en el centro de México: Problemas y propuestas teórico-metodológicos*. Instituto Nacional de Antropología e Historia.

Sanders, W. T. (Ed.). (1986). *The Teotihuacan Valley Project, Final Report, Volume 4: The Toltec period occupation*. Department of Anthropology, Pennsylvania State University.

Sanders, W. T. (1989). The Epiclassic as a stage in Mesoamerican prehistory: An evaluation. In R. A. Diehl & J. C. Berlo (Eds.), *Mesoamerica after the decline of Teotihuacan, A.D. 700-900* (pp. 211–218). Dumbarton Oaks.

Sanders, W. T. (2006). Late Xolalpan-Metepec/Oxtotipac-Coyotlatelco: Ethnic succession or changing patterns of political economy, a reevaluation. In L. Solar Valverde (Ed.), *El fenómeno Coyotlatelco en el centro de México: Tiempo, espacio y significado* (pp. 183–200). Instituto Nacional de Antropología e Historia.

Sanders, W. T., Parsons, J. R., & Santley, R. S. (1979). *The Basin of Mexico: Ecological processes in the evolution of a civilization*. Academic Press.

Santley, R. S., & Rose, E. K. (1979). Diet, nutrition and population dynamics in the Basin of Mexico. *World Archaeology, 11*(2), 185–207. https://doi.org/10.1080/00438243.1979.9979760

Schaaf, P., Solís, G., Manzanilla, L. R., Hernández, T., Lailson, B., & Horn, P. (2012). Isótopos de estroncio aplicados a estudios de migración humana en el centro de barrio de Teopancazco, Teotihuacan. In L. R. Manzanilla (Ed.), *Estudios arqueométricos del centro de barrio de Teopancazco en Teotihuacan* (pp. 425–448). Instituto de Investigaciones Antropológicas, Universidad Nacional Autónoma de México.

Schachner, G. (2012). Population circulation and community organization in small-scale agricultural societies. In *Population circulation and the transformation of ancient Zuni communities* (pp. 9–32). University of Arizona Press.

Schafer, J. L. (1999). Multiple imputation: A primer. *Statistical Methods in Medical Research*, *8*(1), 3–15. https://doi.org/10.1177/096228029900800102

Schafer, J. L., & Olsen, M. K. (1998). Multiple imputation for multivariate missing-data problems: A data analyst’s perspective. *Multivariate Behavioral Research*, *33*(4), 545–571. https://doi.org/10.1207/s15327906mbr3304_5

Schmidt, B. E., & Schröder, I. W. (Eds.). (2001). *Anthropology of violence and conflict*. Routledge.

Schwandner-Sievers, S. (2001). The enactment of “tradition”: Albanian constructions of identity, violence and power in times of crisis. In B. E. Schmidt & I. W. Schröder (Eds.), *Anthropology of violence and conflict* (pp. 97–120). Routledge.

Schwarcz, H. P., Gibbs, L., & Knyf, M. (1991). Oxygen isotope analysis as an indicator of place of origin. In *Snake Hill: An investigation of a military cemetery from the War of 1812* (pp. 263–268). Dundurn Press.

Sealy, J. C., Armstrong, R., & Schrire, C. (1995). Beyond lifetime averages: Tracing life histories through isotopic analysis of different calcified tissues from archaeological human skeletons. *Antiquity*, *69*(263), 290–300. https://doi.org/10.1017/S0003598X00064693

Sealy, J. C., van der Merwe, N. J., Sillen, A., Kruger, F. J., & Krueger, H. W. (1991). 87Sr/86Sr as a dietary indicator in modern and archaeological bone. *Journal of Archaeological Science*, *18*(3), 399–416. https://doi.org/10.1016/0305-4403(91)90074-Y

Sen, A. (2009). Violence in identity. In I. Karawān, W. McCormack, & S. E. Reynolds (Eds.), *Values and violence: Intangible aspects of terrorism* (pp. 3–14). Springer.

Serafin, S., Lope, C. P., & Uc González, E. (2014). Bioarchaeological investigation of ancient Maya violence and warfare in inland northwest Yucatan, Mexico. *American Journal of Physical Anthropology*, *154*(1), 140–151. https://doi.org/10.1002/ajpa.22490

Servicio Geológico Mexicano. (2007). *Carta geológica de la República Mexicana* [Map]. Servicio Geológico Mexicano.

Servicio Geológico Mexicano. (2008). *Estados de Puebla y Tlaxcala: Carta geológico-minera* [Map]. Servicio Geológico Mexicano.

Servicio Geológico Mexicano. (2009). *Distrito Federal, Estado de México y Morelos: Carta geológico-minera* [Map]. Servicio Geológico Mexicano.

Shah, A. D., Bartlett, J. W., Carpenter, J., Nicholas, O., & Hemingway, H. (2014). Comparison of random forest and parametric imputation models for imputing missing data using MICE: A CALIBER study. *American Journal of Epidemiology*, *179*(6), 764–774. https://doi.org/10.1093/aje/kwt312

Sharpe, A. E., Emery, K. F., Inomata, T., Triadan, D., Kamenov, G. D., & Krigbaum, J. (2018). Earliest isotopic evidence in the Maya region for animal management and long-distance trade at the site of Ceibal, Guatemala. *Proceedings of the National Academy of Sciences*, *115*, 3605–3610. https://doi.org/10.1073/pnas.1713880115

Sherif, M. (1966). *Group conflict and cooperation: Their social psychology*. Routledge & Kegan Paul.

Sholts, S. B., Báez-Molgado, S., Morehart, C. T., & Meza Peñaloza, A. (2014, April 10). *Cranial morphometric variation and human sacrifice at the Epiclassic site of Xaltocan, Mexico*. 83rd Annual Meeting of the American Association of Physical Anthropologists, Calgary, Alberta.

Siebe, C. (2000). Age and archaeological implications of Xitle volcano, southwestern Basin of Mexico-City. *Journal of Volcanology and Geothermal Research*, *104*(1), 45–64. https://doi.org/10.1016/S0377-0273(00)00199-2

Sillen, A., & Sealy, J. C. (1989). Chemistry and paleodietary research: No more easy answers. *American Antiquity*, *54*, 504–512.

Simunovic, D., Mifune, N., & Yamagishi, T. (2013). Preemptive strike: An experimental study of fear-based aggression. *Journal of Experimental Social Psychology*, *49*(6), 1120–1123. https://doi.org/10.1016/j.jesp.2013.08.003

Smith, M. E. (2010). The archaeological study of neighborhoods and districts in ancient cities. *Journal of Anthropological Archaeology*, *29*(2), 137–154. https://doi.org/10.1016/j.jaa.2010.01.001

Smith, M. E., & Lind, M. D. (2005). Xoo-phase ceramics from Oaxaca found at Calixtlahuaca in central Mexico. *Ancient Mesoamerica*, *16*(2), 169–177. JSTOR.

Solar Valverde, L. (Ed.). (2006). *El fenómeno Coyotlatelco en el centro de México: Tiempo, espacio y significado*. Instituto Nacional de Antropología e Historia.

Solís Pichardo, G., Schaaf, P., Hernández Treviño, T., Lailson, B., Manzanilla, L. R., & Horn, P. (2017). Migrants in Teopancazco: Evidence from strontium isotopic studies. In L. R. Manzanilla (Ed.), *Multiethnicity and migration at Teopancazco: Investigations of a Teotihuacan neighborhood center* (pp. 143–163). University Press of Florida.

Sołtysiak, A. (2017). Antemortem cranial trauma in ancient Mesopotamia. *International Journal of Osteoarchaeology*, *27*, 119–128. https://doi.org/10.1002/oa.2478

Sosis, R., & Ruffle, B. J. (2003). Religious ritual and cooperation: Testing for a relationship on Israeli religious and secular kibbutzim. *Current Anthropology, 44*(5), 713–722. https://doi.org/10.1086/379260

Spence, M. W. (1974). Residential practices and the distribution of skeletal traits in Teotihuacan, Mexico. *Man*, *9*(2), 262. https://doi.org/10.2307/2800077

Spence, M. W. (1992). Tlailotlacan, a Zapotec enclave in Teotihuacan. In J. C. Berlo (Ed.), *Art, ideology, and the city of Teotihuacan* (pp. 59–88). Dumbarton Oaks.

Spence, M. W. (1994). Human skeletal material from Teotihuacan. In M. L. Sempowski & M. W. Spence (Eds.), *Mortuary practices and skeletal remains at Teotihuacan* (pp. 315–427). University of Utah Press.

Spence, M. W. (2005). A Zapotec diaspora network in Classic-period central Mexico. In G. J. Stein (Ed.), *The archaeology of colonial encounters: Comparative perspectives* (pp. 173–206). School of American Research Press.

Spence, M. W., & Gamboa Cabezas, L. M. (1999). Mortuary practices and social adaptation in the Tlailotlacan enclave. In L. R. Manzanilla & C. Serrano Sánchez (Eds.), *Prácticas funeraria en la Ciudad de los Dioses: Los enterramientos humanos de la antigua Teotihuacan* (pp. 173–201). Universidad Nacional Autónoma de México Instituto de Investigaciones Antropológicas.

Spence, M. W., & White, C. D. (2010). Mesoamerican bioarchaeology: Past and future. *Ancient Mesoamerica*, *20*(2), 233–240. https://doi.org/10.1017/S0956536109990083

Spence, M. W., White, C. D., Longstaffe, F. J., & Law, K. R. (2004). Victims of the victims: Human trophies worn by sacrificed soldiers from the Feathered Serpent Pyramid, Teotihuacan. *Ancient Mesoamerica*, *15*(1), 1–15. https://doi.org/10.1017/S0956536104151018

Spence, M. W., White, C., Rattray, E. C., & Longstaffe, F. J. (2005). Past lives in different places: The origins and relationships of Teotihuacan’s foreign residents. In R. E. Blanton (Ed.), *Settlement, subsistence and social complexity: Essays honoring the legacy of Jeffrey Parsons*. Costen Institute of Archaeology,

University of California, Los Angeles.

Stichler, W. (1995). Interlaboratory comparison of new materials for carbon and oxygen ratio measurements. In IAEA (Ed.), *Reference adn intercomparison materials for stable isotopes of light elements: Proceedigns of a consultants meeting held in Vienna, 1-3 December 1993* (pp. 67–74). International Atomic Energy Agency (IAEA).

Stojanowski, C. M. (2005a). The bioarchaeology of identity in Spanish colonial Florida: Social and evolutionary transformation before, during, and after demographic collapse. *American Anthropologist*, *107*(3), 417–431.

Stojanowski, C. M. (2005b). *Biocultural histories in La Florida: A bioarchaeological perspective*. University of Alabama Press.

Stojanowski, C. M. (2007). Comment on "Alternative dental measurements" by Hillson et al. *American Journal of Physical Anthropology*, *132*(2), 234–237. https://doi.org/10.1002/ajpa.20400

Stojanowski, C. M. (2009). Bridging histories: The bioarchaeology of identity in Postcontact Florida. In K. J. Knudson & C. M. Stojanowski (Eds.), *Bioarchaeology and identity in the Americas* (pp. 59–81). University Press of Florida.

Stojanowski, C. M., & Schillaci, M. A. (2006). Phenotypic approaches for understanding patterns of intracemetery biological variation. *American Journal of Physical Anthropology*, *131*(S43), 49–88. https://doi.org/10.1002/ajpa.20517

Storey, R. (1992). *Life and death in the ancient city of Teotihuacan: A modern paleodemographic synthesis*. University Alabama Press. http://site.ebrary.com/lib/alltitles/docDetail.action?docID=10527765

Stuart, D. (2000). "The arrival of strangers": Teotihuacan and Tollan in Classic Maya history. In D. Carrasco, L. Jones, & S. Sessions (Eds.), *Mesoamerica's Classic heritage: From Teotihuacan to the the Aztecs* (pp. 465–513). University Press of Colorado.

Sugiura Yamamoto, Y. (2006). ¿Cambio gradual o discontinuidad en la cerámica?: Discusión acerca del paso del Clásico al Epiclásico, visto desde el Valle de Toluca. In L. Solar Valverde (Ed.), *El fenómeno Coyotlatelco en el centro de México: Tiempo, espacio y significado* (pp. 127–162). Instituto Nacional de Antropología e Historia.

Tajfel, H. (1959). A note on Lambert's "Evaluational reactions to spoken languages." *Canadian Journal of Psychology, 13,* 86–92.

Tajfel, H., Billig, M. G., Bundy, R. P., & Flament, C. (1971). Social categorization and intergroup behaviour. *European Journal of Social Pyschology, 1,* 149–177.

Tajfel, H., & Turner, J. C. (2004). The social identity theory of intergroup behavior. In J. T. Jost & J. Sidanius (Eds.), *Political psychology: Key readings* (pp. 276–293). Psychology Press.

Thibodeau, A. M., Luján, L. L., Killick, D. J., Berdan, F. F., & Ruiz, J. (2018). Was Aztec and Mixtec turquoise mined in the American Southwest? *SCIENCE ADVANCES*, 9.

Thornton, E. K. (2011). Reconstructing ancient Maya animal trade through strontium isotope (87Sr/86Sr) analysis. *Journal of Archaeological Science, 38*(12), 3254–3263. https://doi.org/10.1016/j.jas.2011.06.035

Tiesler, V., & Cucina, A. (2012). Where are the warriors? Cranial trauma patterns and conflict among the ancient Maya. In D. L. Martin, R. P. Harrod, & V. R. Pérez (Eds.), *The bioarchaeology of violence: Bioarchaeological interpretations of the human past: Local, regional, and global perspectives* (pp. 160–179). University Press of Florida.

Torres-Alvarado, I. S., Verma, S. P., & Carrasco-Núñez, G. (2000). Compilation of radiogenic isotope data in Mexico and their petrogenetic implications. *Journal of Earth System Science*, *109*(1), 67–78. https://doi.org/10.1007/BF02719150

Torres-Lagares, D., Tulasne, J.-F., Pouget, C., Llorens, A., Saffar, J.-L., & Lesclous, P. (2010). Structure and remodelling of the human parietal bone: An age and gender histomorphometric study. *Journal of Cranio-Maxillofacial Surgery, 38*(5), 325–330. https://doi.org/10.1016/j.jcms.2009.07.012

Tozzer, A. M. (1921). *Excavations of a site at Santiago Ahuitzotla City, Mexico*. Bureau of American Ethnology.

Tricca, A., Stille, P., Steinmann, M., Kiefel, B., Samuel, J., & Eikenberg, J. (1999). Rare earth elements and Sr and Nd isotopic compositions of dissolved and suspended loads from small river systems in the Vosges mountains (France), the river Rhine and groundwater. *Chemical Geology*, *160*, 139–158.

Tsuda, T. (2011). Modern perspectives on ancient migrations. In G. S. Cabana & J. J. Clark (Eds.), *Rethinking anthropological perspectives on migration* (pp. 313–338). University Press of Florida.

Tsuda, T., Baker, B. J., Eder, J. F., Knudson, K. J., Maupin, J., Meierotto, L., & Scott, R. E. (2015). Unifying themes in studies of ancient and contemporary migrations. In B. J. Baker & T. Tsuda (Eds.), *Migration and disruptions: Toward a unifying* *theory of ancient and contemporary migrations* (pp. 15–30). University Press of Florida.

Turekian, K. K., & Kulp, J. L. (1956). Strontium content of human bones. *Science, 124*(3218), 405–407.

Turner, A. D. (2019). The murals of Cacaxtla: Monumental art as evidence of migration. In C. S. Beekman (Ed.), *Migrations in late Mesoamerica* (pp. 205–240). University Press of Florida.

Utermohle, C. J., & Zegura, S. L. (1982). Intra- and interobserver error in craniometry: A cautionary tale. *American Journal of Physical Anthropology*, *57*(3), 303–310. https://doi.org/10.1002/ajpa.1330570307

van Buuren, S. (2018). *Flexible imputation of missing data* (2nd ed.). Chapman and Hall/CRC. https://stefvanbuuren.name/fimd/

van Buuren, S., & Groothuis-Oudshoorn, K. (2011). mice: Multivariate imputation by chained equations in R. *Journal of Statistical Software*, *45*(3), 1–67.

Van De Mieroop, M. (2011). *A history of ancient Egypt*. John Wiley & Sons, Ltd.

Vázquez-Sánchez, E., & Jaimes-Palomera, R. (1989). Geología de la cuenca de México. *Geofísica Internacional*, *28*, 133–190.

Veizer, J. (1989). Strontium isotopes in seawater through time. *Annual Review of Earth and Planetary Sciences*, *17*, 141.

Walby, S., Armstrong, J., & Strid, S. (2012). Intersectionality: Multiple inequalities in social theory. *Sociology*, *46*(2), 224–240. https://doi.org/10.1177/0038038511416164

Wallén, C. C. (1955). Some characteristics of precipitation in Mexico. *Geografiska Annaler*, *37*, 51–85. https://doi.org/10.2307/520169

Wassenaar, L. I., Van Wilgenburg, S. L., Larson, K., & Hobson, K. A. (2009). A groundwater isoscape (δD, δ18O) for Mexico. *Journal of Geochemical Exploration*, *102*(3), 123–136. https://doi.org/10.1016/j.gexplo.2009.01.001

White, C. D., Price, T. D., & Longstaffe, F. J. (2007). Residential histories of the human sacrifices at the Moon Pyramid, Teotihuacan: Evidence from oxygen and strontium isotopes. *Ancient Mesoamerica*, *18*(01), 159–172. https://doi.org/10.1017/S0956536107000119

White, C. D., Spence, M. W., Longstaffe, F. J., & Law, K. R. (2000). Testing the nature of Teotihuacán imperialism at Kaminaljuyú using phosphate oxygen-isotope ratios. *Journal of Anthropological Research*, 535–558.

White, C. D., Spence, M. W., Longstaffe, F. J., & Law, K. R. (2004). Demography and ethnic continuity in the Tlailotlacan enclave of Teotihuacan: The evidence from stable oxygen isotopes. *Journal of Anthropological Archaeology*, *23*(4), 385–403. https://doi.org/10.1016/j.jaa.2004.08.002

White, C. D., Spence, M. W., Longstaffe, F. J., Stuart-Williams, H., & Law, K. R. (2002). Geographic identities of the sacrificial victims from the Feathered Serpent Pyramid, Teotihuacan: Implications for the nature of state power. *Latin American Antiquity*, *13*(2), 217–236.

White, C. D., Spence, M. W., Stuart-Williams, H. L. Q., & Schwarcz, H. P. (1998). Oxygen isotopes and the identification of geographical origins: The Valley of Oaxaca versus the Valley of Mexico. *Journal of Archaeological Science*, *25*(7), 643–655. https://doi.org/10.1006/jasc.1997.0259

White, C. D., Storey, R., Longstaffe, F. J., & Spence, M. W. (2004). Immigration, assimilation, and status in the ancient city of Teotihuacan: Stable isotopic evidence from Tlajinga 33. *Latin American Antiquity*, *15*(2(June)), 176–198.

Whitt, S., & Wilson, R. K. (2007). The dictator game, fairness and ethnicity in postwar Bosnia. *American Journal of Political Science*, *51*(3), 655–668. https://doi.org/10.1111/j.1540-5907.2007.00273.x

Wickham, H. (2009). *ggplot2: Elegant graphics for data analysis*. Springer-Verlag.

Widmer, R. J. (1987). The evolution of form and function in a Teotihuacan apartment compound. In E. McClung de Tapia & E. C. Rattray (Eds.), *Teotihuacán: Nuevos datos, nuevas síntesis, nuevos problemas* (pp. 317–368). Universidad Autónoma de México.

Widmer, R. J., & Storey, R. (2017). Skeletal health and patterns of animal food consumption at S3W1:33 (Tlajinga 33), Teotihuacan. *Archaeological and Anthropological Sciences*, *9*(1), 51–60. https://doi.org/10.1007/s12520-016-0417-x

Willermet, C., Edgar, H. J. H., Ragsdale, C., & Aubry, B. S. (2013). Biodistances among Mexica, Maya, Toltec, and Totonac groups of central and coastal Mexicio. *Chungará, Revista de Antropología Chilena*, *45*, 447–459.

Winter, M. C. (1998). Monte Alban and Teotihuacan. In E. C. Rattray (Ed.), *Rutas de intercambio en Mesoamérica: III Coloquio Pedro Bosch Gimpera* (pp. 153–184). Universidad Nacional Autónoma de México.

Wright, L. E. (2005). Identifying immigrants to Tikal, Guatemala: Defining local variability in strontium isotope ratios of human tooth enamel. *Journal of Archaeological Science*, *32*(4), 555–566. https://doi.org/10.1016/j.jas.2004.11.011

Wright, L. E. (2012). Immigration to Tikal, Guatemala: Evidence from stable strontium and oxygen isotopes. *Journal of Anthropological Archaeology*, *31*(3), 334–352. https://doi.org/10.1016/j.jaa.2012.02.001

Wright, L. E., & Schwarcz, H. P. (1998). Stable carbon and oxygen isotopes in human tooth enamel: Identifying breastfeeding and weaning in prehistory. *American Journal of Physical Anthropology*, *106*(1), 1–18. https://doi.org/10.1002/(SICI)1096-8644(199805)106:1<1::AID-AJPA1>3.0.CO;2-W

Wright, L. E., & Schwarcz, H. P. (1999). Correspondence between stable carbon, oxygen and nitrogen isotopes in human tooth enamel and dentine: Infant diets at Kaminaljuyú. *Journal of Archaeological Science*, *26*(9), 1159–1170. https://doi.org/10.1006/jasc.1998.0351

Wrobel, G. D., Freiwald, C., Michael, A., Helmke, C., Awe, J., Kennett, D. J., Gibbs, S., Ferguson, J. M., & Griffith, C. (2017). Social identity and geographic origin of Maya burials at Actun Uayazba Kab, Roaring Creek Valley, Belize. *Journal of Anthropological Archaeology*, *45*, 98–114. https://doi.org/10.1016/j.jaa.2016.11.004

Zakrzewski, S. (2015). Religious disruption and the Islamic conquest of Andalucía. In B. J. Baker & T. Tsuda (Eds.), *Migration and disruptions: Toward a unifying theory of ancient and contemporary migrations* (pp. 52–72). University Press of Florida.

Zárate, M. A., Garcia, B., Garza, A. A., & Hitlan, R. T. (2004). Cultural threat and perceived realistic group conflict as dual predictors of prejudice. *Journal of Experimental Social Psychology*, *40*(1), 99–105. https://doi.org/10.1016/S0022-1031(03)00067-2

APPENDIX A

AUTHOR CONTRIBUTIONS

Chapter 2 of this dissertation was adapted from the article “Expanding Radiogenic Strontium Isotope Baseline Data for Central Mexican Paleomobility Studies” previously published in the journal PLoS ONE (2020). This article was coauthored by the author of this dissertation, Gwyneth W. Gordon, and Kelly J. Knudson. Both Gordon and Knudson have granted their permission for a modified version of this publication to be included in this dissertation.

APPENDIX B

CENTRAL MEXICAN BASELINE ^{87}SR/^{86}SR AND PROVENANCE DATA

Laboratory Number	Site	Material	$^{87}Sr/^{86}Sr$	UTM-E	UTM-N	Altitude (masl)	Cluster
ACL-7409-FT	Tequixquiac, Mexico State	spring water	0.70476	484002	2199133	2239	1
ACL-7409-UF	Tequixquiac, Mexico State	spring water	0.70469	484002	2199133	2239	1
ACL-7410-FT	Tequixquiac, Mexico State	spring water	0.70462	480117	2200273	2533	1
ACL-7410-UF	Tequixquiac, Mexico State	spring water	0.70458	480117	2200273	2533	1
TU-1S	Tula, Hidalgo	soil[a]	0.70500	464348	2218555	2050	1
TU-2S	Tula, Hidalgo	soil[a]	0.70501	464348	2218555	2050	1
TU-3S	Tula, Hidalgo	soil[a]	0.70469	464348	2218555	2050	1
ACL-9058	Texcotzingo, Mexico State	*Opuntia ficus*	0.70471	519433	2155797	2513	2
ACL-9059	Texcotzingo, Mexico State	*Dahlia pinnata*	0.70459	519358	2155730	2504	2
ACL-9060	Texcotzingo, Mexico State	*Agave* spp.	0.70464	519020	2155859	2534	2
ACL-7374	Xaltocan, Mexico State	*Kochia scoparia*	0.70480	495867	2178713	2239	2
ACL-7375	Xaltocan, Mexico State	*Poa* spp.	0.70479	495867	2178716	2239	2
ACL-7376	Xaltocan, Mexico State	*Poa* spp.	0.70480	495878	2178710	2239	2
ACL-7377	Xaltocan, Mexico State	*Chenopodium nuttalliae*	0.70482	495882	2178707	2239	2
ACL-7378	Xaltocan, Mexico State	*Chenopodium nuttalliae*	0.70480	495883	2178708	2239	2

ACL-7379	Xaltocan, Mexico State	*Chenopodium nuttalliae*	0.70479	495892	2178710	2239	2
ACL-7380	Xaltocan, Mexico State	*Avena sativa*	0.70477	495702	2178935	2238	2
ACL-7381	Xaltocan, Mexico State	*Helianthus* spp.	0.70479	494737	2178926	2238	2
ACL-7382	Xaltocan, Mexico State	*Avena sativa*	0.70478	494837	2178943	2239	2
ACL-7383	Xaltocan, Mexico State	*Taraxacum officinale*	0.70474	497854	2178943	2239	2
ACL-7384	Xaltocan, Mexico State	*Taraxacum officinale*	0.70475	495063	2178959	2239	2
ACL-7385	Xaltocan, Mexico State	*Hordeum vulgare*	0.70478	495346	2178978	2239	2
ACL-7386	Xaltocan, Mexico State	*Chenopodium nuttalliae*	0.70481	495347	2178979	2239	2
ACL-7387	Xaltocan, Mexico State	*Hordeum vulgare*	0.70484	495423	2178904	2239	2
ACL-7388	Xaltocan, Mexico State	*Poa* spp.	0.70484	495637	2178998	2239	2
ACL-7389	Xaltocan, Mexico State	*Jaltomata procumbens*	0.70497	495884	2178860	2239	2
ACL-7390	Xaltocan, Mexico State	*Poa* spp.	0.70488	495868	2178714	2239	2
ACL-7391	Xaltocan, Mexico State	*Poa* spp.	0.70490	495868	2178713	2239	2
ACL-7394	Xaltocan, Mexico State	*Helianthus* spp.	0.70481	495846	2178692	2238	2
ACL-7397	Xaltocan, Mexico State	*Kochia scoparia*	0.70482	495826	2178687	2238	2
ACL-7399	Xaltocan, Mexico State	*Agave* spp.	0.70471	495251	2181200	2241	2
ACL-7400	Xaltocan, Mexico State	*Opuntia ficus*	0.70490	495292	2181209	2242	2
11203 CV C2 N334 E96 11	Teotihuacan, Mexico State	*Sylvilagus* spp.[b]	0.70459	516371	2177462	2351	2
11145 CV C2 N331 E93 1k	Teotihuacan, Mexico State	*Sylvilagus* spp.[b]	0.70458	516371	2177462	2351	2
3110 CV C1 N342 E94 1a	Teotihuacan, Mexico State	*Sylvilagus* spp.[b]	0.70468	516371	2177462	2351	2

8186 CV T N333 E81 2d	Teotihuacan, Mexico State	*Sylvilagus* spp.[b]	0.70459	516371	2177462	2351	2
3294 CV C1 N338 E91 1a	Teotihuacan, Mexico State	*Sylvilagus* spp.[b]	0.70464	516371	2177462	2351	2
7531 CV NS N334 E91 1a	Teotihuacan, Mexico State	*Sylvilagus* spp.[b]	0.70471	516371	2177462	2351	2
22422 CP C5 N348 E116 1f/2a	Teotihuacan, Mexico State	*Sylvilagus* spp.[b]	0.70461	516371	2177462	2351	2
790 CB N325 E16 S	Teotihuacan, Mexico State	*Sylvilagus* spp.[b]	0.70470	516371	2177462	2351	2
706 CB N332 E31 S	Teotihuacan, Mexico State	*Sylvilagus* spp.[b]	0.70465	516371	2177462	2351	2
67145s	Teotihuacan, Mexico State	soil[a]	0.70435	516371	2177462	2351	2
67145s	Teotihuacan, Mexico State	soil[a]	0.70432	516371	2177462	2351	2
25166s	Teotihuacan, Mexico State	soil[a]	0.70438	516371	2177462	2351	2
25166s	Teotihuacan, Mexico State	soil[a]	0.70441	516371	2177462	2351	2
ACL-9046	Cuicuilco, Mexico City	*Agave* spp.	0.70507	480790	2134234	2290	3
ACL-9047	Cuicuilco, Mexico City	*Dahlia pinnata*	0.70536	480998	2134251	2288	3
ACL-9048	Cuicuilco, Mexico City	*Verbascum giganteum*	0.70502	481044	2134137	2283	3
ACL-9049	Cuicuilco, Mexico City	*Opuntia ficus*	0.70591	480991	2134066	2286	3
ACL-9050	Tezozomoc, Mexico City	*Schinus molle*	0.70520	477880	2156155	2251	3

ACL-9051	Tezozomoc, Mexico City	*Agave* spp.	0.70618	478014	2156268	2251	3
ACL-9052	Naucalli, Mexico State	*Yucca filifera*	0.70497	474873	2155369	2264	3
ACL-9053	Naucalli, Mexico State	*Opuntia ficus*	0.70503	475008	2155777	2264	3
ACL-9054	Naucalli, Mexico State	*Agave* spp.	0.70469	474863	2155595	2264	3
ACL-9055	Cerro Moctezuma, Mexico State	*Arctostaphylos* spp.	0.70455	473040	2154358	2385	3
ACL-9056	Cerro Moctezuma, Mexico State	*Agave* spp.	0.70489	472950	2154408	2397	3
ACL-9057	Cerro Moctezuma, Mexico State	*Dahlia pinnata*	0.70471	473033	2154438	2382	3
ACL-9061	Tlatelolco, Mexico City	*Poa* spp.	0.70484	485501	2150723	2231	3
ACL-9062	Tlatelolco, Mexico City	*Yucca filifera*	0.70483	485523	2150718	2231	3
ACL-9063	Tlatelolco, Mexico City	*Opuntia ficus*	0.70496	485597	2150719	2233	3
ACL-9064	Tlatelolco, Mexico City	*Agave* spp.	0.70514	485543	2150786	2233	3
ACL-9069	San Pedro Atocpan, Mexico City	*Opuntia ficus*	0.70486	494693	2122995	2239	3
ACL-9070	San Pedro Atocpan, Mexico City	*Poa* spp.	0.70481	494693	2122995	2239	3
ACL-9071	San Pedro Atocpan, Mexico City	*Amaranthus hybridus*	0.70452	494693	2122995	2239	3
ACL-9072	Santiago Tulyehualco, Mexico City	*Pinus* spp.	0.70466	498319	2128955	2252	3
ACL-9073	Santiago Tulyehualco, Mexico City	*Agave* spp.	0.70455	498319	2128955	2252	3
ACL-9074	Santiago Tulyehualco, Mexico City	*Agave* spp.	0.70462	498319	2128955	2252	3

ACL-9075	Cholula, Puebla	*Dorotheanthus* spp.	0.70543	573378	2107043	2148	4
ACL-9076	Cholula, Puebla	*Opuntia ficus*	0.70598	573421	2107130	2150	4
ACL-9077	Cholula, Puebla	*Chenopodium nuttalliae*	0.70575	573314	2107191	2154	4
ACL-9078	Cholula, Puebla	*Agave* spp.	0.70602	573258	2107461	2157	4
ACL-9079	Cacaxtla, Tlaxcala	*Dahlia pinnata*	0.70500	569529	2127993	2298	4
ACL-9080	Cacaxtla, Tlaxcala	*Agave* spp.	0.70553	569461	2128024	2302	4
ACL-9081	Cacaxtla, Tlaxcala	*Quercus* spp.	0.70525	569280	2128072	2305	4
ACL-9082	Cacaxtla, Tlaxcala	*Agave* spp.	0.70541	569395	2127878	2309	4
ACL-9065	Xochicalco, Morelos	*Agave* spp.	0.70641	468747	2079174	1349	5
ACL-9066	Xochicalco, Morelos	*Enterolobium cyclocarpum*	0.70521	468921	2079148	1329	5
ACL-9067	Xochicalco, Morelos	*Agave* spp.	0.70600	468629	2079292	1348	5
ACL-9068	Xochicalco, Morelos	*Agave* spp.	0.70539	468872	2079236	1340	5

[a] Data published in Schaaf et al. (2012)

[b] Data published in Price et al. (2000)

APPENDIX C

BIOGEOCHEMICAL ^{87}SR/^{86}SR AND δ^{18}O DATA FROM NON-GRID 4

Laboratory Number	Individual	Sex[a]	Age[b]	Element	Ca/P	U/Ca	Nd/Ca	$\delta^{18}O_{carbonate}$ (VPDB)	$^{87}Sr/^{86}Sr$
ACL-7969	XAL-C1-1	M	Adult	LRM1	1.99	2.39E-07	5.05E-07	-6.6	0.70564
ACL-7970	XAL-C1-1	M	Adult	URM3	1.97	1.71E-07	5.49E-07	-6.1	0.70558
ACL-7971	XAL-C1-1	M	Adult	L sphenoid	2.23	9.04E-06	7.54E-07	-5.3	0.70478
ACL-7972	XAL-C1-2	M	Adult	LLM1	1.96	1.21E-07	3.67E-07	-5.9	0.70608
ACL-7973	XAL-C1-2	M	Adult	LLM3	1.98	3.68E-07	2.15E-07	-6.3	0.70555
ACL-7974	XAL-C1-2	M	Adult	occipital	2.29	3.31E-05	3.78E-07	-7.4	0.70483
ACL-7975	XAL-C1-4	M	Adult	LLM1	1.98	2.73E-07	3.46E-07	-6.1	0.70466
ACL-7976	XAL-C1-4	M	Adult	URM3	1.96	1.46E-07	1.49E-07	-7.2	0.70596
ACL-7977	XAL-C1-4	M	Adult	L mandible	2.30	3.13E-05	2.27E-07	-8.0	0.70471
ACL-7978	XAL-C2-1	M	Adult	ULM1	1.96	2.12E-07	2.19E-07	-6.2	0.70555
ACL-7979	XAL-C2-1	M	Adult	ULM3	1.99	3.34E-07	1.71E-07	-7.1	0.70541
ACL-7980	XAL-C2-2	M	Adult	LRM1	1.95	1.42E-07	1.38E-07	-6.1	0.70451
ACL-7981	XAL-C2-2	M	Adult	URM3	2.00	1.07E-07	1.30E-07	-7.1	0.70525
ACL-7982	XAL-C2-2	M	Adult	sphenoid	2.27	8.80E-06	3.43E-07	-7.0	0.70477
ACL-7983	XAL-C2-3	M	Adult	LRM1	1.98	2.37E-07	1.24E-07	-5.9	0.70530
ACL-7984	XAL-C2-3	M	Adult	LRM3	1.98	7.33E-08	1.41E-07	-7.3	0.70530
ACL-7985	XAL-C3-3	M	Adult	ULM1	1.96	3.22E-08	1.79E-07	-6.2	0.70387
ACL-7986	XAL-C3-3	M	Adult	ULM3	1.95	3.43E-07	6.18E-07	-6.5	0.70448
ACL-7987	XAL-C4-1	M	Adol.	LLM1	1.96	1.48E-07	2.10E-07	-7.5	0.70602
ACL-7988	XAL-C4-1	M	Adol.	LLM3	1.97	7.53E-08	2.11E-07	-7.0	0.70584
ACL-7989	XAL-C4-1	M	Adol.	L temporal	2.29	3.41E-05	2.17E-06	-7.4	0.70481
ACL-7990	XAL-C4-2	M	Adult	LLM1	1.98	3.40E-07	4.48E-07	-6.1	0.70525
ACL-7991	XAL-C4-2	M	Adult	LLM3	1.99	1.97E-07	9.25E-08	-8.6	0.70530
ACL-7992	XAL-C4-2	M	Adult	L mandible	2.26	2.57E-05	6.92E-07	-8.4	0.70479
ACL-7993	XAL-C4-4	M	Adult	LRM1	1.97	1.89E-07	5.95E-07	-5.5	0.70719

ACL-7994	XAL-C4-4	M	Adult	LRM3	1.97	1.63E-07	6.37E-07	-6.4	0.70703
ACL-7995	XAL-C4-4	M	Adult	R temporal	2.29	6.97E-05	2.81E-07	-11.3	0.70499
ACL-7996	XAL-C5-2	M	Adult	URM1	1.98	6.74E-08	1.36E-07	-5.3	0.70598
ACL-7997	XAL-C5-2	M	Adult	ULM3	1.97	1.36E-07	1.25E-07	-5.2	0.70540
ACL-7998	XAL-C5-2	M	Adult	R mandible	2.23	8.82E-06	1.91E-07	-6.3	0.70485
ACL-7999	XAL-C5-3	M	Adult	LRM1	1.96	9.20E-08	1.01E-07	-5.8	0.70472
ACL-8000	XAL-C5-3	M	Adult	ULM3	1.97	1.14E-07	1.28E-07	-5.8	0.70477
ACL-8001	XAL-C8-2	M	Adult	ULM1	1.96	1.76E-07	4.50E-07	-6.1	0.70475
ACL-8002	XAL-C8-2	M	Adult	LLM3	1.99	1.92E-07	4.29E-07	-6.3	0.70464
ACL-8003	XAL-C8-2	M	Adult	L temporal	2.26	2.69E-05	5.86E-07	-4.5	0.70468
ACL-8004	XAL-C8-3	M	Adult	ULM1	1.97	6.61E-08	1.11E-07	-6.7	0.70602
ACL-8005	XAL-C8-3	M	Adult	URM3	1.95	4.22E-08	1.22E-07	-6.5	0.70603
ACL-8006	XAL-C9-1	F	Adult	LLM1	1.96	7.02E-08	1.18E-07	-6.6	0.70416
ACL-8007	XAL-C9-1	F	Adult	ULM3	1.97	6.98E-08	1.69E-07	-7.3	0.70408
ACL-8008	XAL-C9-1	F	Adult	R parietal	2.23	1.30E-05	6.66E-07	-6.5	0.70472
ACL-8009	XAL-C9-3	Ind.	Adol.	URM1	1.98	2.68E-07	6.46E-07	-6.0	0.70471
ACL-8010	XAL-C9-3	Ind.	Adol.	URM3	1.97	1.23E-07	1.69E-07	-5.5	0.70484
ACL-8011	XAL-C9-3	Ind.	Adol.	R maxilla	2.25	2.37E-05	3.07E-07	-4.9	0.70477
ACL-8012	XAL-C9-4	M	Adult	LRM1	1.95	1.11E-07	3.30E-07	-5.7	0.70469
ACL-8013	XAL-C9-4	M	Adult	LRM3	1.95	7.69E-08	3.94E-07	-8.0	0.70464
ACL-8014	XAL-C9-4	M	Adult	R zygomatic	2.25	2.00E-05	4.94E-07	-7.5	0.70473
ACL-8015	XAL-C10-4	M	Adult	URM1	1.99	5.20E-07	7.37E-07	-5.5	0.70451
ACL-8016	XAL-C10-4	M	Adult	URM3	1.98	5.74E-07	9.42E-07	-6.5	0.70428
ACL-8017	XAL-C12-2	M	Adult	URM1	2.04	1.73E-07	4.22E-07	-5.0	0.70443
ACL-8018	XAL-C12-2	M	Adult	URM3	2.04	1.56E-07	4.30E-07	-5.9	0.70423
ACL-8019	XAL-C12-2	M	Adult	R temporal	2.33	2.62E-05	1.10E-07	-5.7	0.70472
ACL-8020	XAL-C13-1	M	Adult	LRM1	1.98	1.16E-07	4.76E-08	-4.4	0.70507

ACL-8021	XAL-C13-1	M	Adult	LRM3	1.98	7.47E-08	4.04E-08	-5.4	0.70493
ACL-8022	XAL-C13-1	M	Adult	R sphenoid	2.20	2.92E-05	2.75E-07	-3.9	0.70477
ACL-8023	XAL-C13-3	M	Adult	LRM1	1.96	1.44E-07	4.23E-08	-5.8	0.70465
ACL-8024	XAL-C13-3	M	Adult	URM3	1.96	1.45E-07	4.84E-08	-7.0	0.70476
ACL-8025	XAL-C13-4	M	Adult	URM1	1.96	2.78E-07	9.85E-08	-6.2	0.70537
ACL-8026	XAL-C13-4	M	Adult	ULM3	1.97	6.78E-08	5.58E-08	-7.0	0.70499
ACL-8027	XAL-C13-4	M	Adult	occipital	2.24	1.60E-05	4.15E-07	-7.0	0.70475
ACL-8028	XAL-C14-1	Ind.	Adult	LRM1	1.95	4.16E-07	7.58E-08	-5.9	0.70451
ACL-8029	XAL-C14-1	Ind.	Adult	LRM3	1.96	2.15E-07	9.64E-08	-6.6	0.70561
ACL-8030	XAL-C14-5	M	Adult	URM1	1.96	3.38E-07	2.64E-07	-6.9	0.70432
ACL-8031	XAL-C14-5	M	Adult	URM3	1.96	2.73E-07	1.45E-07	-8.4	0.70434
ACL-8032	XAL-C15-3	M	Adult	LRM1	1.97	1.65E-07	6.33E-08	-5.3	0.70448
ACL-8033	XAL-C15-3	M	Adult	LRM3	1.94	1.58E-07	7.43E-08	-5.4	0.70471
ACL-8034	XAL-C15-3	M	Adult	occipital	2.23	1.35E-05	5.06E-07	-7.0	0.70476
ACL-8035	XAL-C15-4	M	Adol.	URM1	1.97	4.93E-07	1.21E-07	-6.3	0.70454
ACL-8036	XAL-C15-4	M	Adol.	URM3	1.97	1.45E-07	5.03E-08	-5.3	0.70466
ACL-8037	XAL-C15-6	M	Adult	ULM1	1.99	1.69E-07	5.00E-08	-5.7	0.70463
ACL-8038	XAL-C15-6	M	Adult	ULM3	1.96	8.69E-08	4.24E-08	-6.7	0.70503
ACL-8039	XAL-C16-1	M	Adult	LLM1	1.98	1.09E-07	1.95E-07	-6.8	0.70463
ACL-8040	XAL-C16-1	M	Adult	LLM3	1.98	2.03E-07	4.95E-07	-7.5	0.70453
ACL-8041	XAL-C16-2	M	Adult	URM1	1.97	2.33E-07	1.60E-07	-6.0	0.70552
ACL-8042	XAL-C16-2	M	Adult	URM3	1.97	8.60E-08	5.17E-08	-6.2	0.70591
ACL-8043	XAL-C16-3	M	Adult	LRM1	1.98	2.25E-07	1.65E-07	-6.1	0.70473
ACL-8044	XAL-C16-3	M	Adult	ULM3	1.96	1.94E-07	2.89E-07	-6.9	0.70473
ACL-8045	XAL-C16-4	F	Adult	LRM1	1.99	1.33E-07	4.05E-08	-6.7	0.70550
ACL-8046	XAL-C16-4	F	Adult	URM3	2.06	1.55E-07	4.50E-08	-7.7	0.70552
ACL-8047	XAL-C16-5	M	Adol.	URM1	2.05	8.26E-08	3.60E-08	-6.2	0.70550

ACL-8048	XAL-C16-5	M	Adol.	URM3	2.03	7.54E-08	4.30E-08	-7.4	0.70559
ACL-8049	XAL-C16-5	M	Adol.	R sphenoid	2.21	1.25E-05	1.70E-07	-6.0	0.70480
ACL-8050	XAL-C17-1	Ind.	Adol.	LLM1	1.96	6.07E-08	4.30E-08	-6.5	0.70591
ACL-8051	XAL-C17-1	Ind.	Adol.	LLM3	1.98	1.17E-07	4.30E-08	-6.6	0.70575
ACL-8052	XAL-C17-1	Ind.	Adol.	occipital	2.21	3.01E-05	3.95E-07	-0.4	0.70483
ACL-8053	XAL-C17-4	M	Adult	LRM1	1.97	1.74E-07	2.31E-08	-5.2	0.70472
ACL-8054	XAL-C17-4	M	Adult	ULM3	1.95	1.44E-07	2.24E-08	-5.1	0.70459
ACL-8055	XAL-C17-5	F	Adol.	ULM1	1.96	1.95E-07	5.13E-08	-3.2	0.70595
ACL-8056	XAL-C17-5	F	Adol.	ULM3	1.96	1.37E-07	3.72E-08	-3.6	0.70698
ACL-8057	XAL-C17-5	F	Adol.	R zygomatic	2.26	3.42E-05	1.14E-06	-5.0	0.70478
ACL-8058	XAL-C17-6	M	Adol.	LLM1	1.95	9.84E-08	3.82E-08	-5.9	0.70463
ACL-8059	XAL-C17-6	M	Adol.	LLM3	1.96	7.49E-08	3.16E-08	-6.7	0.70452
ACL-8060	XAL-C17-6	M	Adol.	L mandible	2.25	4.03E-05	1.61E-07	-5.8	0.70468
ACL-8061	XAL-C18-1	M	Adol.	URM1	1.99	2.11E-07	1.02E-07	-6.7	0.70402
ACL-8062	XAL-C18-1	M	Adol.	URM3	1.98	9.50E-08	6.22E-08	-7.8	0.70419
ACL-8063	XAL-C18-1	M	Adol.	L frontal	2.15	2.07E-05	1.78E-07	-6.8	0.70465
ACL-8064	XAL-C18-3	M	Adult	URM1	1.96	1.61E-07	7.38E-08	-5.9	0.70579
ACL-8065	XAL-C18-3	M	Adult	URM3	1.95	5.91E-08	3.67E-08	-5.8	0.70525
ACL-8066	XAL-C18-3	M	Adult	R maxilla	2.19	1.54E-05	7.13E-07	-4.0	0.70476
ACL-8067	XAL-C19-1	M	Adult	URM1	1.94	1.24E-07	6.79E-08	-5.0	0.70478
ACL-8068	XAL-C19-1	M	Adult	ULM3	1.96	2.09E-07	5.85E-07	-7.0	0.70457
ACL-8069	XAL-C19-1	M	Adult	R occipital	2.17	4.32E-05	2.99E-07	-5.8	0.70476
ACL-8070	XAL-C19-6	M	Adult	URM1	1.97	1.13E-07	1.27E-07	-5.8	0.70539
ACL-8071	XAL-C19-6	M	Adult	ULM3	1.96	1.42E-07	4.06E-07	-7.1	0.70564
ACL-8072	XAL-C21-3	M	Adult	URM1	1.97	3.26E-07	2.03E-07	-4.9	0.70448
ACL-8073	XAL-C21-3	M	Adult	ULM3	1.95	9.36E-08	1.56E-07	-6.9	0.70475
ACL-8074	XAL-C22-1	M	Adult	URM1	1.96	2.97E-07	4.96E-07	-6.4	0.70605

ACL-8075	XAL-C22-1	M	Adult	URM3	1.96	9.90E-08	9.52E-08	-6.8	0.70636
ACL-8076	XAL-C22-3	M	Adult	ULM1	1.97	1.06E-06	3.41E-07	-5.5	0.70459
ACL-8077	XAL-C22-3	M	Adult	LRM3	1.96	8.25E-08	1.38E-07	-5.3	0.70445
ACL-8078	XAL-C22-4	M	Adult	LRM1	1.97	4.92E-07	1.01E-07	-6.6	0.70519
ACL-8079	XAL-C22-4	M	Adult	LRM3	1.97	1.18E-07	1.07E-07	-7.9	0.70529
ACL-8080	XAL-C22-4	M	Adult	R zygomatic	2.27	4.01E-05	1.53E-07	-5.5	0.70477
ACL-8081	XAL-C23-2	M	Adult	LRM1	1.96	2.03E-07	1.83E-07	-5.6	0.70539
ACL-8082	XAL-C23-2	M	Adult	LRM3	1.97	3.49E-07	1.01E-07	-6.9	0.70525
ACL-8083	XAL-C23-2	M	Adult	R mandible	2.26	3.39E-05	6.59E-08	-6.3	0.70476
ACL-8084	XAL-C23-5	M	Adult	ULM1	1.96	1.70E-07	5.15E-07	-5.6	0.70450
ACL-8085	XAL-C23-5	M	Adult	URM3	1.96	4.99E-08	4.85E-08	-6.9	0.70448
ACL-8086	XAL-C24-2	M	Adult	URM1	1.97	1.21E-06	2.28E-07	-5.0	0.70546
ACL-8087	XAL-C24-2	M	Adult	URM3	1.96	7.97E-08	2.09E-07	-6.7	0.70573
ACL-8088	XAL-C24-4	F	Adol.	LLM1	1.97	6.35E-07	2.91E-07	-7.2	0.70546
ACL-8089	XAL-C24-4	F	Adol.	ULM3	2.05	6.88E-06	3.02E-07	-7.0	0.70486
ACL-8090	XAL-C24-4	F	Adol.	R zygomatic	2.18	4.04E-05	1.59E-07	-5.1	0.70476
ACL-8091	XAL-C24-5	M	Adol.	ULM1	1.95	5.32E-08	5.19E-08	-6.0	0.70531
ACL-8092	XAL-C24-5	M	Adol.	ULM3	1.97	6.20E-08	5.48E-08	-6.1	0.70523
ACL-8093	XAL-C24-5	M	Adol.	L sphenoid	2.25	2.24E-05	7.56E-07	-3.7	0.70481
ACL-8094	XAL-C24-6	M	Adult	ULM1	1.97	6.01E-07	5.46E-07	-7.2	0.70632
ACL-8095	XAL-C24-6	M	Adult	ULM3	1.96	1.55E-07	1.05E-07	-6.9	0.70738
ACL-8096	XAL-C25-2	M	Adult	LRM1	1.96	1.98E-07	1.29E-07	-4.5	0.70464
ACL-8097	XAL-C25-2	M	Adult	URM3	1.96	1.83E-07	1.93E-07	-5.7	0.70472
ACL-8098	XAL-C25-3	Ind.	Adol.	ULM1	1.96	3.29E-07	2.33E-07	-6.2	0.70482
ACL-8099	XAL-C25-3	Ind.	Adol.	ULM3	1.95	9.33E-08	4.01E-08	-6.3	0.70493
ACL-8100	XAL-C25-3	Ind.	Adol.	L sphenoid	2.21	2.02E-05	4.22E-07	-6.0	0.70477
ACL-8101	XAL-C25-4	M	Adult	URM1	1.96	2.71E-07	2.80E-07	-5.9	0.70473

ACL-8102	XAL-C25-4	M	Adult	ULM3	1.96	2.42E-07	1.15E-07	-6.5	0.70462
ACL-8103	XAL-C25-4	M	Adult	R & L parietal	2.07	2.57E-05	3.03E-07	-5.9	0.70473
ACL-8104	XAL-C25-5	M	Adult	URM1	1.96	1.46E-06	4.26E-07	-4.0	0.70483
ACL-8105	XAL-C25-5	M	Adult	ULM3	1.97	6.99E-07	1.28E-07	-4.2	0.70491
ACL-8106	XAL-C25-5	M	Adult	R maxilla	2.24	4.00E-05	1.58E-07	-5.3	0.70477
ACL-8107	XAL-C26-1	M	Adult	URM1	1.96	2.92E-07	1.48E-07	-6.9	0.70438
ACL-8108	XAL-C26-1	M	Adult	ULM3	1.97	1.32E-07	2.08E-07	-5.8	0.70446
ACL-8109	XAL-C26-3	M	Adult	URM1	1.97	2.84E-07	7.63E-07	-6.1	0.70438
ACL-8110	XAL-C26-3	M	Adult	LRM3	1.97	6.51E-08	7.92E-08	-5.7	0.70432
ACL-8111	XAL-C26-3	M	Adult	R zygomatic	1.97	9.78E-06	NA	-6.4	0.70468
ACL-8112	XAL-C26-4	M	Adult	ULM1	1.96	2.00E-07	1.99E-07	-7.1	0.70447
ACL-8113	XAL-C26-4	M	Adult	ULM3	1.96	2.41E-07	2.65E-07	-6.8	0.70439
ACL-8114	XAL-C26-4	M	Adult	L zygomatic	2.29	6.20E-05	6.31E-07	-5.6	0.70472
ACL-8115	XAL-C27-2	M	Adol.	LLM1	1.97	1.04E-07	8.30E-08	-6.0	0.70494
ACL-8116	XAL-C27-2	M	Adol.	URM3	1.97	1.44E-07	5.80E-08	-6.8	0.70460
ACL-8117	XAL-C27-2	M	Adol.	R parietal	2.19	3.62E-05	2.09E-07	-6.6	0.70472
ACL-8118	XAL-C27-4	M	Adult	URM1	1.96	1.32E-07	4.82E-07	-6.3	0.70443
ACL-8119	XAL-C27-4	M	Adult	LRM3	1.99	4.79E-07	4.64E-07	-6.8	0.70451
ACL-8120	XAL-C27-4	M	Adult	L mandible	2.25	2.37E-05	1.17E-07	-5.7	0.70472
ACL-8121	XAL-C27-5	M	Adult	ULM1	1.95	1.91E-07	4.10E-07	-4.9	0.70481
ACL-8122	XAL-C27-5	M	Adult	URM3	1.97	1.74E-07	5.49E-07	-7.8	0.70464
ACL-8123	XAL-C27-5	M	Adult	L parietal	2.19	3.30E-05	7.92E-08	-5.8	0.70474
ACL-8124	XAL-C28-2	M	Adol.	URM1	1.98	1.71E-07	1.16E-07	-4.9	0.70595
ACL-8125	XAL-C28-2	M	Adol.	ULM3	2.07	7.00E-06	1.76E-06	-4.8	0.70510
ACL-8126	XAL-C28-2	M	Adol.	R parietal	2.20	3.35E-05	2.09E-07	-5.2	0.70489
ACL-8127	XAL-C28-3	M	Adult	LRM1	1.97	1.10E-07	1.21E-07	-4.1	0.70599
ACL-8128	XAL-C28-3	M	Adult	LLM3	1.99	4.95E-07	1.59E-06	-6.3	0.70627

ACL-8129	XAL-C28-3	M	Adult	L zygomatic	2.22	3.68E-05	2.80E-07	-4.8	0.70482
ACL-8130	XAL-C28-4	M	Adult	URM1	1.97	2.24E-07	5.84E-07	-5.7	0.70459
ACL-8131	XAL-C28-4	M	Adult	URM3	1.96	4.76E-07	5.97E-07	-6.4	0.70459
ACL-8132	XAL-C28-4	M	Adult	L zygomatic	2.21	2.37E-05	8.39E-07	-5.3	0.70475
ACL-8133	XAL-C29-1	F	Adol.	LRM1	1.95	6.53E-08	3.87E-08	-5.2	0.70632
ACL-8134	XAL-C29-1	F	Adol.	LRM3	1.97	2.05E-07	8.24E-08	-6.6	0.70522
ACL-8135	XAL-C29-1	F	Adol.	R mandible	2.22	1.25E-05	2.51E-07	-5.7	0.70485
ACL-8136	XAL-C29-3	M	Adult	LRM1	1.96	5.85E-07	2.74E-07	-4.9	0.70462
ACL-8137	XAL-C29-3	M	Adult	LRM3	1.97	1.42E-06	1.65E-06	-7.2	0.70464
ACL-8138	XAL-C29-3	M	Adult	L parietal	2.21	1.85E-05	1.02E-06	-6.6	0.70474
ACL-8139	XAL-C30-2	M	Adult	ULM1	1.96	6.58E-08	7.19E-08	-6.2	0.70620
ACL-8140	XAL-C30-2	M	Adult	ULM3	1.96	3.28E-07	6.66E-07	-7.1	0.70454
ACL-8141	XAL-C30-2	M	Adult	R occipital	2.29	5.29E-06	2.22E-07	-3.8	0.70482
ACL-8142	XAL-C30-5	M	Adult	LLM1	1.96	3.65E-07	7.16E-07	-4.9	0.70494
ACL-8143	XAL-C30-5	M	Adult	LLM3	1.98	7.19E-07	2.49E-07	-5.0	0.70484
ACL-8144	XAL-C30-5	M	Adult	R parietal	2.26	1.24E-05	1.49E-07	-5.5	0.70476
ACL-8145	XAL-C31-1	F	Adol.	URM1	1.97	2.46E-07	5.50E-07	-4.8	0.70526
ACL-8146	XAL-C31-1	F	Adol.	URM3	1.95	1.82E-07	7.08E-07	-5.4	0.70556
ACL-8147	XAL-C31-1	F	Adol.	R frontal	2.23	2.11E-05	1.29E-07	-4.5	0.70479
ACL-8148	XAL-C32-4	M	Adult	LLM1	1.97	1.49E-07	5.31E-08	-6.1	0.70452
ACL-8149	XAL-C32-4	M	Adult	ULM3	1.94	5.54E-08	6.04E-08	-6.1	0.70432
ACL-8150	XAL-C32-4	M	Adult	R occipital	2.23	3.17E-05	6.86E-07	-5.8	0.70471
ACL-8151	XAL-C32-5	M	Adult	URM1	1.94	1.93E-07	5.63E-07	-4.9	0.70622
ACL-8152	XAL-C32-5	M	Adult	LRM3	1.95	3.56E-07	4.34E-07	-6.7	0.70617
ACL-8153	XAL-C32-5	M	Adult	R parietal	2.16	2.73E-05	1.93E-07	-7.2	0.70485
ACL-8154	XAL-C34-1	M	Adult	URM1	1.98	1.19E-06	5.25E-07	-5.0	0.70465
ACL-8155	XAL-C34-1	M	Adult	URM3	1.98	3.57E-07	2.58E-07	-6.2	0.70453

ACL-8156	XAL-C34-1	M	Adult	L frontal	2.20	2.01E-05	2.62E-07	-6.4	0.70472
ACL-8157	XAL-C34-2	M	Adult	LLM1	1.94	2.09E-07	8.24E-08	-6.4	0.70455
ACL-8158	XAL-C34-2	M	Adult	LRM3	2.04	6.73E-06	1.38E-07	-4.2	0.70474
ACL-8159	XAL-C34-2	M	Adult	R parietal	2.19	2.46E-05	9.23E-08	-5.7	0.70476
ACL-8160	XAL-C34-3	M	Adult	LRM1	1.96	5.26E-07	3.26E-07	-5.6	0.70450
ACL-8161	XAL-C34-3	M	Adult	LLM3	1.95	3.14E-07	1.22E-07	-6.6	0.70448
ACL-8162	XAL-C34-3	M	Adult	R parietal	2.23	2.79E-05	1.53E-07	-6.2	0.70472

[a] Sex estimates based on cranial morphology following Buikstra and Ubelaker (1994). M = male; F = female; Ind = Indeterminate

[b] Age estimates based on dental eruption following Buikstra and Ubelaker (1994). Adol = Adolescent