Local Practice Between Empires:

The Bioarchaeology of El Japón (San Gregorio Atlapulco, Mexico), 1550–1650 CE

by

Edgar Alarcón Tinajero

(Under the Direction of Laurie J. Reitsema)

ABSTRACT

This study explores human skeletal patterns rooted in genetic, dietary, and physical activity patterns within a El Japón, an archaeological site on the southern edge of Mexico City. The site was previously inferred to date to the late Postclassic period (1200–1521 CE) based on material remains, especially postclassic ceramics and near absence of colonial ones. Radiocarbon dating and statistical modeling in this research narrow the estimate of El Japón cemetery use to a 90-year period after European contact in the Basin of Mexico, 1550–1640 CE. Dating and modeling facilitate comparison of El Japón's occupation with the prevalent historical narratives that indicate near complete population relocation of Indigenous communities to larger settlements termed *reducciones* or *congregaciones*. Modeling of the radiocarbon results permits discussion of the cemetery sample as a diachronic one to hypothesize and test transformations in lifeways concomitant with Spanish colonization. Interpopulation comparison of dental nonmetric traits permit characterization of the individuals as genetically linked to other local Indigenous populations both predating and postdating European colonization. Radiocarbon and biodistance analysis identify El Japón as a postcontact Indigenous community in a period where an ethnic identity had implications for political stature. These two analyses also contextualize subsequent investigation of subsistence and dietary patterns at El Japón.

Cross-sectional properties are employed as proxies of life-long physical activity patterns, and these separate El Japón adults from comparative agricultural and urban European communities of the late Medieval (1250–1500 CE) and early modern periods (1500–1800 CE). Only minor diachronic change took place at El Japón over several decades. Stable isotopic data from bone collagen and bioapatite in El Japón individuals are consistent with precontact populations that relied on local crops and animal protein sources. Continuity in the methods and technologies of agricultural labor and consumption of its products build an image of a small community that persisted in long-rooted lifeways despite the bouts of political and economic change, epidemic health stress, and demographic decline throughout post-Columbian North America.

INDEX WORDS: bioarchaeology, Spanish colonialism, *congregación*, agriculture, stable isotope analysis, cross-sectional geometry, radiocarbon, biodistance

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Chapter 1. Introduction

This dissertation addresses what happens when hierarchically structured societies meet. Novel encounters between stratified complex societies has occurred innumerable times in human history, but the collision of the American and European worlds beginning in the late 15th century was potentially unique in the size of human populations newly interacting or with new growing knowledge of each other. The meeting of the American and European worlds (and their constellations of ideas, genes, foods, microbes) had lasting effects for worldwide history beyond the physical limits of these two regions. Incorporation of individuals into new societies or the gradual amalgamation of previously uncontacted populations is one possible outcome. The centuries after sustained European presence in southern North America (Mesoamerica) are often celebrated as the development of Mestizo population identities (Castillo Ramírez 2014, Wade 2007) based on the idea that most living people in modern Mexico have mixed European and Indigenous — and sometimes also African — ancestries.

Mestizo in this sense encompasses the sustained pattern of intermarriage between ethnic groups and concomitant cultural exchange. The last century of archaeology in Mexico was influenced by Mestizo identities and narratives with the frequent goals to aggrandize the accomplishments of bygone prehispanic cultures and to demonstrate the origins of a Mestizo national identity (Robles García 2012) with direct service to the state (Castillo Ramírez 2014). In that paradigm, archaeology and history were tools of not only scientific research but also tools of statecraft (Castillo Ramírez 2014). This paradigm of past indigenous grandeur, social evolution, and national patrimony informed decades of archaeological and cultural anthropological research in Mesoamerica for decades (García Macías 2007).

More recent genetic and historical research, however, elicit a slow process of mestizaje (Swann 1979; Pescador 1992) that varied by region (Silva-Zolezzi et al. 2009). Colonial period mestizaje as a cultural process has been typically presumed based on the modern results of a majority Mestizo identification of large majorities of the Mexican national population. A more contextualized analysis of mestizaje can be explored using evidence from human skeletons in archaeological contexts. The human skeleton is plastic and records experiences with its environment including diet, nutrition, disease, and activity patterns (Larsen 2015). These experiences impact growth and maintenance of the skeleton in ways that can be interpreted alongside contextual archaeological and historical information as indicators of human relationships with each other and the environment. Bioarchaeology, the study of human skeletons from archaeological contexts, offers an opportunity to evaluate the creation and significance of mestizo identities in the earliest generations after known contact between Mesoamerican societies and Spanish colonizers.

In addition to varied processes of mestizaje, archaeology, paleodemography, and historic records demonstrate long demographic decline of Indigenous North American populations in the two centuries following initial European contact (Gibson 1964; Prem 1992; Newson 1993; Storey 2012). Based on current scholarship, Spanish colonialism resulted in immense loss of human life contributing to political disintegration and population decline (Gibson 1964; Larsen 1994; Klaus and Tam 2009; Warinner 2012) and at times resulting in discontinuity with pre-contact economies and subsistence practices (Larsen 1994; Leigh et al. 2013). Relocation of settlements either by force or under pressure, by civil and religious Spanish authorities first (Cline 1949; de la Torre

Villar 1995) are among the first direct effects on population health and lifestyles. It is unpolemical to say the Spanish empire and its constituent institutions restructured settlements. Known population decline, however, may have played out in various ways depending on the size and type of community examined. This research examines a single rural settlement, El Japón, in that context of demographic spatial restructuring and Spanish colonization. The Indigenous language name (very likely Náhuatl) of the site has not been ascertained and the community that inhabited El Japón is referred by the archaeological site name throughout this study.

This dissertation focuses on a narrow chronological sample to question and quantify how Spanish contact affected Indigenous lives (specifically subsistence practices and diet) and tests whether the presumed process of mestizaje occurred. The constituent studies of this dissertation were proposed considering the settlement patterns and hierarchy described by regional archaeological survey (Sanders et al. 1979) and by the documentary evidence of the precontact and early colonial eras (McAfee and Barlow 1952; Pérez Zevallos and Reyes García 2003). Both bodies of data identify hierarchical organization of settlements whose leadership had relatively more and relatively less political influence. The city of Xochimilco for example is often identified as the head of the polity that includes several smaller settlements in its hinterland which includes El Japón archaeological site. The town of San Gregorio Atlapulco received various smaller hamlets that aggregated or congregated (cf., *congregación*¸ Pérez Zevallos and Reyes García 2003) potentially grouping individuals from a microregion with preexisting ancestral and kin connections.

Two Indigenous written documents from the Xochimilco area – *Los Anales de San Gregorio Atlapulco* and *La Fundación de San Luís Tlaxialtemalco* – document the aggregation into larger settlements in addition to demonstrating how Indigenous communities used the budding colonial legal system to reiterate their rights to land (Pérez Zevallos and Reyes García 2003; Inoue 2007). *Los Anales de San Gregorio Atlapulco* are a retrospective history written by Indigenous people of San Gregorio in 1603. Though the names of the authors are unknown, the *tlacuilos* of San Gregorio Atlapulco might be credited: these occupied civil roles similar to notaries (Gibson 1964; Lockhart 1992).

Demographic decline in the Valley of Mexico together with demanding taxation strained geographically adapted *chinampa* agricultural systems that for centuries relied on communal labor to facilitate agriculture in the marshland environment (Rojas Rabiela 1977, 1991). Colonial documents from central Mesoamerica attest to the raising and planting of European livestock and crops alongside native ones (Zamudio Espinosa 2001; Jalpa Flores 2008). European-introduced foods seemingly made their way into central Mesoamerica as part of what has been historically termed the post-Columbian exchange (e.g., Crosby 1972; Price et al. 2012). Ownership or propagation of these newly introduced food sources was predominantly within the means of wealthier households, both Spanish and Indigenous (Jalpa Flores 2008). The extent to which Indigenous people, especially of the rural commoner class (*macehual*) consumed these newly introduced foods though is not adequately quantified or addressed.

Given the above, a reevaluation of the impacts of Spanish colonialism in the Basin of Mexico is warranted, as the impacts likely varied with preexisting social categories, political allegiances, and economic roles. Examining the historical record of the colonial Valley of Mexico, such as *Los Anales San Gregorio Atlapulco* (McAfee et al.1952) or *La Fundación de San Luís Tlaxialtemalco* (Pérez Zevallos and Reyes García 2003), it is apparent that multiple agricultural towns in the southern Valley Mexico secured legal recognition of sovereignty within decades of European colonization due to situationally favorable allegiances with Spanish newcomers. Early native allies to Spanish defeat of the Mexica (Aztec) empire were recognized by Spanish military officials, shortly after the Conquest and later incorporated into the Spanish empire as subjects (MacLachlan 2015). Early colonial allies of the Spanish tended to maintain autonomy in some level of self-governance in comparison to conquered Indigenous kingdoms or city-states (singular, *altepetl*) (León-Portilla 2007; Díaz Serrano 2012). Xochimilco (which includes El Japón and San Gregorio Atlapulco) was one of these early allies in an incipient colonial system makes a paradigm of domination less fitting than one that examines the pervasive effects of colonialism even an ostensibly favorable position.

Theoretical Approach

Evidence from the human skeleton is employed to address the colonial transformations in Mesoamerica which in turn is interpreted using two theoretical frameworks. Political ecology is an approach that frames differential access to social resources or material resources in both political and economic contexts (Blaikie and Brookfield 1987; Bauer et al. 2007). A political ecology approach does not necessitate a specific type of dataset (Thompson et al. 2018) but the links between biophysical and political-economic phenomena (Brannstrom 2004) make a bioarchaeological dataset fitting to explore the lived results of political and economic phenomena on human lives. Furthermore, political ecology can be expected to be especially useful interpreting bioarchaeological data from El Japón due to the intensive nature of chinampa upkeep. The construction and maintenance of the chinampas was intimately linked to market participation, household sustenance, tribute payment and by extension the political and economic systems of the region. Chinampas and the canals that transported them were sustained for centuries to manage the abundance of water in favor of agriculture. The abundance of water rather than the need to introduce water is an uncommon management need in Mesoamerica and makes the ecological dimension of interpretation relevant even with human biological datasets.

This research assumes interrelatedness between the environment, politics, and economics, as it examines the impacts of new political forms on human bodies. This research also interprets human skeletal data in consideration of *entanglements* between two or more groups previously unknown to one another. Cultural entanglement is a term that encapsulates a particular viewpoint on what happens to human lifeways when two or more cultural groups come into interaction with one another (Jordan 2009). An approach centering cultural entanglement permits examination of datasets where the paradigm is demonstrated to be one of situational inequalities in access to power. In colonial contexts, one group may seek to impose lifeways on another group, and this can be labeled as assimilation (Belmessous 2005) or acculturation (Bollwerk 2006). However, there are colonial contexts in which interactions are less skewed and two or more groups interact in limited cases or in limited cases with relatively equal opportunities to use force or power. One example of these limited interactions includes the Calusa polity at the time of 16th century contact in southern Florida. Unlike nearby sedentary Indigenous communities, the Calusa chose to interact sparingly with European newcomers and sometimes violently to maintain autonomy (Thompson et al. 2018). Recent archaeological work centered in the contemporaneous 16th century Basin of Mexico indicates Indigenous-initiated use and transformation of European material and immaterial culture rather than forced changes (Rodríguez-Alegría 2005, 2010). Indigenous use of novel materials or symbols can be treated as an example of entanglement of European items in new cultural logics. An approach that centers cultural entanglements as the vehicle for cultural change is favorable over one that centers domination in some cases of early colonial interactions in Mesoamerica.

The cultural entanglement approach in examining diachronic datasets in this research aims to understand hypothesized continuities and changes as local processes rather than simply labeling as precontact and postcontact. More specifically, this approach permits evaluation of hypothesized changes in population structure and daily activities (food production and consumption) via morphological and chemical bioarchaeological methods. These changes in food production and consumption may have occurred as the result of cultural and genetic mestizaje: seldomly empirically tested (cf. genetic study, Silva-Zolezzi 2009). Analysis of skeletal remains permits a survey into the lifeways of the sample to empirically establish observations about diet, physical labor, timing of rural hamlet inhabitation and biological ancestries that have been inferred with ethnohistoric and archaeological contexts of the postcontact Basin of Mexico or Mesoamerica more broadly. By cross-examining assumptions of cultural mestizaje with bioarchaeological methods, it is possible to identify the means an Indigenous community had to mitigate the challenges of Spanish colonialism and contribute to ongoing discussion of the effects of colonialism more broadly.

Dissertation Outline

Chapter 2 provides an outline of political and economic organization in central Mesoamerica prior to European contact. In other Spanish colonial contexts, historical and archaeological evidence indicate Spanish authorities manipulated existing structures to reorient tribute or labor (Deagan 1985). This pattern is also demonstrated throughout Mesoamerica (León-Portilla 2007; Díaz Serrano 2012) and in the Xochimilco area where El Japón is located (Conway 2014). Discussion of conquest and domination guided archaeological research in central Mesoamerica for decades. Conquest and domination-oriented explanations may fail to identify apparent non-adoption of materials or technologies following colonization outside explanations based on access to such materials. A more recent theoretical approach, entanglement (Jordan 2009), is explained in Chapter 2 as a productive way to understand colonial transformations in the site of El Japón where direct manipulation of lifeways (food production and consumption) may have been absent. Colonial period transformation, however, goes beyond acculturation. The lack of observable changes in an archaeological dataset, for example may not indicate a lack of pressure from broader political and economic changes.

Known changes in population structure and the defeat of the Mexica Empire and ascent of Spanish colonies produces a context for the study of El Japón that must consider the role of colonial period encounter between previously uncontacted populations. The entanglement approach is fitting for study of El Japón due to the Indigenous majority context of the region even a century and half after European contact (i.e., the mid-17th century, Jalpa Flores 2008). In applying cultural entanglement, it is important to not lose sight of the pervasive effects of colonization. Indigenous communities were subject to labor demands not experienced by Spanish-born individuals or individuals of Spanish descent. Indigenous communities were encouraged or forced to relocate to areas more accessible to Spanish authorities. Knowledge of population relocation due to colonial pressures makes it critical to understand the chronology of the site to interpret the studied lifeways in accurate political context, i.e., as a relocated settlement or a preexisting town.

Radiocarbon chronology and Bayesian modeling in Chapter 3 places the site of El Japón (Figure 1. 1) within a decadal scale in the colonial period of Mesoamerica (1521–1821 CE). Early scholarship on El Japón presumed the site predated European contact in central Mesoamerica (1519) due to near complete absence of European-produced and European style items (Ávila López 1995). More recent work postulates a colonial chronology in discussion of paleopathological and demographic processes within the site and comparative sites (e.g., Márquez Morfín and Hernández

Espinoza 2016), but no radiocarbon analyses have been carried out. A precise radiocarbon-based chronology is warranted to better contextualize any further bioarchaeological study, including the three subsequent chapters of this dissertation.

Figure 1. 1 Basin of Mexico settlements included in text. Maximum extent of chinampas is identified by Armillas (1971) and is filled iconographically. Illustrated canals and causeways are identified in multiple historical records (Palerm 1973). Map modified from an image with a Free Art License (YAVIDAXIU 2007).

Chapter 4 employs phenotypic indicators of biological relatedness to provide insight into population continuity within El Japón in the focal period of study defined in Chapter 3 (1565–1640 CE) spanning some of the first generations after European contact in central Mesoamerica. Comparison to European, Indigenous North American, and South American, as well as Asian population samples permit the characterization of the El Japón skeletal collection as one rooted in local native biological populations and inference of their social identities as Indigenous persons.

This approach of identifying biological similarity to other population samples is pertinent to the study of postcontact Indigenous society as evidence of mestizaje would imply political standing different from that of an Indigenous community — Indigenous, Mestizo, and European-born or American-born European individuals were often subject to different laws and rights (MacLachlan 2015). Because biological and lived social experiences were linked in the colonial context, biological traits are a possible approach towards inference of what social and political contexts individuals from the El Japón cemetery sample may have occupied.

Dental nonmetric traits are employed in Chapter 4 as proxies of genetic relationships to estimate interpopulation differences between El Japón and populations from Europe, Asia, and the Americas. Dental traits are subsequently used to estimate intrapopulation variation. Dental nonmetric traits are variations in tooth enamel and roots with continuous variation based in genetic variation (Scott and Turner 1997; Hubbard et al. 2015; Irish et al. 2020). This can be carried out rooted in the premise that these genetically determined traits successfully identify links between individuals and between populations (Hanihara 2008; Pilloud et al. 2016; Rathmann and Reyes-Centeno 2020). The comparative sample includes individuals from archaeological settlements from Europe, Asia, North America, and South America. The diachronic El Japón sample consists of earlier burials from lower strata and more recent burials from upper strata. The diachronic subsamples permit examination of changes in biological variation within El Japón in a time of regional and continental population due to successive epidemics following European contact (Gibson 1964; Prem 1992; Newson 1993; Storey 2012).

As an Indigenous settlement, El Japón is hypothesized to have experienced similar epidemic stress as communities in other regions following European contact. Similar to other colonial Spanish contexts (i.e., colonial Florida, Stojanowski 2005), decreasing population may decrease genetic and concomitant phenetic diversity within a single population sample, e.g., a city or a town. Phenetic similarity within the El Japón sample in serves as a proxy of population continuity which in turn contextualizes hypothesized continuities in food production and consumption that are reconstructed from macroscopic and chemical properties of bone (Chapters 5 and 6).

Chapter 5 explores skeletal morphological variation (cross-sectional properties of bone) rooted in individual life-long activity patterns to gauge continuities and population variation in economic activity. Colonial period change in governance, economic products, demands, and opportunities changed the landscape in which households subsisted through agriculture. Agriculture, nonetheless, was the principal subsistence method before and after European contact. El Japón, like other marshland communities in the southern Basin of Mexico, maintained wetland *chinampa* agriculture — anthropogenic islands replenished with lakebed sediments (Morehart and Frederick 2014).

Chapter 5 gauges individual and population level experience with the locally developed and adapted chinampa subsistence regime via comparison to European agriculturalists known to have employed plow and draft animal agriculture. Cross-sectional properties from adult bone provide a summary of individual physical activity (Mosley et al. 1997; Shaw and Stock 2009), with strong influence from activity in the years near skeletal maturity: adolescence and early adulthood (Pearson and Lieberman 2004). Cross-sectional shape of bone varies in response to intense and repetitive physical demands (Frost 1988; Mosley et al. 1997). Controlled studies in animals (Mosley et al. 1997; Mosley and Lanyon 1998; Robling et al. 2001). Semi-controlled study of athletes further reiterates this theory of bone function-structure links (Shaw and Stock 2009).

Cross-sectional properties are applied to skeletal remains of individuals from historic populations to discuss diverse experiences or patterns in physical activity often dominated by economically oriented physical labor, e.g., intensive agriculture or demanding craft activities. Broad differences distinguish agriculture in the historic Basin of Mexico and European though both can ostensibly be classified with similar terms of intensive agriculture. Hand tools were exclusively used in chinampa agriculture prior to European contact thought the presence of European draft animals following colonization is unexplored in the archaeological record. Both precontact and postcontact chinampa labor was carried out communally (Rojas Rabiela 1977; 1991; Cano Vallado 1992; Conway 2012) making the question of intrapopulation similarity more appropriate than an emphasis on individual variation.

The continental scale comparative framework uses linear discriminant analysis to attempt mathematical discrimination from late Medieval — early Modern European agricultural and urban communities where historical and archaeological context point towards subsistence methods and economic models different from El Japón (Ruff, ed. 2018). More than intrapopulation comparison, the same cross-sectional properties permit intrapopulation analysis that quantify sex-based differences in labor as well as postulated diachronic change within the settlement potentially tied to new technologies. The ethnohistoric record of postclassic and early colonial Mesoamerica (Soustelle 1956; Anderson and Dibble 1975), as well as interpretation of the entheseal effects of activity patterns (Medrano Enríquez 2001) support the interpretation that household and economic labor was divided along gendered lines providing an impetus for exploring sex-based variation in physical activity in Chapter 5.

Chapter 6 develops a stable isotope analysis of bone collagen and bone bioapatite to identify dietary patterns and their links to postcontact political and economic changes in Mesoamerica. The patterns addressed within the El Japón sample include broad carbohydrate sources, relative importance of animal product consumption, and gender parity in diets. Stable isotope analysis that addressed diversity in dietary habits between populations and within populations samples is premised on decades of stable isotopic work that begins with stable carbon ($\delta^{13}C$) diversity in producers — generally plants where it concerns human diets.

Worldwide, plants are classified C_3 and C_4, or CAM based on the differing photosynthetic pathways (Smith and Epstein 1971). Dietary staples domesticated and propagated by humans most importantly cluster in the C_3 and C_4 pathways. C_4 are generally adapted to warmer and dryer climates than C_3 plants (Tieszen 1991). Maize and amaranth were and continue to be important crops in Mesoamerican diets and both are C_4. European crops that formed important contributions to diet include barley, wheat, and oats — all of which are C_3 plants. Because C_3 and C_4 differ in stable carbon isotope ratios ($\delta^{13}C$), then organisms consuming these (herbivorous animals and omnivorous humans) will also differ. Measurement of $\delta^{13}C$ and $\delta^{15}N$ in human remains permits inference of dietary sources in the years before death.

The isotopic analyses provide insight into intrapopulation dietary variation contextualized by El Japón as an agricultural hamlet site dating to only decades after European contact (Chapter 3). Ideally, stable isotope analyses of human diets begin from faunal and botanical baselines that provide a range of variation which may be expected synchronically or diachronically (e.g., Sharpe et al. 2018). An extensive isotopic baseline is lacking for central Mesoamerica, though researchers address the issue with isotopic work of faunal and botanical materials (Moreiras Reynaga et al. 2020; Pacheco-Forés et al. 2020). Identification of zooarchaeological materials from an adequate sample of multiple central Mesoamerican sites, securing access, and carrying out stable isotopic analyses would be an endeavor of its own. To address the lack of stable isotopic faunal and botanical baselines for the southern Basin of Mexico, Chapter 6 incorporates data from published sources of archaeological sites from Europe, Asia, South America, and North America as a robust comparative baseline. This baseline permits estimation of individual food sources that may have formed part of El Japón diets.

Agricultural foods and domestic animals crossed the Atlantic Ocean following European contact as novelties, emerging changes in foodways, or via personal preferences. This may be termed the post-Columbian exchange (Price et al. 2012). Eurasian domestic animals and crops typically form part of modern Mesoamerican diets. The exact speed of adoption of these plants and animals into regional Mesoamerican diets and more specifically into the diets of the majority of the population is not explored systematically. Precontact diets inferred indirectly from zooarchaeological remains, site locations, and evidence of material processing, indicate a pattern of long-term investment in agriculture over other food-procuring activities and diverse protein sources that included wild fish, game, fowl, and various plant sources (Manzanilla and Serra 1987; Corona Martínez 2012; Valadez Azúa and Rodríguez Galicia 2013; McClung de Tapia and Acosta Ochoa 2015). Biochemical analysis of human tissues will provide a more direct interpretation of human dietary patterns in the Valley of Mexico and identify diachronic changes concurrent with European colonization. Stable isotopic data from human tissue (collagen and bioapatite from bone) permit direct estimation of the carbohydrate and protein sources of diet via published regression transformations (Kellner and Schoeninger 2007).

Estimation of dietary patterns in turns permits discussion of the social significance of these animal and plant products' production, exchange, and even taxation in the southern Valley of Mexico during the colonial period. Stable isotope results of El Japón individuals are interpreted in the geographic context of hierarchically organized settlements of the late Postclassic and early colonial periods (Sanders et al. 1979; Parsons et al. 1983). The interpretation of dietary patterns is also contextualized by the economic context of early colonial Mesoamerica-agricultural products were both tributed goods and local staples.

Research Questions and Hypotheses

Chapter 3 aims for a chronological estimate of the use of the cemetery of El Japón that is more specific than individual calibrated dates which may span more than one hundred years offering little benefit over chronological inference based on material remains at the site. Research questions regarding biodistance, cross-sectional geometry, and stable isotope datasets (Chapters 4–6) are presented individually in this section as these follow a hypothetico-deductive framework forming hypotheses based in consistency with the broad-stroke reading of colonial period change for surviving Indigenous communities.

Chronology

Based in radiocarbon age determinations of human remains, what age do El Japón burials span? Radiocarbon applications of materials from the early 16th century often result in ambiguous and long calibrated date ranges – and this is the case in the models of El Japón that do not restrain the dates with independent information (Chapter 3). Bayesian radiocarbon modeling with the OxCal program is used expecting to produce a statistically acceptable and narrower chronological estimate of the use of El Japón cemetery beyond calibration of sampled burials. The models do not directly test a hypothesis of precontact or postcontact origin but rather test the acceptability of a series of models that incorporate independent historical information (i.e., *a priori* information) about mortuary treatment in the region of central Mesoamerica. This section begins from the seemingly Christian-influenced burial patterns and individual mortuary treatments at El Japón to deduce that such a pattern can only happen after direct contact with European missionaries or *laypersons* (those without formal religious roles).

El Japón is geographically separated from the town it was subject to, San Gregorio Atlapulco, despite government-spearheaded efforts to relocate and centralize communities. The same radiocarbon age determinations and OxCal models that address the first research will simultaneously address the second question: whether use of the El Japón cemetery predates or postdates presumed completion of population replacement to congregaciones, ca. 1610 CE? El Japón burials are expected to predate population replacement to congregaciones in 1610 CE in lin with historical narratives that identify relocation of rural communities surrounding San Gregorio Atlapulco (McAfee and Barlow 1952).

Biodistance

Q_1

Based on hierarchical clustering of population samples calculated from high utility dental nonmetric traits (i.e., Rathmann and Reyes-Centeno 2020), who are the individuals interred at El Japón cemetery in relation to continental populations (e.g., Europeans, East Asians, Indigenous North Americans and South Americans)?

H_1

El Japón samples will cluster together with other Basin of Mexico and North American Indigenous samples that predate European contact indicating little or no gene flow between previously isolated gene pools at El Japón.

$H_{1\ alternative}$

El Japón samples will cluster separately from other Basin of Mexico and North American Indigenous samples indicating gene flow from populations with previously isolated gene pools, i.e., Europe and North America.

Q_2

Based on Mahalanobis distances (Mahalanobis D^2) — calculated distances between individuals within a population sample — is there diachronic change in phenetic diversity within El Japón?

H_2

Based in Mahalanobis D^2, no diachronic change in phenetic diversity is expected implying no reduction in genetic variation within the community that used El Japón cemetery.

$H_{2\ alternative}$

Based in Mahalanobis D^2, diachronic decrease in phenetic diversity is expected implying reduction in genetic variation within the community that used El Japón cemetery.

Physical Activity

Q_1

Based in a Linear Discriminant Analysis (LDA) — a dimensionality reducing technique — can cross-sectional properties (CSPs) calculated from periosteal measurements of the humerus discriminate El Japón from samples of European agricultural communities known to have used different agricultural methods?

H_1

LDA will not successfully discriminate El Japón individuals from agricultural European groups based in insufficiently differing cross-sectional properties despite widely different agricultural methods.

$H_{1\ alternative}$

LDA will successfully discriminate El Japón individuals from agricultural European groups based in differing cross-sectional properties produced by widely different agricultural methods.

Q_2

Based in LDA, do CSPs discriminate El Japón from samples of European urban communities with archaeological and historical contexts that identify craft specialization as opposed to agriculture?

H_2

The LDA will not successfully discriminate El Japón individuals from urban European groups due to insufficiently different CSPs despite different activity patterns.

$H_{2\ alternative}$

The LDA will successfully discriminate El Japón individuals from urban European groups based in sufficiently different CSPs produced by different activity patterns.

Q_3

Is there diachronic change in the cross-sectional indicators of physical activity within El Japón?

H_3

No diachronic change will be observed in CSPs within El Japón indicating consistency in patterns of physical activity and continuity in the labor intensive chinampa agricultural regime.

$H_{3\ alternative}$

Diachronic change will be observed in CSPs within El Japón indicating diachronic change in physical activity and chinampa agriculture.

Q_4

Do the CSPs indicate sex-based difference in physical activity within the El Japón adult sample?

H_4

No significant differences between adult males and females will be observed in CSPs indicating low sex-based division of physical activity.

$H_{4\ alternative}$

Significant differences between adult males and females will be observed in CSPs indicating substantive sex-based division of physical activity.

Diet

Q_1

Are carbon stable isotopes ($\delta^{13}C$) consistent with agricultural Mesoamerican population samples indicating a C_4-centered diet (near -13$^0/_{00}$ PDB) as opposed to a C_3 based diet (near -23 $^0/_{00}$ PDB).

H_1

Carbon stable isotope samples in collagen will be near -23$^0/_{00}$ PDB, indicating primary reliance on introduced European C_3 crops known to have been *produced* in central Mesoamerica (e.g., Chalco region, Jalpa Flores 2008).

$H_{1\ alternative}$ Collagen $\delta^{13}C$ will be oscillate near -13$^0/_{00}$ PDB indicating primary reliance on C_4 sources over C_3 European crops and indicating continuity of local precolonial dietary staples.

Q_2

Is $\delta^{13}C$ in the El Japón sample consistent with agricultural Mesoamerican population samples in indicating a C_4 centered diet, i.e., $\delta^{13}C_{collagen}$, near -13$^0/_{00}$ PDB?

H_2

$\delta^{13}C_{collagen}$ will approximate $-13^{0}/_{00}$ PDB indicating primary reliance on C_4 sources over C_3 European crops known to have been *produced* in the Basin of Mexico.

$H_{2\ alternative}$

$\delta^{13}C_{collagen}$ will approximate $-23^{0}/_{00}$ PDB indicating primary reliance on C_3 sources over native C_4 Mesoamerican staple crops.

Q_3

As the El Japón sample is hypothesized to provide a diachronic sample, is there evidence for diachronic change in the individual stable isotopic indicators of diet ($\delta^{15}N$, $\delta^{13}C_{collagen}$, $\delta^{13}C_{bioapatite}$) within El Japón?

H_3

No diachronic change is hypothesized in stable isotopic indicators of diet ($\delta^{15}N$, $\delta^{13}C_{collagen}$, $\delta^{13}C_{bioapatite}$) indicating consistent dietary sources over the lifespans of the generations that used El Japón cemetery.

$H_{3\ alternative}$

Diachronic change is hypothesized indicating change in dietary sources over the lifespans of the generations that used El Japón cemetery. More specifically, *depletion* relative to the PDB standard is hypothesized (approaching $-23\ ^{0}/_{00}$ PDB rather than $-13\ ^{0}/_{00}$ PDB). If found, this may be evidence for incorporation of C_3 (Eurasian) plant food sources.

Q_4

Are there sex-based differences in dietary patterns within El Japón ($\delta^{15}N$, $\delta^{13}C_{collagen}$, $\delta^{13}C_{bioapatite}$)?

H_4

No sex-based differences are expected within the El Japón sample in stable isotopic indicators of diet ($\delta^{15}N$, $\delta^{13}C_{collagen}$, $\delta^{13}C_{bioapatite}$) indicating gender parity in food sources.

$H_{4\ alternative}$

Consistent with the ethnohistoric record that identifies salient gendered norms, sex-based differences in stable isotopic indicators of diet ($\delta^{15}N$, $\delta^{13}C_{collagen}$, $\delta^{13}C_{bioapatite}$) thus identifying disparity in food sources.

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Chapter 2. Biocultural Context

Postclassic Antecedents

Any archaeological or bioarchaeological endeavor into colonial period dynamics must consider the postclassic antecedents as the Postclassic period witnessed the crystallization and growth of the Mexica empire that permeated Mesoamerican life for approximately a century and half prior to Spanish arrival. Archaeological and historical consideration of the Valley of Mexico document a hierarchically organized network of urban and agricultural settlements with economically stratified classes in the Basin of Mexico in the decade of 1520–1530 CE (Sanders et al. 1979; Parsons et al. 1983). Hierarchically organized urban societies were a norm and not an exception far before the beginning of Mexica imperial advances through the Basin of Mexico and into what may be collectively called the lowlands of Mesoamerica. Mesoamerican urbanism has its roots in unequal economic and political influences between competing lineages and settlements in the late Formative period (Blanton 2012) with the *altepetl* or city-state at the core of each (McAfee and Barlow 1952; Smith 1986, 2003; Charlton and Nichols 1998).

Altepetl political economy can be understood to be self-contained (Morehart 2018) or self-sustaining (Manahan et al. 2012) whereby each was capable of and often produced most of what was needed for the survival of its inhabitants. Economies of the Basin of Mexico city-states were largely agrarian where even craft specialized households were involved in subsistence agriculture and or communal agriculture projects (Morehart 2016). Communal agricultural infrastructure was generally managed by a community-level institutions common throughout Nahuatl-speaking regions and the Aztec Empire beginning in the 1420s and lasting to European contact: the *coatequitl* (Rojas Rabiela 1977; after the Codex Mendoza). The coatequitl maintained infrastructure including terracing and canals in the temperate foothills of the Valley of Mexico (Rojas Rabiela 1977).

More intense coordination and labor input was required for communal agricultural resources like canals, causeways, and dikes around Lake Texcoco (Morehart 2016). These marshland landesque investments (sensu, Blaikie and Brookfield 1987), permitted agriculture mitigating the abundance of water. Coatequitl labor likely required high time investment in areas of chinampa agriculture (e.g., Xochimilco, Xico, and Chalco) in comparison to the dry land farther from lakeshores. Geoarchaeological research problematizes the historically based generalizations of tethered woven islands often summarized from mid-colonial sources (González 1992). Substantial geographic and temporal variation in the methods of chinampa creation, maintenance and expansion took place throughout the Lake Texcoco system (Frederick 2007) over at least five centuries preceding European contact.

Historical literature and recent archaeological work support the general principle that chinampa and canal building was carried out as a communal affair (Rojas Rabiela 1977, 1991; González 1992; Conway 2012; Morehart and Frederick 2014; Morehart 2016). Chinampas required regular maintenance (replenishing with lacustrine sediment) in addition to regular clearing of the canals to maintain ideal water conditions (Rojas Rabiela 1977; Morehart and Frederick 2014). Examination of the historical sources over several decades also consistently supports the interpretation that communal labor underlies the chinampa system throughout the Postclassic (Armillas 1971) and colonial periods (Conway 2012).

Communal labor for local purposes or as a payment of tribute was carried out as a function of the *calpulli* or *tlaxilacalli* (Soustelle 1956; Rojas Rabiela 1977; Lockhart 1992). Records of colonial authorities using the calpulli as a unit of labor extraction (McAfee and Barlow 1952; Hicks 2012) exist in the southern Basin of Mexico and central Mesoamerica more broadly. The terms calpulli and *tlaxilacalli* are sometimes used interchangeably and this is especially pertinent for discussion of the southern Basin of Mexico as important historical documents use the latter rarer term (Pérez Zevallos and Reyes García 2003).

Historical sources of the early colonial period also demonstrate that tribute was extracted through the calpulli (Gibson 1964; Lockhart 1992). Although there is an absence of written documents specific to El Japón, it is assumed here that El Japón consisted of a single calpulli (consistent with Civera Cercedo 2018). By contrast, larger towns and cities in central Mesoamerica consisted of various calpullis (Lockhart 1992; Smith 1993; Hirth 1995; Conway 2012). Common-pool labor of the coatequitl was not commodified meaning the labor invested in communal projects was not bought or sold. Ideal social organization in the Postclassic implied a corporate membership of each individual in a calpulli: the primary unit of social organization, tribute payment which often overlapped with ambilineal kinship ties (Kellog 1995). Calpullis membership most importantly implied relationships of tribute payment (Gibson 1964) and as such could vary from well-known and established to fluid territorial designations.

The household in Postclassic Mesoamerica was the primary unit of economic production below the level of the calpulli. The necessity of tribute payment and the local economic practices structure the political economy at the medium scale of the calpulli. Adults and children both participated in the economic production of the household (Anderson and Dibble 1975; Medrano

Enríquez 2001) and young adults in Postclassic Mesoamerica may have been expected to have high productivity similar to adults (Anderson and Dibble 1975).

Study of Colonialism and Theoretical Options

Archaeologists who theorize colonial encounters documented in historical literature and archaeological remains make important distinctions and even classifications of the types of colonialism that has been experienced in geographically diverse regions over thousands of years (e.g., Stein 2002; Silliman 2005; Fitzmaurice 2007; Stockhammer 2013). Ambiguous power differences between colonizers and colonized or indirect influences (Jordan 2009) between the colonized and colonial institutions make an approach of entanglement favorable over approaches that emphasize domination. Gosden (2004; 2012) and researchers of Euroamerican colonialism in North America (e.g., Bollwerk 2006; Voss 2015) recognize an array of relations ranging from relatively equal political clout towards widely unequal.

When power relations are unequal, consideration of acculturation — whether forced or willful — may inform a research question. Some Potowatomi households in the 19th century Midwest, for example, purposely acculturated in terms of household and clothing expressions in order to secure acceptance within a growing Euroamerican society on the Midwestern frontier and by extension working toward land recognition (Bollwerk 2006). Distinguishing colonialism as acculturation (whether forced or not) from *middle-ground colonialism* (Gosden 2004) or *cultural entanglement* (Jordan 2009: 32) improves the applicability of concepts to specific colonial settings. Middle ground colonialism (Gosden 2004) includes extended events of culture contact with relatively equal power dynamics and only situationally differences in control. Cultural entanglement (Jordan 2009) focuses the phenomena in question as the product of new colonial contexts with roughly equitable power dynamics similar to those described by middle ground colonialism. A studied phenomenon could include any archaeological dataset, including bioarchaeological data.

Framing bioarchaeological datasets as proxies of lifeways as a measure of acculturation or lack thereof is not the best way forward in analyzing El Japón given the Indigenous demographic majority in the Indigenous city-state of Xochimilco (Conway 2012) with a formally monarchy-recognized Indigenous-majority government (Inoue 2007). Xochimilco and its surrounding area is often identified as an Indigenous city-state and the presence of Spanish merchants, tradespeople, and residents are notable enough to be counted and named (Conway 2014). Rather, a theoretical approach that centers cultural entanglement is more productive in the Xochimilcan context where individuals may have been geographically distant from Europeans but still experienced transformations including changes in political and religious identities.

Relational entanglement (sensu, Stockhammer 2013) can be used to explore the colonial period outcomes of ostensibly native or unchanged objects. The objects in this bioarchaeological analysis are intangible measures of the architecture and chemical properties of bone: isotopes: cross-sectional measures of strength and shape, dental indicators of similarity to individuals who share genes, and biochemical products of long-term dietary patterns, all recorded in bone. The *objects* however are interpreted as the tangible results of economic and political contexts mediated by household and community units that were apparent and meaningful to both Indigenous individuals and a hybrid (*sensu lato*) political leadership of the city-states of early colonial Mesoamerica. These units are the household, calpulli, and the hamlet settlement. Though prehispanic in origin, these units became tools for the colonial state to tailor proselytization and taxation efforts. The unit of analysis can be expanded by grouping and subdividing by chronology and stratigraphy (as is done in this study) or through inferred and demonstrated kin groups as done in other contexts that include the American Southeast colonial context (Stojanwoski 2005).

The entanglement approach is not novel in the Basin of Mexico. For example, Charlton et al. (2005) and Rodríguez-Alegría (2005; 2010) make arguments akin to material entanglement where objects from a European cultural context were employed by individuals in a new Mesoamerican Indigenous cultural context within local logics. The Mesoamerican example fits the definition of material entanglement whereby objects from one cultural context are given new meaning in settings of culture contact and colonialism (Stockhammer 2012). Indigenous elites and individuals vying for power in the early Colonial Basin of Mexico developed novel uses of European items (e.g., fine ceramics, insignias, and weapons) or adapted prestigious symbols and objects to local situations.

Relational entanglement of the early colonial period can bring to bear the importance of formal land recognition by an incipient Spanish colonial government through primordial titles. *Títulos Primordiales de San Luís Tlaxialtemalco* for example are written in in Náhuatl with Latin script addressing the reader in combined European and Indigenous styles of prose and honorific titles (Pérez Zevallos and Reyes García 2003). This is a truly hybrid document in the colloquial sense of the term. The *Títulos Primordiales…,* however, reiterate claims to traditional communal land ownership and economic relationships of tribute payment that are much older than the document extending into the Postclassic period. Relational entanglement also provides an opportunity to contextualize the biochemical or morphological object of study (e.g., isotopic interpretation of dietary patterns) in a diachronic context that bridges precontact and postcontact labels.

The political ecology framework provides expectations when examining diversity in experiences with physical environments and experiences with diachronic environmental change. These patterns are constructed from observation of 20th century communities but have been demonstrated to hold in historic contexts that include the colonial Basin of Mexico, i.e., Xaltocan (Morehart 2016, 2018). In Xaltocan, Morehart (2016) highlights decreased agricultural production and eventual chinampa abandonment following middle Postclassic (1200–1350 CE) political change and disruption of existing relationships between environmental use and household economies. In the colonial Caribbean, Handler and Wallman (2014) highlight limited decision-making autonomy in supplemental horticulture and market trade among enslaved persons in colonial Barbados. In comparison, enslaved individuals in Martinique's plantations, took advantage of limited decision-making liberties by participating in markets selling their own crops and provisioning their households. Both the Xaltocan and the colonial Caribbean cases demonstrate productive discussion of the interplay between food production, physical geographic contexts, and the political contexts of both.

Based in a wide array of case studies, Robbins (2004:14) summarizes two major expectations in the political ecology approach to understanding human environmental use. These are that 1) environmental change is rooted in economic and political contexts, and 2) environmental conflicts are part of larger struggles with class, race, and gendered inequalities. Furthermore, unequal distribution of costs and benefits are often reproduced under new regimes or institutional shifts if the underlying inequalities are not addressed (Blaikie and Brookfield 1987; Robbins 2004). The political ecology approach is appropriate for comparing production and consumption at El Japón due to the historically documented transition from a Mexica imperial system to an incipient Spanish colonial one and due to its role as a colonial subject town.

Definition of research questions and interpretation of results in the four constituent studies of this dissertation overlay an environmentally defined economic context — the chinampa system.

The political ecology approach is specifically appropriate to study of the past through human remains — bioarchaeological study. Brannstrom (2004) highlights that a central focus of political ecological research elicits how political-economic phenomena are linked to biophysical results. The political-economic phenomena in summary of political ecology studies include political entities of varying scales, population-wide interests, and subsistence practices. Biophysical phenomena in political ecological research endeavors refer to the natural environment and the non-human organisms that inhabit it. In this research specifically, human bodies as biological products also encapsulate the political-economic phenomena that are linked to biophysical products like crops and wild foods, livestock, and wild game. As such, examination of human remains as the products of interactions with the immediately surrounding environment are an opportunity to understand politically and economically contextualized lived experiences.

Early Colonial Transformation

The Altepetl generally survived as territorial units into the colonial period. Shortly into Spanish intrusion, Indigenous parties in military and civic leadership roles allied with the Spanish — specifically including the city-states of Tlaxcalla, Xochimilco, and Chalco (León-Portilla 2007; Díaz Serrano 2012). The altepetl model that evolved over the early colonial period can be described as a product of entangled postclassic logics of territoriality, sovereignty, and tribute-payment relationships with newly constructed or imposed logics of monarchical subjectivity. Indigenous elites — termed *principales* by Spanish authorities — used new monarchical subjectivity to retain or create new political leadership roles on an ad hoc basis with two important exceptions:

vocational religious roles and civil judicial roles both of which were reserved for the Spanish (MacLachlan 2015).

Indigenous allies were recognized by Spanish military officials, namely, Cortés, shortly after the Conquest and later by the Spanish monarchy as subjects of noble Indigenous birth (MacLachlan 2015). *Los Anales de San Gregorio Atlapulco* and *La Fundación de San Luís Tlaxialtemalco* (Pérez Zevallos and Reyes García 2003; Inoue 2007) are two examples of how medium-sized Indigenous communities (towns) used the European methods of writing and written legal claims to reiterate their rights to land within the context of the transformed altepetl, which can be summarized as persistent institution (Charlton and Nichols 1998).

The persistence of the altepetl however should not imply absolute or unchallenged continuity of social and economic organization into the colonial period. The *encomienda* system placed novel demands of tributed labor on the Indigenous population — especially in the beginning of the colonial period when tribute was generally unstandardized and open to ad hoc demands (Gibson 1964; Lockhart 1992; Chuchiak 2006). The Spanish crown granted *encomiendas*: tributary rights over geographic regions encompassing Indigenous towns, hamlets, and villages (Zamudio Espinosa 2001). Smaller settlements were required to consolidate to make more manageable units in both taxation and proselytization efforts (Gibson 1964; Lockhart 1992; Zamudio Espinosa 2001).

The smallest types of settlements (hamlets and villages) were labeled *doctrinas* or *visitas* with often interchangeable use of the terms denoting communities of new believers that were periodically visited by missionaries. Encomienda holders exercised economic control over Indigenous settlements in addition to being sponsors of proselytization and religious instruction efforts for adult conversions. Encomienda-motivated resettlement for labor extraction and proselytization was often disastrous to human health due to a mismatch between environmental use, carrying-capacities, income production, and decreased decision-making faculties of Indigenous households or entire communities (Stojanowski 2005; Klaus and Tam 2009).

In the decades following European incursion into Mesoamerica, growing colonial structures often coopted and modified the demands of tribute and political recognition of previous Mexica imperial structure. Historical sources (Anderson and Dibble 1975) document religious beliefs and practices and the changes to practices concomitant with a new Spanish colonial order. The growing bureaucracies of New Spain coopted the demands of tribute and allegiance while the exchange of persons, information, material objects, and microbes stood to influence the everyday choices of communities in central Mesoamerica.

Social organization gradually changed in a new political and economic context. The heads of city-states continued to collect tribute, that by the mid-16th century was going toward Mexico City. The *cacicazgo* or chieftanship, was recognized among limited city-states as hereditary elites (Munch 1976; Inoue 2007). The sovereignty of Indigenous elites was recognized in the budding Spanish imperial system by application of the Laws of Burgos of 1512 and 1513, and later by specific concessions from the Spanish monarchy (Jalpa Flores 2008; McLachlan 2015). Legal recognition of even the smallest towns (e.g., San Gregorio Atlapulco and San Luís Tlaxialtemalco) within decades after conquest validated religious-political doctrines that distinguished the limits of a Spanish monarch or of a monarch's representative to appropriate land and material goods from subjects as opposed to conquered enemies in Europe or the Mideast (McLachlan 2015).

Similar to prehispanic antecessors, *caciques* (i.e, *chiefs*) and principales occupying civil roles collected tribute, and exercised some control over community councils and communal labor organization (akin to the coatequitl). Calpullis did not immediately disappear; land allotment and corporate membership survived in some areas of the Basin of Mexico well into the final decades of the 16th century, e.g., Culhuacán (Cline 1984). The role of the calpulli gradually declined because of directed institutional changes by Spanish civil and religious authorities (Lockhart 1992) including increasing commodification of land (Cline 1984) which may have been all but absent prior to European influence on central Mesoamerican economies (Smith 2017).

Study of rural and agrarian societies in contact period Mesoamerica often highlight the activation or galvanization of economically based differences as opportunities for political and social challenge to authorities (Pollard 2005; Jalpa Flores 2008; Rodríguez-Alegría 2005, 2010). Indigenous *macehuales* and principales had varying interests within the two broad socio-political categories. The most salient difference may be the absence of birthright to titles and income among macehuales in comparison to the sometimes-protracted birthrights of the latter in the colonial period, namely including the Xochimilco area (Conway 2014). Protracted or newly developed privileges often had visible material correlates in the Basin of Mexico including insignia like swords, costly clothing, or even horses used by hereditary Indigenous principales (Rodríguez-Alegría 2005). Non-hereditary elites in the same city of Xaltocan actively employed Spanish wares as markers of economic means (Rodríguez-Alegría 2010).

Law-based regulation of economic roles created more institutionalized influences on everyday life as the colonial period advanced. The *cabildo* of Mexico City — similar to a city council — regulated commerce and reified the separation of Indigenous and Spanish interests in the colony (Porras Munoz 1982; McLachlan 2015). The cabildo enforced racially based division of products, locations, and timing of sales in marketplaces throughout the Basin of Mexico (Porras Munoz 1982). The cabildo and the church defined *trazas* or quarters of the city and the Basin of Mexico limiting where individuals could settle based on racial categories (Conway 2012). Spanish individuals were prohibited or dissuaded from living in Indigenous cities in an effort to promote self-governance at the local scale (McLachlan 2015).

More extensive designations of land for inhabitance by specific races applied to Indigenous people. Documents written by Spanish and Indigenous people attest to relocation of households and communities to aggregated locations: *reducciones* (Jalpa Flores 2008). Spanish religious and civil authorities intended to facilitate proselytization and labor drafts through geographic centralization (MacLachlan 2015). This process of colonial period population relocation has been studied for decades (Cline 1949; Ricard 1966; de la Torre Villar 1995; Zamudio Espinosa 2001) through extensive areas of what is today Mexico: The Valley of Mexico (Lockhart 1992), the Valley of Toluca (Zamudio Espinosa 2001; Santiago Cortez 2021), Morelos (Gómez Serafín 2011), Queretaro and Guanajuato (Crespo 2010). The sources often concur that reducción formation lasted from 1550 and 1610 CE (Jalpa Flores 2008) with support from both religious and civil authorities (Cline 1949; Aguirre Salvador 2021).

The Xochimilco Area and El Japón Site

Pérez Zevallos and Reyes García (2003) describe the aggregation of farming hamlets to form the town of San Gregorio Atlapulco in the Xochimilco area of the southern Valley of Mexico. *Los Anales de San Gregorio Atlapulco*, the literature of the Indigenous scribes associated with civil government (Gibson 1964), tell us that in 1555 San Gregorio secured self-governance through a royal charter (Pérez Zevallos 1984). Self-governance reasserted communal Indigenous claims to land and authority to control labor drafts for communal projects. New and modified political institutions (Lockhart 1992; Pérez Zevallos 1984; Conway 2014) however placed a variety of demands on the partisans involved in the politics of the early colonial system. Náhuatl and Spanish language records of the early to mid-colonial period document that Indigenous individuals and towns engaged with new legal methods that included legal documents and specialized courts (Pérez Zevallos and Reyes García 2003; Kellog 1995; Díaz Serrano 2012).

The archaeological site of El Japón consists of hundreds of relict farm fields and house plots atop chinampas which dotted the Lake Xochimilco marshlands (Parsons et al. 1983; Sanders et al. 1979). Archaeological surveys of the 1970s identified and methodically described the palimpsest of lakeshore and lakebed sites that left an imprint on the terrain now covered by the 20th century urban sprawl of Mexico City. The largely obliterated remains of chinampas were anthropogenic islands built throughout the Lake Texcoco system from lakebed sediments since at least the 14th century (Morehart and Frederick 2014). Few chinampa settlements have been subject to more recent systematic research (e.g, Overholtzer 2015). Regionally tailored chronologies underlie interpretation of the interplay of politics, settlement and economics predating and postdating European contact.

El Japón burials occupy the greater portion of a platform mound (Ávila López 1995), or *tlatel*. Cordova et al. (2021) and Morehart and Frederick (2014) more recently revisited the sites with radiocarbon methods refining chronologies of tlatels within the Formative period (550 BCE–250 CE) in the northeastern Basin of Mexico. Though an imperfect analogy, the tlatels of El Japón may be inferred to predate the chinampa use of the area. The cemetery of El Japón was excavated as a salvage project from 1993 to 1994 (Ávila López 1995) with approval from the San Gregorio Atlapulco town council of the time and the national archaeological agency: Instituto Nacional de Antropología e Historia (INAH). El Japón burials were largely austere and placed in consistent positioning. (Ávila López 1995) with East-West orientation.

Price et al. (2012) and Pugh et al. (2012) identify change in mortuary practice with European Christian influence: single austere burials with East-West orientation in the Yucatan peninsula. East-West orientation at El Japón is a first impetus for hypothesizing a postcontact origin. Postcontact ethnohistoric sources like de Sahagún's *General History of the things of New Spain* (Anderson and Dibble 1975) and Landa's *Relación de las Cosas de Yucatán* (Tozzer 1941) describe Indigenous practices of mortuary treatment which tended to vary with geography, gender, and social status. Mortuary treatment change with Christianization is a major research area in Mesoamerica together with the study of religious change as a whole.

Pérez Zevallos and Reyes García (2003) identify Christian baptisms in San Gregorio Atlapulco as early as 1525 CE. Records of Catholic sacraments in the Xochimilco area further document postcontact religious change (Gibson 1964). Koch (1983) and Price et al. (2012) identify normative Christian mortuary practices as of inhumation in plain shrouds in designated and sanctified places like chapels, churches, and cemeteries. Graham (2011) posits that cemeteries containing early Christian converts in the Yucatán Peninsula were likely marked with ephemeral materials.

Such may have been the case in the cemetery of El Japón where archaeologists highlight the absence of any enduring grave markers (Ávila López 1995). In analysis of the ecclesiastical and civil records of the early colonial period, Ricard (1966) identifies *fiscales* or *tepizques*: ad hoc religious roles within parish communities whose occupants may have been involved in propagating new burial norms including the austerity of burials. The demographically diverse skeletal assemblage of El Japón includes adults and subadults: likely a sample closer to a theoretical sample of the living community that occupied the space.

The large sample from El Japón cemetery and the inclusion of various age categories has facilitated paleodemographic analyses (Bullock et al. 2013) which may otherwise be difficult in precontact mortuary samples. Research projects (McClung de Tapia and Acosta Ochoa 2015, Civera Cercedo 2018) expanded the archaeological, geoarchaeological, and bioarchaeological understanding of the site of El Japón from the Archaic period to colonial period.

Márquez Morfín (2009) highlights the general underrepresentation of subadult human remains in Mesoamerican skeletal assemblages as a source of bias for analyses. Absent subadult remains and samples that fail to approach the demographics of a living community were noted decades earlier in other regions of Mesoamerica (e.g., Whalen 1976). Varying types of mortuary treatment, including cremation, secondary disinterment, and reburial contribute to varying age and sex biases in mortuary collections (Pinhasi and Borbou 2008). Secular and geographic variation along age and gender divisions is observed in secondary mortuary treatment throughout Mesoamerica including the site of La Quemada (Nelson et al. 1992), the Maya cultural region (Gillespie 2001), the Gulf Coast, (Gómez Santiago and García Cook 2016), and the site of Teotihuacan (Elson and Mowbray 2005). The complete demographic profile at El Japón makes a valuable collection for understanding Mesoamerican population dynamics regardless of the results of hypotheses-based radiocarbon dating aiming to define in terms of a pre-colonial or post-colonial origin. Radiocarbon chronology (Chapter 3) aims to contextualize these important paleodemographics measures of postcontact Indigenous population dynamics.

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Chapter 3. Amidst Plague and Conquest: Assessing Community Continuity in early Colonial El Japón, San Gregorio Atlapulco through Radiocarbon Chronology [a]

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Abstract

Events of the colonial era are not often subject to detailed chronometric analysis owing to their categorization as historic or colonial, or because of assumptions related to the documentary record. Developing absolute timeframes is important to illuminate the lived experiences of people on the periphery of mainstream historical discourse. This research creates such a timeframe for the early colonial cemetery of El Japón, in the southern Basin of Mexico located within the territory of San Gregorio Atlapulco, Xochimilco, Mexico City. This is accomplished through consideration of stratigraphic provenience in conjunction with radiocarbon dates, Bayesian statistics, and historical documents. Calibrated dates of human burials from El Japón site in this project identify use of the cemetery between 1565 and 1640 CE, bracketed by the founding of San Gregorio Atlapulco and the historically documented process of Indigenous population aggregation in *congregaciones*. By incorporating the historical context, the presented Bayesian models address challenges to early Modern (16th–17th centuries) radiocarbon chronology building: multiple calibration curve intercepts and long calibrated date ranges. A refined chronology challenges understanding of the timing of population movement in the southern Valley of Mexico following European contact by demonstrating persistence in a relatively remote hamlet despite a historically documented process of state sponsored population relocation.

Resumen

Eventos de la época colonial suelen no estudiarse mediante análisis cronométrico debido a su designación como simplemente históricos o coloniales o por presunción con base en los documentos históricos. Argumentamos que son necesarios los marcos cronométricos que iluminan las experiencias cotidianas de individuos al margen del discurso histórico prevalente. Esta investigación crea una cronología radiométrica de un cementerio de principios del periodo colonial en la Cuenca de México con base en estadística bayesiana, datos estratigráficos, y el contexto histórico. El cementerio de El Japón se ubica dentro del territorio de San Gregorio Atlapulco, Xochimilco, Ciudad de México. Las fechas de radiocarbono calibradas en este proyecto demuestran un uso del cementerio entre 1540 y 1640 n.e., coincidiendo entre la fundación de San Gregorio Atlapulco y el proceso documentado de congregación de pueblos indígenas. Mediante la inclusión del contexto histórico, los modelos bayesianos presentados abordan los retos al estudio radiométrico de los siglos XVI–XVII incluyendo múltiples intersecciones en la curva de calibración y dataciones calibradas excesivamente largas. La cronología mejorada contextualiza el conocimiento de los cambios en creencias y prácticas religiosas en las décadas tras el contacto europeo.

Introduction

At Spanish contact in 1520, agricultural towns and hamlets in the Basin of Mexico were part of the densely populated urban network of the Aztec Empire (Sanders et al. 1979; Parsons et al. 1983; Nichols 2017). Communities in the marshlands and lake edges in the southern end of the Basin (Lakes Chalco and Xochimilco) specialized in agriculture, craft production, and to a lesser extent, collection of wild foods. Spanish- and Indigenous-authored documents attest to relocation of households and communities to aggregated locations: *reducciones* (Jalpa Flores 2008a). Spanish religious and civil authorities intended for Indigenous populations to aggregate in the reducciones to facilitate proselytization and labor drafts (Ricard 1966; de la Torre Villar 1995; Zamudio Espinosa 2001; MacLachlan 2015). The process of relocation lasted several decades generally occurring between 1530 and 1610 CE (Jalpa Flores 2008b). Support for population relocation came from both religious and civil authorities (Cline 1949; Aguirre Salvador 2021) throughout what is today Mexico including the Valley of Mexico (Lockhart 1992), the Valley of Toluca (Zamudio Espinosa 2001; Santiago Cortez 2021), Morelos (Gómez Serafín 2011), Queretaro, and Guanajuato (Crespo 2010).

One of the communities in the Xochimilco area, San Gregorio Atlapulco (Figure 3. 1), aggregated from farming hamlets within an approximately 6-km radius (Pérez Zevallos and Reyes García 2003). By 1555 San Gregorio Atlapulco secured self-governance through a royal charter (Pérez Zevallos 1984). Self-governance through a locally elected *cabildo* (council) of town residents (Lockhart 1992) reasserted communal Indigenous claims to land and authority to control labor drafts for communal projects. Legal recognition offered some capacity to negotiate amid political flux that accompanied European contact. In addition to new political institutions (Pérez Zevallos 1984; Lockhart 1992; Conway 2014), Indigenous towns engaged with new legal venues (Pérez Zevallos and Reyes García 2003; Kellogg 1995; Díaz Serrano 2012), a transformed market system (Gibson 1964; Hassig 1985; Rodríguez-Alegría et al. 2013), and new religious beliefs and practices (Ricard 1966; Inoue 2007).

Figure 3. 1 Location of El Japón in the southern Basin of Mexico.
Estimated maximum extent of chinampas in the southern Basin of Mexico (Armillas 1971) is filled iconographically. Illustrated canals and causeways are identified in multiple historical records (Palerm 1973). Not all chinampa areas may have been used simultaneously. Map modified from an image with a Free Art License (YAVIDAXIU 2007).

The archaeological site of El Japón consists of hundreds of relict farm fields and house plots atop *chinampas* which dotted the Lake Xochimilco marshlands over an area of about 200 ha (Parsons 1976; Sanders et al. 1979). The *chinampas* are a palimpsest of anthropogenic islands built throughout the Lake Texcoco system from lakebed sediments since at least the 14th century (Morehart and Frederick 2014).

The cemetery of El Japón was excavated as a salvage project from 1993 to 1994 (Ávila López 1995). The project identified a multi-room structure, and a cemetery consistent with European churchyards (Malvido and Viesca 1985; Cohen et al. 1994; Price et al. 2012). Of the 389 primary burials, 99% are in supine position and face east (Ávila López 1995). Interments were generally austere as only 3% of articulated primary burials (8 of 256, Ávila López 1995) included any objects in close association to be labeled as burial goods (Supplemental Table 3. 1). Artifacts including beads and spindle whorls were found near seven other burials without clear association to the burials. Burials within the cemetery are oriented East-West (with a slight offset), consistent with European Christian cemeteries at the time. Religious influence and rapid changes in burial style are often a first sign of colonial encounter (Cohen 1994; Wright 2006; Graham 2011; Warinner et al. 2012; Price et al. 2012). Changes in a value-laden practice like human funerary practices and treatment of bodies likely indicate engagement with newly introduced European and Christian ideas of death, mourning, and the role of the community in the mourning process.

El Japón burials occupy a small area: 360 m^2. Hamlet dwellers may have purposely limited the amount of space allotted for burials as land above the water table was scarce in the marshlands of Lake Xochimilco. The burials occupy the greater portion of a platform mound (Ávila López 1995; Supplemental Figure 3. 1), or *tlatel*. Tlatels have been radiocarbon dated to the latter half of the Formative period (550 BCE–250 CE) in the northeastern Basin of Mexico (Cordova et al. 2021) and the tlatels in the southern Basin may be cautiously inferred to have similar chronology. These tlatels facilitated lacustrine habitation and resource exploitation. Archaeological remains of houses including stone foundations, daub, and utilitarian ceramics are found in various smaller mounds in the area surrounding El Japón cemetery (González 1996). Based on ceramic remains at the site, González (1996) inferred that the residential structures and *chinampas* of El Japón were primarily used in the late Postclassic and first 50 years after European contact.

The cemetery burials at El Japón represent colonial period mortuary reuse of a space with long-term subsistence and residential purpose. Prehispanic mortuary treatment varied with geography, gender, social status, and, in some cases, personal attributes such as parental status (Tozzer 1941; Chuchiak 2006). Subadults in this early colonial cemetery received similar burial treatment as adults. The El Japón burial assemblage is notable in its inclusion of subadult and neonate individuals (Bullock et al. 2013) making dating of the skeletal series valuable for paleodemographic study of postcontact Indigenous populations.

Christian baptisms and marriages are documented as early as 1525 in San Gregorio Atlapulco (Pérez Zevallos and Reyes García 2003). It can be inferred beliefs about a person's status after death, or ideas about what constitutes appropriate mortuary treatment were among the influence of Christian proselytization. In the context of Christian conversion, mortuary and burial practices are historically and archaeologically documented to have changed. The most prominent change from prehispanic to postcontact contexts is the identification of human burials consistent with modern western cemeteries (Pugh et al. 2012; Price et al. 2012) as prehispanic burial varied greatly in type and location within settlements. The Bayesian chronological models in this project offer a more precise estimate of that mortuary change in addition to dating the use of the cemetery and potential inhabitance of the rural hamlet site despite ongoing relocation of Indigenous people.

Nahuatl-speaking communities on the eve of European contact may have practiced household burials (courtyards or under house floors). Cremation in prehispanic time was likely reserved for notable individuals (Anderson and Dibble 1975; Soustelle 1995; Cobean and Mastache de Escobar 1999; Bassett 2014). Ávila López (1995:22) identifies "secondary burials" throughout the colonial cemetery. These are likely burials that were rearranged to make room for more recent burials in the same space. Human remains may not have been removed for secondary mortuary treatment as was the case in common prehispanic mortuary ritual.

Subsequent burials atop or in proximity of earlier burials happened due to scarcity of cemetery space and personal connections between the earlier and later decedents like marriage or descent. Similar interpretations of burial space reuse are made in other newly Christianizing contexts, including colonial period Mayan communities (Pugh et al. 2012; Price et al. 2012). More recent burials would have encountered earlier cemetery burials producing the archaeologically observed pattern: most are primary burials and only few are secondary burials. No stone lining of burial shafts is identified in the excavation record (Ávila López 1995). Individual burials may have been marked by the low tumuli of displaced sediment and perishable markers which were not identified archaeologically.

Mesoamerican archaeologists often note the underrepresentation of subadult human remains in skeletal assemblages (Márquez Morfín 2009). Human skeletal assemblages from prehispanic sites might fail to represent the demographics of a living community (Whalen 1976) because of the diversity of postmortem treatment including cremation, disinterment, reburial (Pinhasi and Borbou 2008). Mortuary treatment beyond primary burials is known throughout prehispanic Mesoamerica including the Mayan cultural region (Gillespie 2001), the Gulf Coast, (Gómez Santiago and García Cook 2016), and the sites of La Quemada (Nelson et al. 1992), and Teotihuacan (Elson and Mowbray 2005). Normative Christian mortuary practices of the 16th and 17th century on the other hand consisted of inhumation in a shroud or coffin (Koch 1983; Price et al. 2012) in designated places like chapels, churches, and cemeteries. Similar to cemeteries of recent converts in the Yucatán Peninsula, individual burials were likely marked with ephemeral materials as disturbance by subsequent burials was infrequent (Graham 2011).

In postcontact rural Mesoamerica, priests were not numerous enough to be assigned to rural parishes (Gibson 1964; Masson 2021). Similar to rural Yucatan, priests may have been infrequently present at burials (Chuchiak 2006) in the farming villages of the Xochimilco area. Yet almost all burials at El Japón were placed in a normative fashion. Lay persons with ad hoc religious roles from each community, known as *fiscales* or *tepizques* (Ricard 1966; Lockhart 1992), may have been involved in the funerary rites and as such were influential in reinforcing new burial norms. The relatively more uniform mortuary treatment under Christian influence produced a demographically diverse skeletal assemblage where adults and subadults are included.

In the postcontact mortuary practices influenced by Catholic belief, burial timing is assumed to be co-terminus with the death of an individual. As such, the cemetery of El Japón is interpreted as a bioarchaeological sample of the community that occupied the space. The timing of El Japón cemetery use is not currently known. Population aggregation to larger towns — including San Gregorio Atlapulco — occurred over several decades from the 1530s to 1610s CE (Pérez Zevallos 1984; Jalpa Flores 2008a). Radiocarbon dating offers an opportunity to contextualize this population within the timing of reducciones.

Radiocarbon dates give an estimate of the age since formation and renewal of the bone samples that then serve as a proxy of human lifespans. Biological uptake of carbon isotopes in humans necessarily ends at biological death. Therefore, measurement and calibration of individual deaths provides an estimate of age since death, and by extension, burial. Dating and calibration of samples of burials from the cemetery allows for an estimate of the use of the cemetery site and by extension an estimate of the occupation of the community.

Materials and Methods

Accelerated mass spectrometry (AMS) radiocarbon dating is used to derive independent absolute date estimates, estimate the range of use of the cemetery, and anchor the lifespans of individual persons within decadal scales. Eleven human skeletal samples (Table 3. 1; (Supplemental Figure 3. 3) from El Japón cemetery were selected in proportion to the number of burials of each cemetery stratum (Upper and Lower). Only primary burials were selected for radiocarbon dating. The first objective of this analysis is to estimate the date range of the lower stratum (Layers 11-8) and upper stratum (Layers 7–4) relying on superimposition as a priori information for Bayesian modeling. The second objective aims to identify a range of use of the cemetery. Layers were assigned as ten-centimeter increments below surface at the time of excavation (Ávila López 1995) while the upper and lower strata are generalizations of the layers for incorporation of stratigraphic information in models that are not too constraining.

Table 3. 1 Osteological Samples

Burial	Age at death[1]	Sex[1]	Layer[2]	Stratum[3]
2	20	Female	4	Upper
3	42	Female	4	Upper
7	19	Male	4	Upper
29	12	Female	7	Upper
50	22	Male	7.5	Lower
53	20	Female	8	Lower
87	24	Female	8	Lower
90	25	Male	8	Lower
180	23	Female	8	Lower
145	35	Male	9	Lower
357	39	Male	9	Lower

1. Age and sex estimates calculated by Márquez Morfín and Hernández Espinoza (2005).
2. Corresponds to ten-centimeter increments below surface — assigned during excavation.
3. "Stratum" designation in stratigraphic relation to foundations of architecture in eastern end of the cemetery (Supplemental Figure 3. 4). Upper burials are shallower than the depth of foundations. Lower burials are deeper than the depth of foundations. Of radiocarbon dated individuals, only Burial 53 was below foundations.

Bayesian statistics express the degree of belief in a model created using contextual information about the radiocarbon dated artifacts (Hamilton and Krus 2017). This study uses OxCal 4.4 (https://c14.arch.ox.ac.uk/) to create and test chronological models. Radiocarbon dating through accelerator mass spectrometry (AMS) measures the ratio of stable (^{12}C and ^{13}C) to radiogenic (^{14}C). That date estimation is a range of uncalibrated ^{14}C years that must then be calibrated with an appropriate calibration curve depending on the origin of carbon in the sample considering geographic origin, and sources of marine or atmospheric carbon.

Radiocarbon dating in this study was carried out exclusively on human bone collagen samples. Bone collagen extraction followed Center for Applied Isotope Studies (CAIS) protocol for whole bone which consists of an acid-base-acid procedure: a modified Longin (1971) method. One milligram of purified collagen aliquot was analyzed from each sample in an elemental analyzer isotope ratio mass spectrometer (EA-IRMS) to obtain stable carbon and nitrogen isotope ratios. Five milligram aliquots were combusted using CuO to produce CO_2 samples which are catalytically converted to graphite (Vogel et al. 1984). Samples were analyzed in the CAIS 0.5 MeV AMS. Purified collagen samples selected for radiocarbon dating had atomic carbon-nitrogen ratios between 3.2 and 3.3, indicating low diagenetic alteration to molecular structure in the depositional environment (DeNiro and Hastorf 1985).

Human bone collagen primarily incorporates carbon (including ^{14}C) from protein sources (Ambrose and Norr 1993) as opposed to carbohydrate or lipids in diet. Bone mass is acquired and conserved in the years leading to skeletal maturity which oscillates around 19–25 years of age (Hedges et al. 2007). Bone mass is generally maintained or gradually decreases past skeletal maturity in late adolescence/ early adulthood. Collagen in bone — like other bodily tissues — is gradually replaced at the cellular level producing a multi-year average (Hedges and Reynard 2007; Hedges et al. 2007). Archaeological samples of human tissues average ^{14}C incorporated over several years of life. Cortical femur bone in adult humans is one of the densest regions of bone and has relatively slow turnover rates of up to more than ten years (Hedges et al. 2007). Thinner elements (e.g., fibulae and ribs) are expected to have faster turnover rates providing opportunities for more precise age estimates.

Sources of dietary protein (animal meat and fats or plant proteins) must be considered as the trophic and geographic origin of those dietary sources determine the carbon source ultimately contributing to radiocarbon age determinations. Dietary protein sources in Postclassic central Mesoamerica included domestic crops, small domestic animals, wild game, and wild terrestrial or lacustrine foods (Valadez Azúa and Rodríguez Galicia 2014; Moreiras Reynaga et al. 2020). As agricultural societies, central Mesoamerican communities primarily invested labor in domestic sources of nutrition and supplemented with local wild foods and foods acquired through the markets. Stable isotopic results (carbon and nitrogen) of El Japón groups these individuals with other agriculturally centered Mesoamerican societies (Figure 3. 2). Based in paired stable carbon ($\delta^{13}C$) isotope analysis of bioapatite and collagen from El Japón, it is identified that terrestrial C_4 plants (i.e., maize and amaranth) formed more than 50% of dietary protein and more than 70% of dietary carbohydrates (Alarcón Tinajero et al. 2022). Secondary contributions of other food groups likely included maize-fed domestic animals, freshwater plants and animals, as well as terrestrial wild game and fowl.

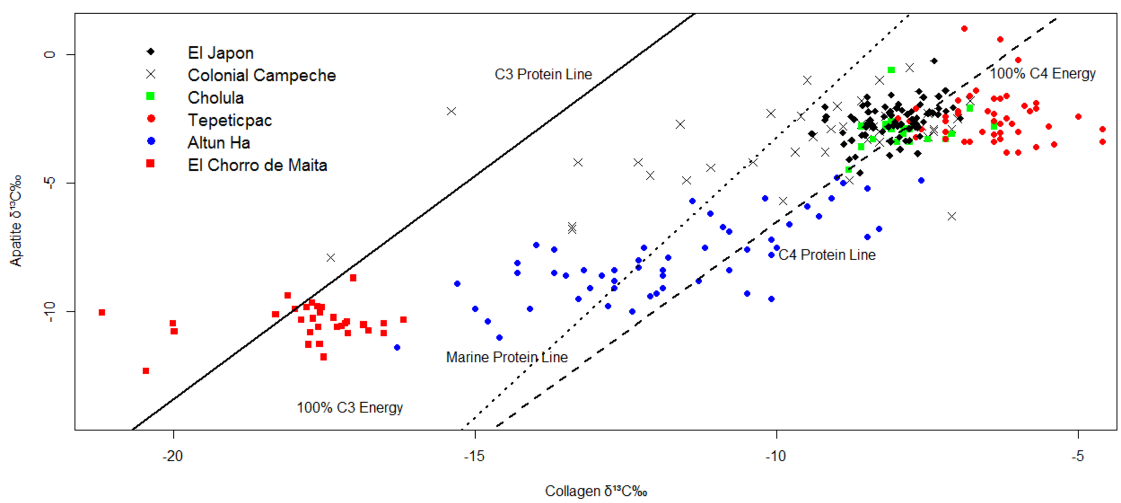

Figure 3. 2 $\delta^{13}C_{bioapatite}$ and $\delta^{13}C_{collagen}$ Plot of Comparative Population Samples.
The figure plots regressions of carbon isotope ratios in collagen and bioapatite from single individuals. El Japón individuals and other highland samples (Postclassic Tepeticpac and early colonial Cholula, (Alcantara-Russell 2020) plot distinctly from population with marine foods as important dietary sources: El Chorro de Maíta, Cuba (Laffoon et al. 2020), and Altun Ha (White et al. 2001) and Campeche City (Price et al. 2012) in the Yucatán Peninsula.

In areas with market economies, like the Postclassic and colonial Basin of Mexico, humans consumed local foods and foods imported from outside the immediate environment. Diverse carbon sources warrant consideration of isotopic variation in food sources and their and influence on isotopic variation in human tissues. As a hamlet subject to a larger town and as an agricultural settlement, El Japón households mainly occupied a commoner status. Commoners throughout Mesoamerica participated in the market system consuming less nonlocal or costly foods in favor of locally procured foods. Marine foods and foods from outside central Mesoamerica likely formed a very small or nonexistent share of diet for residents of El Japón (Figure 3. 2). Both domestic and wild foods consumed by people in the Basin of Mexico likely originated in non-sedimentary geologic regions as non-sedimentary formations predominate (López-Acosta et al. 2019).

In other regions, limestone contribution to soils or limestone weathering into bodies of water are documented sources of dissolved inorganic carbon (Gustafsson et al. 2011; Schulting et al. 2015; Svyatko et al. 2017; Hadden and Cherkinsky 2017) that may skew radiocarbon age determination toward erroneously older ages. The majority of the Basin of Mexico lies over igneous substrate (de Cserna 1989; López-Acosta et al. 2019) and as such dissolved inorganic carbon from sedimentary is unlikely to play any important part of carbon cycling in the lacustrine system of the southern Basin of Mexico. For this reason, corrections to radiocarbon dates are unnecessary.

Preliminary acetic acid treatment (Garvie-Lok et al. 2004) for bioapatite stable isotope analysis on El Japón bone samples demonstrates little effervescent reaction: one indicator of low presence of labile carbonates (Alarcón Tinajero et al. 2022). In contrast, archaeological bone samples from calcareous soils would react substantially in acetic acid treatment due to absorbed carbonates. Recent studies of carbon cycling in the Lake Xochimilco and Lake Chalco environments may be inappropriate baselines for stable isotopic and radiocarbon understanding due to severe environmental transformation in the last half millennium since European contact.

Relying on the scarcity of calcareous formations in the lacustrine soils of the southern Basin of Mexico, radiocarbon dates from El Japón human bone with atmospheric curve calibrations are accepted as germane to the lifespans of the individuals in question even if mollusks, fish, fowl, and other aquatic foods formed minor portions of diets. In other ecological contexts, *e.g.,* Lake Baikal, freshwater food consumption warrants caution in interpretation of radiocarbon dates from human bone collagen due to a freshwater reservoir effect or uptake of carbon sequestered in sedimentary bedrock (Schulting et al. 2015).

Sample preparation

Collagen extraction methods for radiocarbon dating began with inspection for adhesives using UV light. If necessary, samples were sonicated in three consecutive acetone baths then rinsed and soaked in (Milli-Q) ultrapure water to neutrality. Samples were abrasively cleaned, and the surface cortical bone was removed. Bone samples were demineralized in a 1 N HCL solution at 4º C for 24 hours after an initial vacuum pump. Samples were decanted and rinsed to neutrality before going into an NaOH wash. Samples were rinsed to neutrality and placed in a second HCL soak for 30 minutes. The base solution step is consistent with multiple studies isolating collagen for isotope analysis (Haynes 1968, Berglund et al. 1976, and Gurfinkel 1987). Samples were decanted, rinsed to be slightly acidic (pH 3–4), and dissolved at 80º C for 12 hours. Samples were filtered using a glass fiber filter and vacuum pump and placed in pre-weighed beakers for evaporation at 80º C. Samples were briefly cooled at room temperature then loosely covered with foil and placed in an -80º C freezer. Samples were then placed in a freezer dryer for 15 hours. One milligram collagen subsamples were encapsulated in tin to measure elemental concentrations (%C and %N) and stable isotope ratios ($\delta^{13}C$ and $\delta^{15}N$) using a Costech elemental analyzer isotope ratio mass spectrometer (EA-IRMS). Values are expressed as $\delta^{13}C$ with respect to the Peedee Belemnite standard (PDB) and $\delta^{15}N$ with respect to AIR.

Bone samples for bioapatite analysis were sonicated three times in (Milli-Q) ultrapure water in 30-minute increments to remove any sediment or small organic materials in pores not removed by abrasive cleaning. The remaining procedure for bioapatite samples follows Cherkinsky (2009). Samples were demineralized for 24 hours in a 1 N acetic acid solution and periodically pumped under vacuum to incite reaction. At 24 hours, samples were decanted and soaked for 30 minutes to better release absorbed acetic acid then rinsed to neutrality. Samples were then placed in a warm oven for 12 hours to evaporate any remaining liquid. 3mg of crushed pretreated bone samples were placed in exetainers and purged with helium for 20 minutes. Samples are subsequently acidified with 100% H_3PO_4 and heated for 12 hours at 50º C.

Results

Stable carbon isotope results on collagen and bioapatite for the sampled El Japón individuals are consistent with populations consuming maize-based diets. Mean $\delta^{13}C$ in bone collagen for El Japón individuals (*n=74*) was -8.1$^{0}/_{00}$ PDB (Chapter 6; Alarcón Tinajero et al. 2022). Quality indicators of all purified collagen samples: carbon-nitrogen atomic ratios (C:N ratio, Ambrose 1990) and collagen yields (van Klinken 1999) are within acceptable range (Table 3.2). Collagen fractions of most samples may not have been heavily modified in their depositional environment. The lowest collagen yield (11%) of the radiocarbon samples was from Burial 50. The role of Burial 50 in Bayesian Model results is discussed for each model.

Table 3. 2 Radiocarbon Results.

Dates calibrated in Model 1 (Chapter 3 Appendix)

Burial	Element	Collagen Yield (%)	%C	%N	Atomic C:N	$\delta^{13}C$	$\delta^{15}N$	^{14}C age (BP)	PMC	Unmodelled calibrated dates (CE)	
										68.30%	95.40%
2	Rib	20.0	44.4	16.2	3.2	-8.4	8.4	370 ± 25	95.49 ± 0.259	1461–1619	1454–1632
3	Rib	21.0	44.4	16.2	3.2	-7.7	8.9	312 ± 25	96.18 ± 0.277	1521–1640	1496–1646
7	Radius	16.6	42.9	15.3	3.3	-8	7.5	330 ± 25	95.90 ± 0.273	1505–1635	1485–1640
29	Fibula	14.0	42.7	15.2	3.3	-8.8	8.3	370 ± 25	95.51 ± 0.284	1461–1619	1454–1632
50	Fibula	11.0	42.2	15.0	3.3	-7.6	8.7	399 ± 25	95.14 ± 0.254	1449–1492	1441–1623
53	Fibula	21.0	41.0	14.9	3.2	-8.5	7.9	350 ± 25	95.69 ± 0.240	1482–1626	1465–1636
87	Radius	20.9	44.2	15.8	3.3	-9.2	8.2	360 ± 25	95.66 ± 0.259	1478–1624	1459–1635
90	Fibula	16.0	41.2	15.0	3.2	-7.5	8.9	300 ± 25	96.35 ± 0.240	1523–1645	1500–1655
145	Fibula	12.0	39.8	14.3	3.2	-7.8	8.7	360 ± 25	94.99 ± 0.251	1475–1623	1457–1634
180	Rib	19.6	44.2	15.9	3.2	-8.9	8.7	330 ± 25	95.99 ± 0.270	1505–1635	1485–1640
357	Rib	21.0	44.1	16.2	3.2	-7.3	8.78	361 ± 25	95.59 ± 0.250	1473–1623	1457–1634

The Bayesian Models

This study develops five iterations of a Bayesian model working with the *modus operandi* of moving from a model with the most conservative (*sensu*, moderate or cautious) assumptions and parameters to the most. Complete codes are included in Chapter 3 Appendix. Radiocarbon dates in all models are calibrated using the North American IntCal20 Curve (Reimer et al. 2020). This atmospheric calibration curve is the most appropriate as the site is located far from the coast and because modeling of stable isotopic results (Alarcón Tinajero et al. 2022) and the zooarchaeological evidence of the site demonstrate predominance of terrestrial animal remains over marine or freshwater aquatic ones (Corona Martínez 2002). In addition to selection of an appropriate calibration curve, commands in the OxCal program are used to group or divide uncalibrated radiocarbon dates.

Commands in the OxCal program are specified in capitalized and italicized form, i.e., *Calendar Date, Interval*, *Phase,* and *Sequence*. *Phases* are unordered groupings of radiocarbon dates that are believed to be contemporaneous or closely related (Bronk Ramsey 1995). Ordered *Phases* can be grouped using the *Sequence* command informing the model that the *Phases* must be sequential. The *Interval* command in models produces a date range based on the distribution of dates in the phase where the command is included. This can be thought of as an estimate of the sampling universe from the event from where dates are drawn.

Agreement and *overall indices* generated by the OxCal are used to evaluate each model. These indices quantify how well modeled calibrated dates fit unmodeled dates (Bronk Ramsey 1995). An *Overall index* qualifies the model as significant or non-significant (Bronk Ramsey 1995). Indices for each run of a model vary stochastically and are, therefore, not listed in discussion of each model. Acceptable indices for each run are denoted by a score of 60 or higher.

Model 1 incorporates all dates into a single *Phase* and thus ignores stratigraphic relationships between the burials within El Japón cemetery (Supplemental Figure 3. 2 and 3.3). Burials in the lower levels that predate architectural foundations occupy the majority of a single platform mound (Supplemental Figure 3. 1). Upper burials, shallower than architectural foundations, occupy space between earlier burials or are primarily grouped in the eastern end of the platform mound (Supplemental Figure 3. 3).

Models 3–5 place dates in two *Phases* within a single *Sequence* implying the contained *Phases* must be sequential and thus incorporate the chronological interpretation possible through consideration of broad stratigraphic categories, i.e., Upper and Lower. The precise order of individual human deaths and burials within phases is not critical for the argument that stratigraphic separation facilitates a better estimate of burials than a model with a single *Phase*. Because sequential *Phases* are incorporated, the *Agreement* and *Overall Indices* are calculated under the premise that the stratigraphy-based sequence is true.

Models 1–3 do not incorporate a *Calendar date*. Placing the *Calendar date* in a *Sequence* requires the Oxcal model to constrain modelled calibrated dates (Thompson et al. 2018). Without the *Calendar date*, calibrated date ranges for burials in Models 1–3 predate European contact and normative Christian mortuary treatment. Accepting those 15th century dates would be inconsistent with Postclassic mortuary patterns. Models 4 and 5 include a *Calendar date* of 1521 as the earliest date a pattern of inhumation consistent with European cemeteries could begin. Calibrated dates may intercept in two or more discrete points producing calibrated ranges that span much longer than the lifespan of the organism dated. Justified use of the *Calendar date* limits that calibrated range.

Model 1

No stratigraphic relationships are included, and all radiocarbon dated samples are included. No Calendar date is included so as not to limit the model. The model produces acceptable agreement and overall model indices, and acceptable indices for all dates except Burial 50. Burial dates span *1480–1629* (cal. CE 95%).

Model 2

Model 2 includes no stratigraphic relationships and includes all dated burials in a single phase. Burial 50 is flagged as an outlier to be included and calibrated but without affecting the rest of the model. No *Calendar date* is employed in this model, resulting in calibrated date ranges that at least partially predate European contact. Satisfactory agreement and overall indices are produced for the model. Excluding Burial 50 which is not constrained, burial dates span *1500–1655* (cal. CE 95%).

Model 3

Model 3 groups burials stratigraphically with two sequential *Phases* based on burial stratigraphy (Supplemental Figure 3. 5). Model 3 produces satisfactory agreement and overall indices. Excluding Burial 50 which is not constrained, Burial dates span *1492–1639* (cal. CE 95%).

Model 4

Model 4 incorporates a *Calendar date* of 1521 in a *Sequence* prior to the lower and upper burial *Phases*. Model 4 produces satisfactory agreement and overall indices. Dates in Model 4 span *1565–1639* (cal. CE 95%). Model four is the favored model as it uses the most conservative commands and retains ten of eleven radiocarbon dates without specific weighting of most dates.

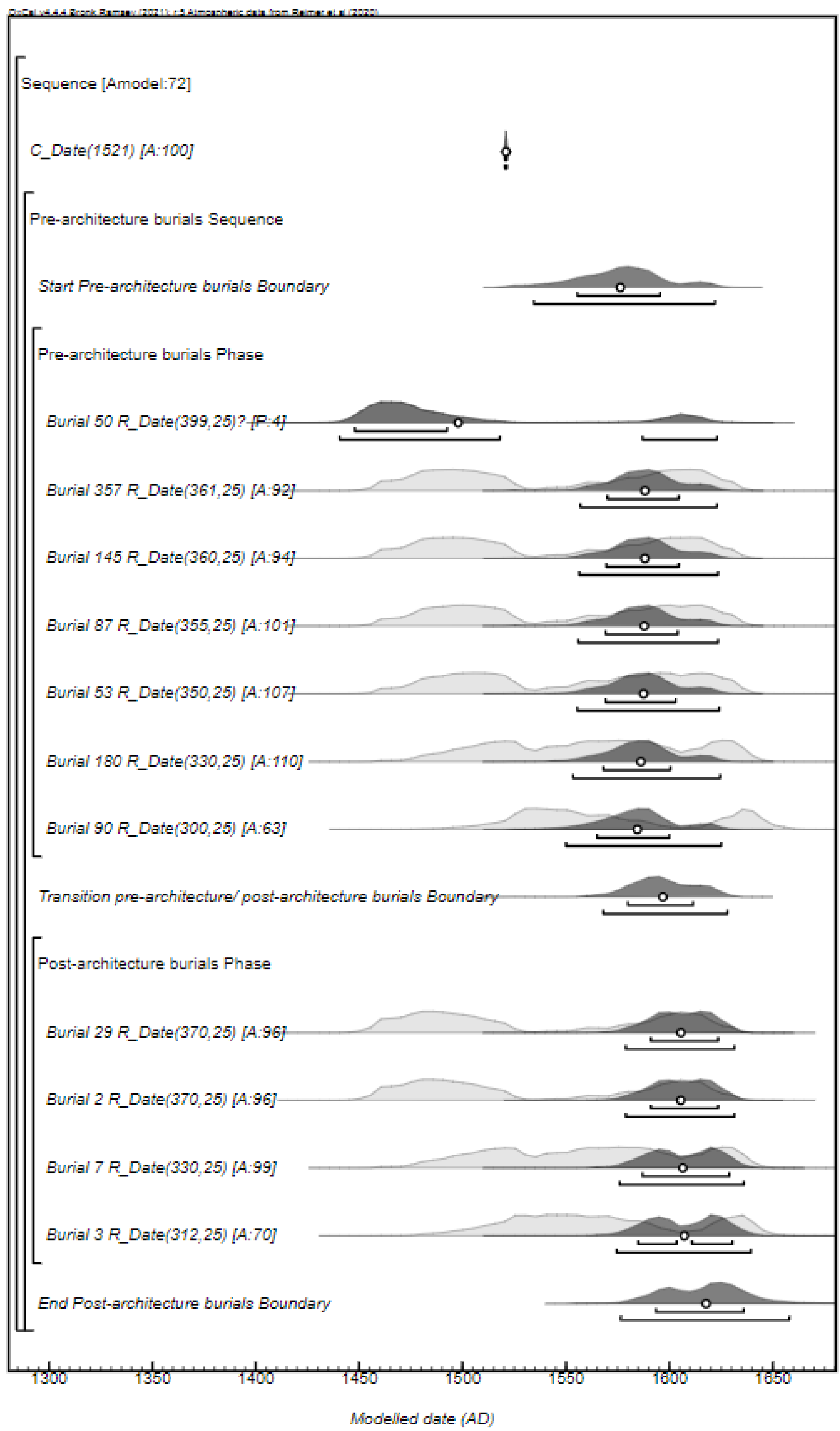

Figure 3. 3 Model 4 Plot.
Mean values of modelled dates marked with "○". 68.3% and 95.4% modelled date ranges are marked. Agreement indices (A:) shown in brackets.

Model 5

Model 5 is an *Outlier Model* (Bronk Ramsey 2009) with a *Calendar date* of 1521. The *Outlier Model* addresses the discord of Burials 50 and 90 with other dates in models 1–4. Outlier models assume each individual radiocarbon measurement has a likelihood of being problematic and downweighs each sample. Indices resulting from an Outlier Model are an "average between a model in which the measurement is accepted and one in which it is rejected" (Bronk Ramsey 2009:3). The model produces marginally acceptable or unacceptable agreement and overall indices. Agreement indices for Burial 50 and 90 are unambiguously unacceptable. El Japón burials in this model span *1561–1640* (cal. CE 95%).

Burial treatment for individuals 50 and 90 is consistent with all other burials lacking contextual evidence that may suggest an older – prehispanic – origin. Carbon-nitrogen atomic ratios for all samples is within acceptable range: 2.9-3.5 (Ambrose 1990). Calculated collagen yield of samples from Burials 50 and 90, however, are among the lowest 50% of yields from El Japón samples (n=74, Chapter 3). The sample from Burial 50 is within the lowest 25% collagen yield and highest 25% carbon-nitrogen atomic ratios of samples.

Discussion

Calibrated dates of upper and lower strata from El Japón demonstrate the cemetery was in use between *1560–1640* (cal. CE 95%). Mortuary treatment at El Japón was distinctive from prehispanic burials in the area and justified a *Calendar date* of 1521 in the Bayesian models. The cemetery of El Japón was the site of funerary ritual and burial decades after the onset of settlement relocation by Spanish authorities. The *congregaciones*, including San Gregorio Atlapulco, intended to relocate Indigenous households from isolated hamlets to larger towns, partially to attempt social control (Zamudio Espinosa 2001). The cemetery of El Japón, however, is about 2 km from the parish church and center of colonial and modern San Gregorio Atlapulco. Two interpretations are offered.

The hamlet dwellers of what is now the ejido of San Gregorio Atlapulco maintained ties to the cemetery site and returned even after decades of population relocation to bury their relatives and community members in sanctified ground. This is not a parsimonious explanation and parish churches generally had adjacent graveyards for local burials. Another possibility is that the hamlet settlements were not relocated as quickly as led to believe by narratives that document relocation from the 1530s–1610s CE (Jalpa Flores 2008a). If this is the case, the narrative of Spanish influence on settlement patterns and the rapidity of cultural change must be reexamined in the southern Basin of Mexico considering refined radiocarbon chronology.

The cemetery of El Japón is roughly equidistant from San Lorenzo Tezonco and San Gregorio Atlapulco. Dispersed settlement in hamlets likely persisted despite "intensified" programs of population aggregation during the first quarter of the XVII century (Pérez Zevallos 1984; Inoue 2007:117). Individuals from hamlets and farmsteads likely contributed to the El Japón cemetery "population" distinct from the cemeteries of the parishes of more centralized settlements of Xochimilco, San Lorenzo Tezonco, and San Gregorio Atlapulco. Change in religious belief and religious practices that included mortuary treatment and inhumation may have occurred despite diffuse settlement patterns and funerary ritual outside the purview of Spanish religious authorities.

Bayesian modeling of calibrated radiocarbon dates on human bone collagen dates burials from the cemetery of El Japón to the decades following European contact in central Mesoamerica. The span of dates from the sampled burials are consistent with rapid use of the cemetery area (no more than 130 years, per Model 4). Rapid use of the cemetery area is consistent with high mortality rates (Warinner et al. 2012) caused by epidemics that followed European contact (Pérez Zevallos and Reyes García 2003). Based in 19^{th} and early 20^{th} century maps of the Xochimilco area, the ejido lands north of San Gregorio Atlapulco and southwest of San Lorenzo Tezonco seem to be depopulated and instead used for *chinampa* farming and pasture of livestock (Chapa 1957). Demographic decline and population consolidation in larger towns likely contributed to decline in burial in a rural location like El Japón. Habitation and agriculture in the area between 1565–1640 CE distinguishes El Japón's chronology from the regional historical narrative that early Spanish authorities relocated Indigenous people to larger settlements.

Future radiocarbon and Bayesian modeling in the archaeological contexts of the Basin of Mexico will benefit from considering isotopic variability of domestic and wild flora and fauna that formed the bases of human nutrition. Variation in meteoric water and the freshwater and saltwater portions of the Lake Texcoco system likely influenced nitrogen and carbon isotopic variability. Recent stable isotopic research (Moreiras Reynaga et al. 2020; Pacheco-Forés et al. 2020) and future work in faunal, botanical, and geological baselines will permit more tailored interpretation of radiocarbon variability in the Basin of Mexico and contribute to understanding human behavior and settlement following European-Indigenous contact. Stable isotope study of geographic origin of prehistoric individuals can also substantiate more robust consideration of radiocarbon variation due to diverse geographic origins.

Conclusion

A series of five iterative models were developed to estimate the use of the cemetery in the hamlet of El Japón. A statistically acceptable model was achieved by downweighing one dated sample with acceptable preservation parameters (C:N ratio and collagen yield percentage). Site-specific consideration of preservation parameters may be fruitful for future selection of radiocarbon samples. Based in Model 4, the cemetery was in use during the colonial period between *1565–1640* (cal. CE 95%). This was the preferred statistically acceptable model that retained the largest possible dataset. Multiple calibration curve intercepts and long calibrated date ranges (some predating European contact) are addressed through incorporation of contextual information: site stratigraphy and site affiliation to historically documented settlements. Use of the cemetery was likely coterminous with use of the immediately surrounding *chinampa* landscape for habitation and agriculture.

Habitation and agriculture in the area between 1565–1640 problematizes the historical narrative that early Spanish authorities relocated Indigenous people to larger settlements: *congregaciones*. Chronometric analysis identifies inconformity of this hamlet community with the dominant historical narrative. El Japón was a hamlet — a settlement of the lowest economic order — during the Postclassic and Colonial periods. Population would have been low in relation to neighboring towns like San Gregorio Atlapulco and cities like Xochimilco. Cemetery use spanning nearly one hundred years following European contact testifies to persistence in place of one Indigenous community despite the challenges that accompanied a new colonial order.

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YAVIDAXIU (username)

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Chapter 3 Appendix. Tables and Figures.

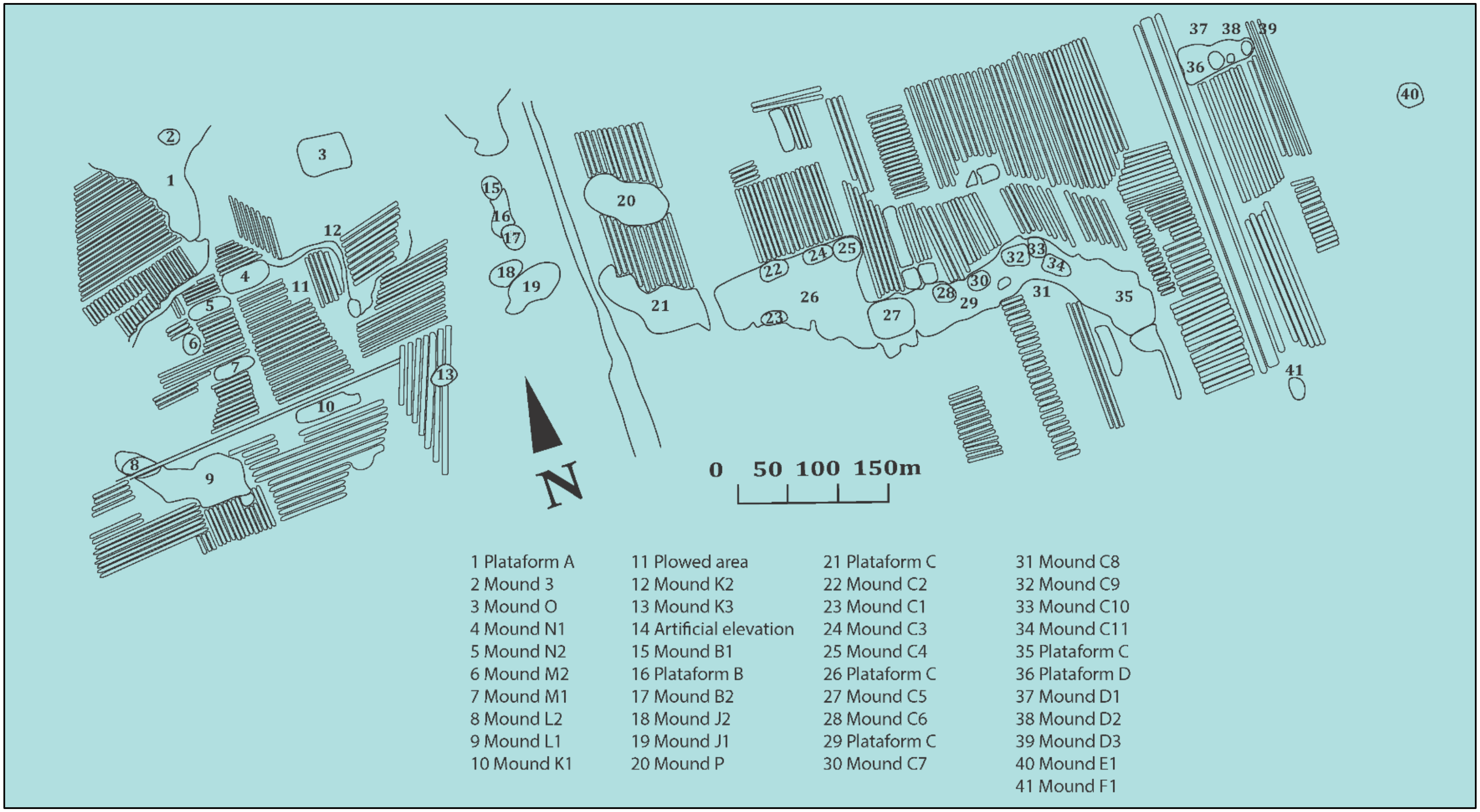
Supplemental Table 3. 1 Objects associated with El Japón Burials.

Reproduced from the original site excavation report “Proyecto de Rescate Arqueológico San Gregorio Atlapulco…” (Ávila López 1995).

Burial Number	Burial Type	Sex[1]	Object	Count	Area of Body[2]
78	Primary	M	Figurine fragment	1	Head
82	Primary	I	Bead	26	Neck
160	Primary	F*	Bead	2	Head
161	Primary	M*	Bead	8	Arm
182	Primary	F*	Bead	1	-
198	Primary	I*	Copper bell	1	Torso
209	Primary	F*	Spindle whorl	1	-
212	Primary	I	Spindle whorl	1	-
233	Primary	F*	Copper bell	6	Feet
234	Primary	M*	Bead	1	-
290	Primary	M	Bead	1	-
323	Primary	M*	Bead	3	-
346	Primary	M	Spindle whorl	1	Neck
381	Primary	F	Spindle whorl	1	Feet
388	Primary	M	Bead	6	-

1. M-male, F-females, I-indeterminate. Age estimates on subadults (mean age-at-death <15) marked with asterisks as subadults are not routinely assessed.

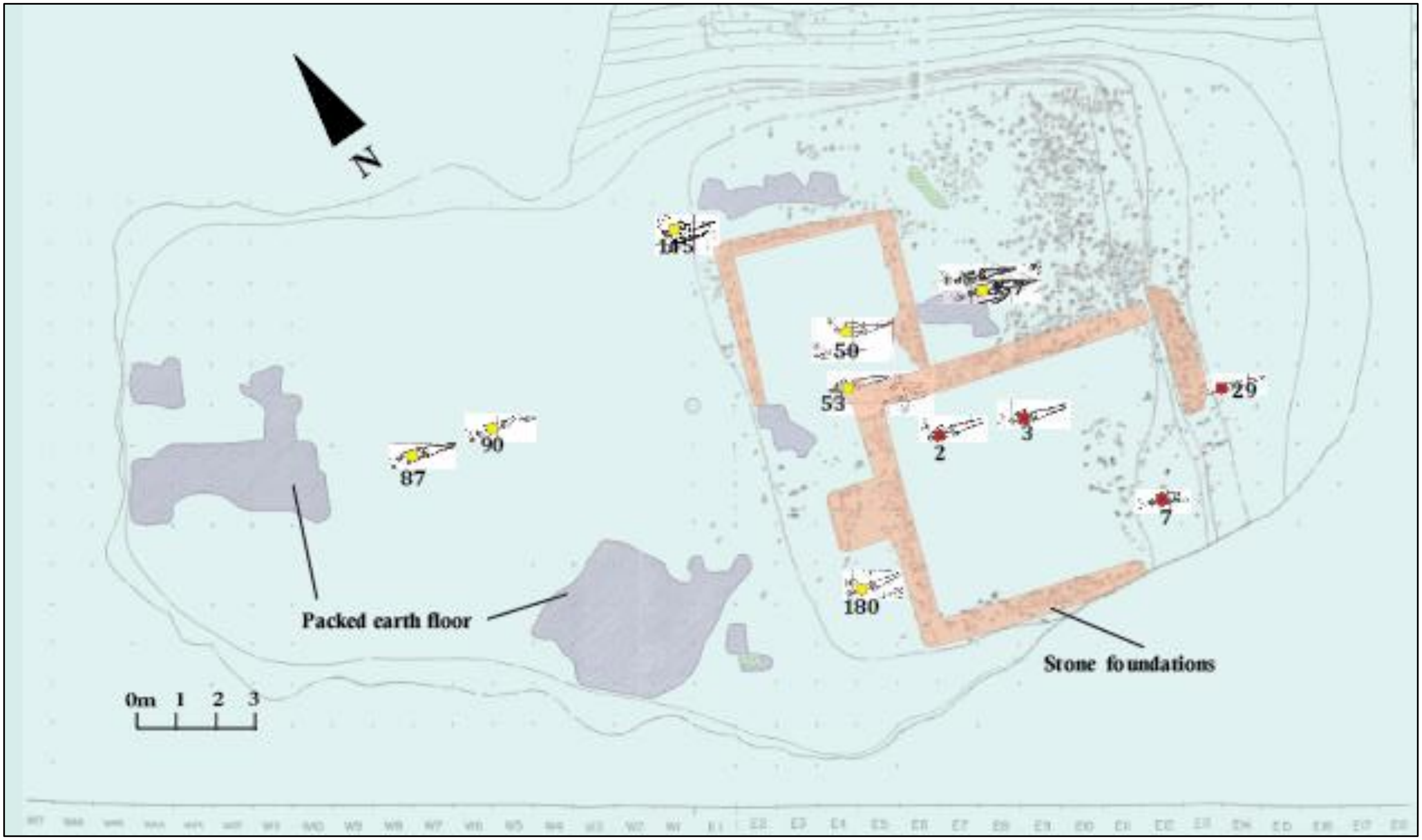
2. Area of Body of body omitted from skeletal excavation record from cases with missing entries. This may indicate unclear association to the burial.



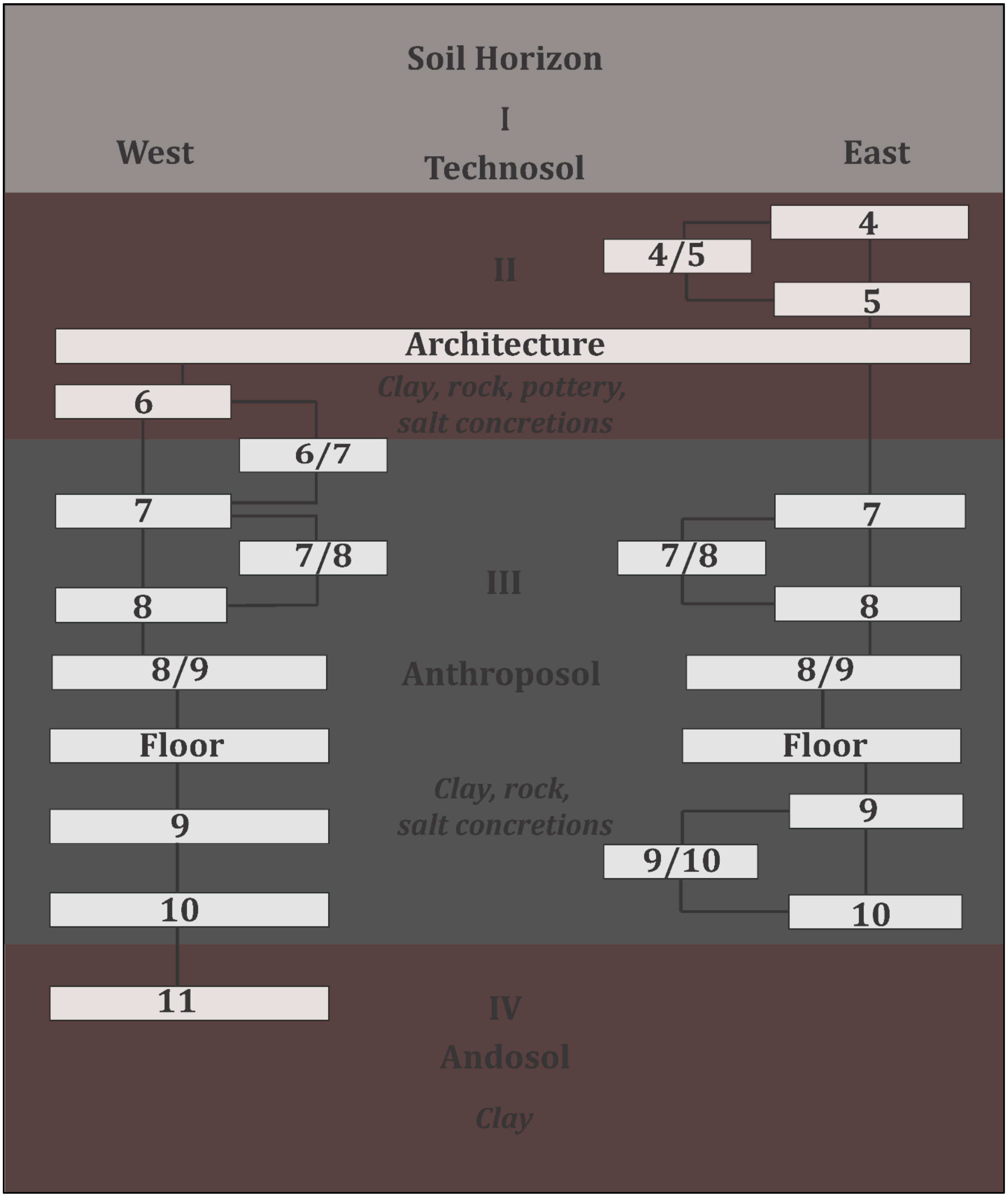
Supplemental Figure 3. 1 El Japón archaeological site map. Map adapted from González (1996).

Supplemental Figure 3. 2 Lower stratigraphy burials. Map adapted from Ávila López (1995).

Supplemental Figure 3. 3 Upper stratigraphy burials. Map adapted from Ávila López (1995).



Supplemental Figure 3. 4 Radiocarbon sampled burials. Red squares denote burials from upper stratigraphy. Yellow squares denote burials from lower levels. Adapted from Ávila López (1995).



Supplemental Figure 3. 5 Stratigraphic schema of El Japón cemetery site. Burial depth information from the San Gregorio Atlapulco salvage project (Ávila López 1995). Stratigraphic information is from geoarchaeological research (McClung de Tapia and Acosta Ochoa 2015).

Chapter 3. Appendix. OxCal Model Codes and Graphics

Model 1 Code

Single phase model that does not incorporate stratigraphic information. No calendar date is included.

```
Plot()
{
Sequence()
{
Boundary("Start all burials");
Phase("All burials")
{
R_Date("Burial 50", 399, 25)
R_Date("Burial 357", 361, 25);
R_Date("Burial 145", 360, 25);
R_Date("Burial 87", 355, 25);
R_Date("Burial 53", 350, 25);
R_Date("Burial 180", 330, 25);
R_Date("Burial 90", 300, 25);
R_Date("Burial 29", 370, 25);
R_Date("Burial 2", 370, 25);
R_Date("Burial 7", 330, 25);
```

R_Date("Burial 3", 312, 25);

Interval("All burial Interval");

};

Boundary("End all burials");

};

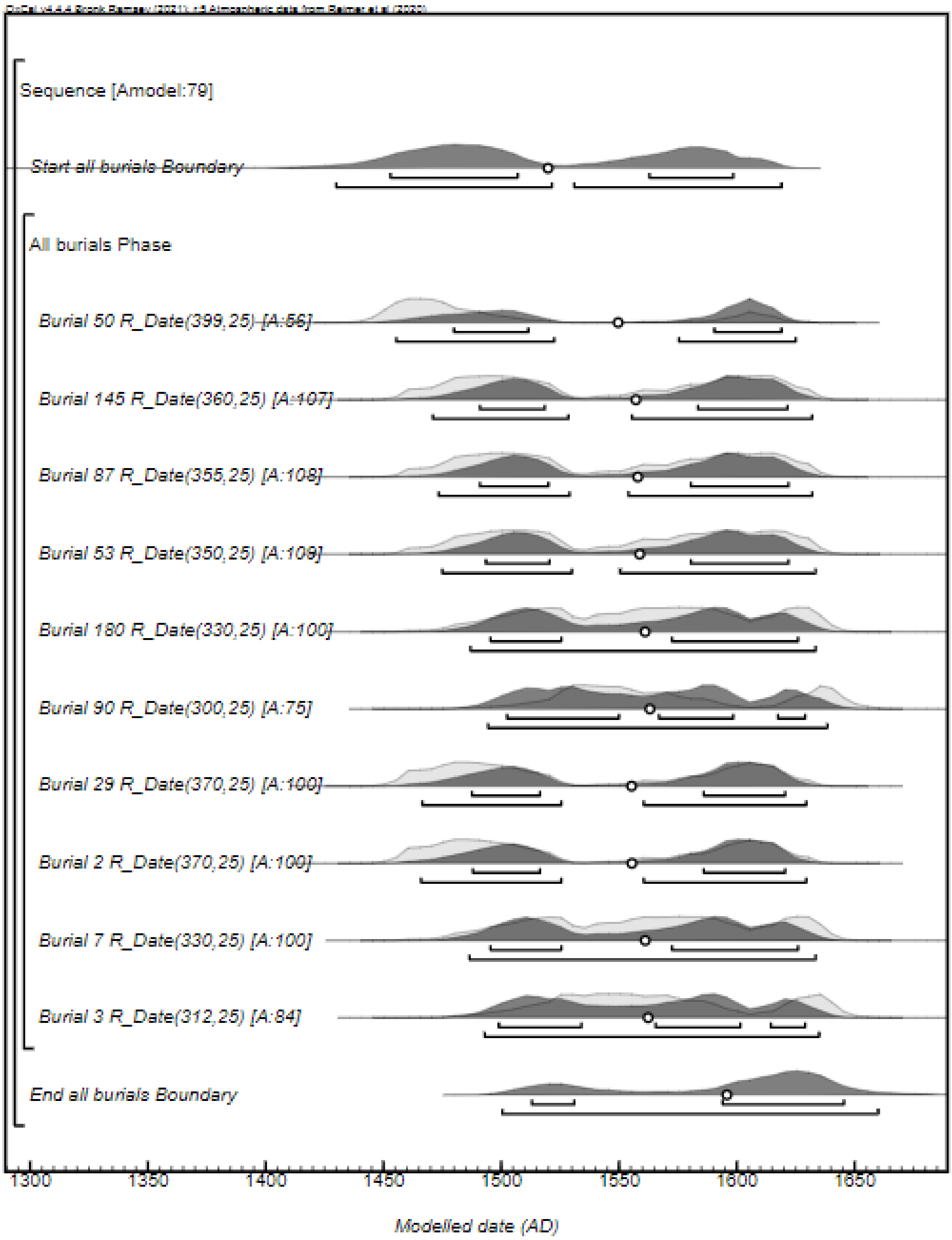
};

};

Model 1 Results

	Unmodelled				Modelled			
	68.3%		95.4%		68.3%		95.4%	
	From	To	From	To	From	To	From	To
Boundary, start					1453	1599	1430	1619
Burial 50	1449	1492	1441	1623	1480	1619	1456	1625
Burial 145	1475	1623	1457	1634	1491	1622	1471	1632
Burial 87	1478	1624	1459	1635	1491	1622	1474	1632
Burial 53	1482	1626	1465	1636	1494	1622	1475	1634
Burial 180	1505	1635	1485	1640	1496	1626	1487	1634
Burial 90	1523	1645	1500	1655	1503	1629	1495	1639
Burial 29	1461	1619	1454	1632	1488	1621	1467	1630
Burial 2	1461	1619	1454	1632	1488	1621	1466	1630
Burial 7	1505	1635	1485	1640	1496	1626	1487	1634
Burial 3	1521	1640	1496	1646	1499	1629	1493	1635
Interval, all burials					0	95	0	199
Boundary, end					1513	1646	1501	1660

Model 1 Plot


Sequence [Amodel:79]
Start all burials Boundary
All burials Phase
Burial 50 R_Date(399,25) [A:56]
Burial 145 R_Date(360,25) [A:107]
Burial 87 R_Date(355,25) [A:108]
Burial 53 R_Date(350,25) [A:109]
Burial 180 R_Date(330,25) [A:100]
Burial 90 R_Date(300,25) [A:75]
Burial 29 R_Date(370,25) [A:100]
Burial 2 R_Date(370,25) [A:100]
Burial 7 R_Date(330,25) [A:100]
Burial 3 R_Date(312,25) [A:84]
End all burials Boundary
1300
1350
1400
1450
1500
1550
1600
1650
Modelled date (AD)

Model 2 Code

Single phase model that does not incorporate stratigraphic information. No calendar date included. Burial 50 is flagged as an outlier.

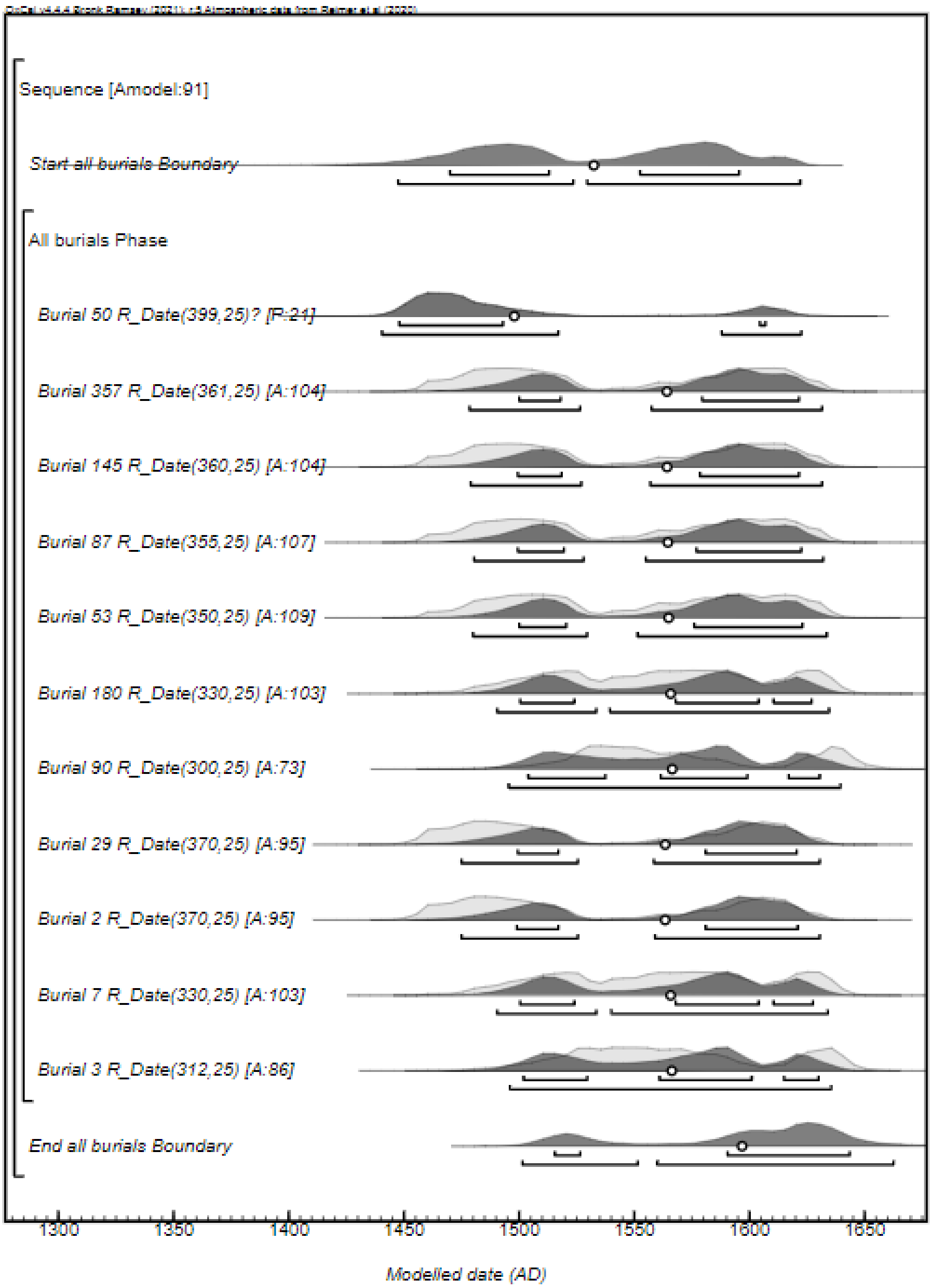
```
Plot()
{
Sequence()
{
Boundary(“Start all burials”);
Phase(“All burials”)
{
R_Date(“Burial 50”, 399, 25)
{
Outlier();
};
R_Date(“Burial 357”, 361, 25);
R_Date(“Burial 145”, 360, 25);
R_Date(“Burial 87”, 355, 25);
R_Date(“Burial 53”, 350, 25);
R_Date(“Burial 180”, 330, 25);
R_Date(“Burial 90”, 300, 25);
R_Date(“Burial 29”, 370, 25);
R_Date(“Burial 2”, 370, 25);
```

```
R_Date("Burial 7", 330, 25);

R_Date("Burial 3", 312, 25);

Interval("All burial Interval");

};

Boundary("End all burials");

};

};

};
```

Model 2 Results

	Unmodelled				Modelled			
	68.3%		95.4%		68.3%		95.4%	
	From	To	From	To	From	To	From	To
Boundary, start					1470	1596	1448	1622
Burial 50	1449	1492	1441	1623	1448	1607	1441	1623
Burial 357	1473	1623	1457	1634	1500	1622	1479	1632
Burial 145	1475	1623	1457	1634	1500	1622	1479	1632
Burial 87	1478	1624	1459	1635	1500	1623	1481	1632
Burial 53	1482	1626	1465	1636	1500	1623	1480	1634
Burial 180	1505	1635	1485	1640	1501	1627	1491	1635
Burial 90	1523	1645	1500	1655	1504	1631	1496	1640
Burial 29	1461	1619	1454	1632	1500	1621	1475	1631
Burial 2	1461	1619	1454	1632	1499	1621	1475	1631
Burial 7	1505	1635	1485	1640	1501	1628	1491	1634
Burial 3	1521	1640	1496	1646	1502	1630	1496	1636
Interval, all burials					0	79	0	182
Boundary, end					1516	1644	1502	1663

Model 2 Plot


Sequence [Amodel:91]
Start all burials Boundary
All burials Phase
Burial 50 R_Date(399,25)? [P:21]
Burial 357 R_Date(361,25) [A:104]
Burial 145 R_Date(360,25) [A:104]
Burial 87 R_Date(355,25) [A:107]
Burial 53 R_Date(350,25) [A:109]
Burial 180 R_Date(330,25) [A:103]
Burial 90 R_Date(300,25) [A:73]
Burial 29 R_Date(370,25) [A:95]
Burial 2 R_Date(370,25) [A:95]
Burial 7 R_Date(330,25) [A:103]
Burial 3 R_Date(312,25) [A:86]
End all burials Boundary
1300
1350
1400
1450
1500
1550
1600
1650
Modelled date (AD)

Model 3 Code

Two phase model separated by strata. No calendar date is included.

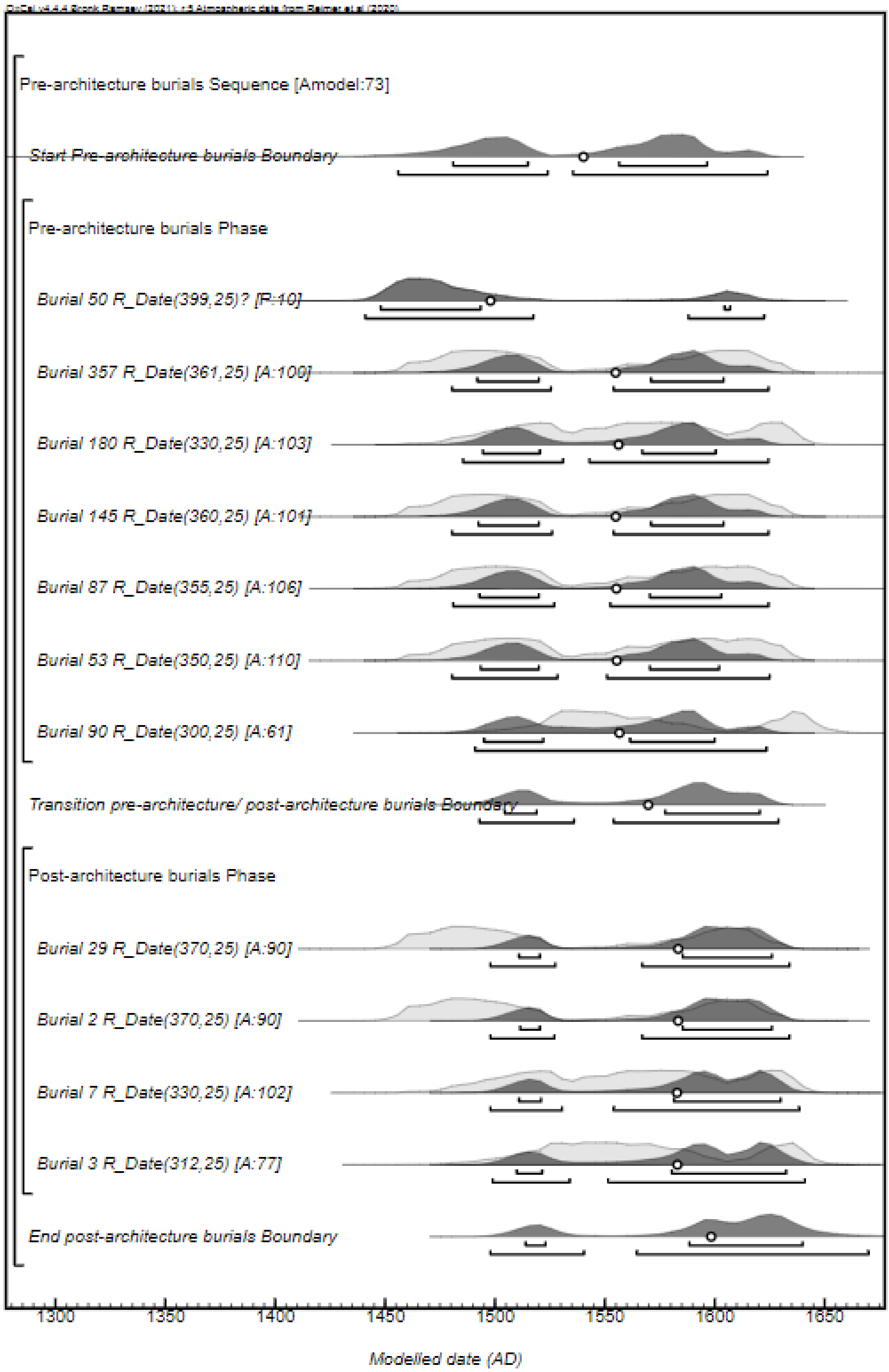
```
Plot()
{
Sequence(“Pre-architecture burials”)
{
Boundary(“Start Pre-architecture burials”);
Phase(“Pre-architecture burials”)
{
R_Date(“Burial 50”, 399, 25)
{
Outlier();
};
R_Date(“Burial 357”, 361, 25);
R_Date(“Burial 180”, 330, 25);
R_Date(“Burial 145”, 360, 25);
R_Date(“Burial 87”, 355, 25);
R_Date(“Burial 53”, 350, 25);
R_Date(“Burial 90”, 300, 25);
Interval(“Pre-architecture burials”);
};
Boundary(“Transition pre-architecture/ post-architecture burials”);
```

```
Phase("Post-architecture burials")

{

R_Date("Burial 29", 370, 25);

R_Date("Burial 2", 370, 25);

R_Date("Burial 7", 330, 25);

R_Date("Burial 3", 312, 25);

Interval("Post-architecture burials");

};

Boundary("End post-architecture burials");

};

};

};
```

Model 3 Results

	Unmodelled				Modelled			
	68.3%		95.4%		68.3%		95.4%	
	From	To	From	To	From	To	From	To
Boundary, start					1481	1597	1456	1624
Burial 50	1449	1492	1441	1623	1448	1607	1441	1623
Burial 357	1473	1623	1457	1634	1492	1604	1481	1625
Burial 180	1505	1635	1485	1640	1495	1601	1486	1625
Burial 145	1475	1623	1457	1634	1493	1604	1481	1625
Burial 87	1478	1624	1459	1635	1493	1603	1481	1625
Burial 53	1482	1626	1465	1636	1494	1602	1481	1625
Burial 90	1523	1645	1500	1655	1495	1600	1491	1624
Interval, lower burials					0	65	0	29
Boundary, transition					1568	1628	1580	1612
Burial 29	1461	1619	1454	1632	1591	1624	1579	1631
Burial 2	1461	1619	1454	1632	1587	1629	1579	1631
Burial 7	1505	1635	1485	1640	1585	1631	1576	1636
Burial 3	1521	1640	1496	1646	1574	1639	1574	1639
Interval, upper burials					0	66	0	28
Boundary, end					1577	1658	1594	1636

Model 3 Plot



Pre-architecture burials Sequence [Amodel:73]
Start Pre-architecture burials Boundary
Pre-architecture burials Phase
Burial 50 R_Date(399,25)? [P:10]
Burial 357 R_Date(361,25) [A:100]
Burial 180 R_Date(330,25) [A:103]
Burial 145 R_Date(360,25) [A:101]
Burial 87 R_Date(355,25) [A:106]
Burial 53 R_Date(350,25) [A:110]
Burial 90 R_Date(300,25) [A:61]
Transition pre-architecture/ post-architecture burials Boundary
Post-architecture burials Phase
Burial 29 R_Date(370,25) [A:90]
Burial 2 R_Date(370,25) [A:90]
Burial 7 R_Date(330,25) [A:102]
Burial 3 R_Date(312,25) [A:77]
End post-architecture burials Boundary
1300
1350
1400
1450
1500
1550
1600
1650
Modelled date (AD)

Model 4 Code

Two phase model separated by strata. Calendar date of 1521 is included.

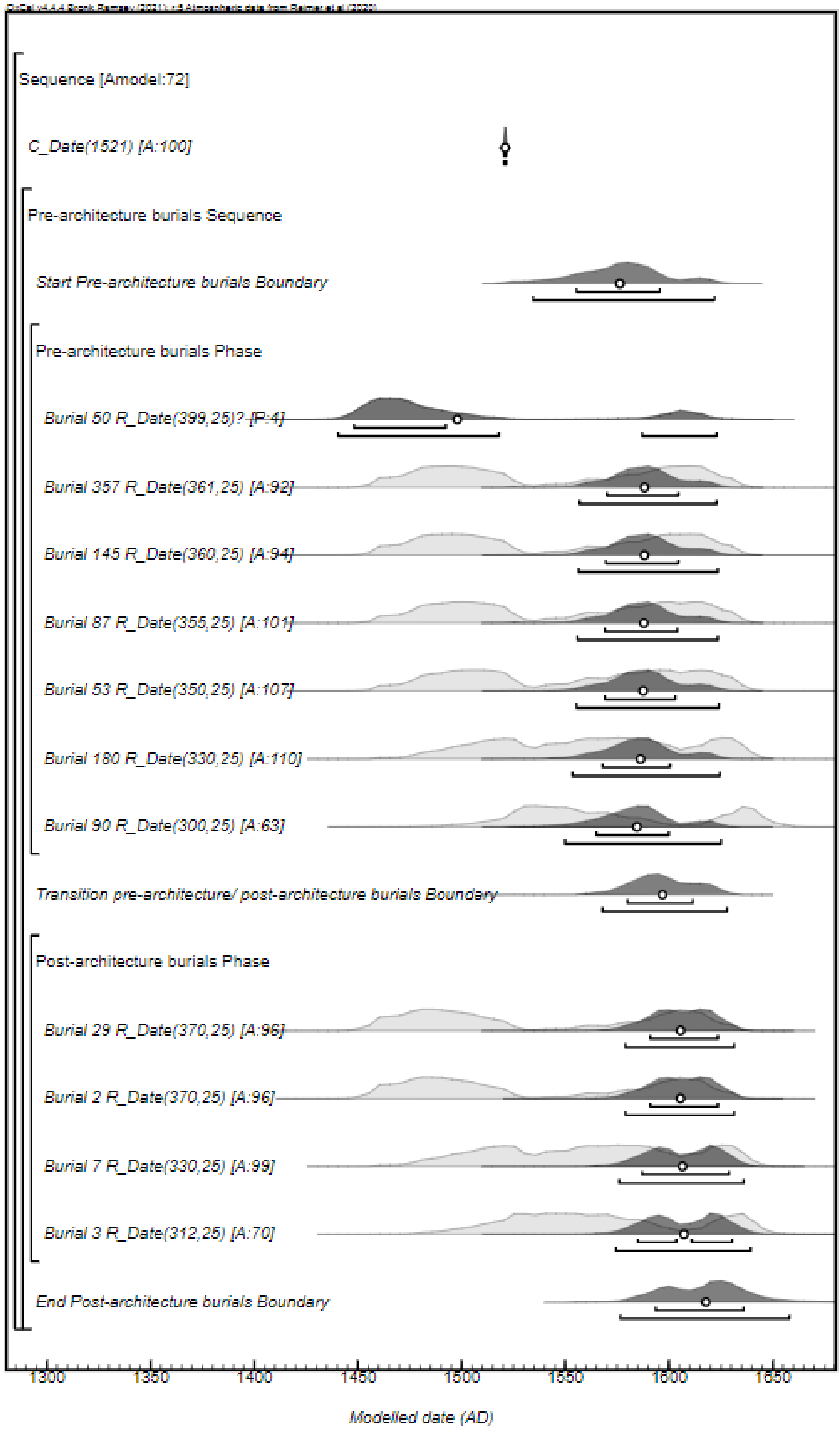
```
Plot()
{
Sequence()
{
C_Date(1521);
Sequence(“Pre-architecture burials”)
{
Boundary(“Start Pre-architecture burials”);
Phase(“Pre-architecture burials”)
{
R_Date(“Burial 50”, 399, 25)
{
Outlier();
};
R_Date(“Burial 357”, 361, 25);
R_Date(“Burial 145”, 360, 25);
R_Date(“Burial 87”, 355, 25);
R_Date(“Burial 53”, 350, 25);
R_Date(“Burial 180”, 330, 25);
R_Date(“Burial 90”, 300, 25);
```

```
Interval("Pre-architecture burials");

};

Boundary("Transition pre-architecture/ post-architecture burials");

Phase("Post-architecture burials")

{

R_Date("Burial 29", 370, 25);

R_Date("Burial 2", 370, 25);

R_Date("Burial 7", 330, 25);

R_Date("Burial 3", 312, 25);

Interval("Post-architecture burials");

};

Boundary("End Post-architecture burials");

};

};

};
```

Model 4 Results

C_Date(1521)	Unmodelled				1521 Modelled			
	68.3%		95.4%		68.3%		95.4%	
	From	To	From	To	From	To	From	To
Boundary, start					1556	1596	1535	1622
Burial 50	1449	1492	1441	1623	1448	1493	1441	1623
Burial 357	1473	1623	1457	1634	1570	1605	1557	1623
Burial 145	1475	1623	1457	1634	1570	1605	1557	1624
Burial 87	1478	1624	1459	1635	1569	1604	1556	1624
Burial 53	1482	1626	1465	1636	1569	1603	1556	1624
Burial 180	1505	1635	1485	1640	1568	1601	1554	1625
Burial 90	1523	1645	1500	1655	1565	1600	1550	1625
Interval, lower burials					0	29	0	65
Boundary, transition					1580	1611	1568	1628
Burial 29	1461	1619	1454	1632	1591	1623	1579	1631
Burial 2	1461	1619	1454	1632	1591	1623	1579	1631
Burial 7	1505	1635	1485	1640	1587	1629	1576	1636
Burial 3	1521	1640	1496	1646	1585	1630	1574	1639
Interval, upper burials					0	28	0	66
Boundary, end					1594	1636	1577	1658

Model 4 Plot



Sequence [Amodel:72]
C_Date(1521) [A:100]
Pre-architecture burials Sequence
Start Pre-architecture burials Boundary
Pre-architecture burials Phase
Burial 50 R_Date(399,25)? [P:4]
Burial 357 R_Date(361,25) [A:92]
Burial 145 R_Date(360,25) [A:94]
Burial 87 R_Date(355,25) [A:101]
Burial 53 R_Date(350,25) [A:107]
Burial 180 R_Date(330,25) [A:110]
Burial 90 R_Date(300,25) [A:63]
Transition pre-architecture/ post-architecture burials Boundary
Post-architecture burials Phase
Burial 29 R_Date(370,25) [A:96]
Burial 2 R_Date(370,25) [A:96]
Burial 7 R_Date(330,25) [A:99]
Burial 3 R_Date(312,25) [A:70]
End Post-architecture burials Boundary
1300
1350
1400
1450
1500
1550
1600
1650
Modelled date (AD)

Model 5 Code

```
Plot()
{
Outlier_Model(“General”,T(5),U(0,4),”t”);
Sequence()
{
C_Date(1521);
Boundary(“Pre-architecture burials”);
Phase(“Pre-architecture”)
{
R_Date(“Burial 50”, 399, 25)
{
Outlier(“General”,0.05);
};
R_Date(“Burial 357”, 361, 25)
{
Outlier(“General”,0.05);
};
R_Date(“Burial 145”, 360, 25)
{
Outlier(“General”,0.05);
};
R_Date(“Burial 87”, 360, 25)
```

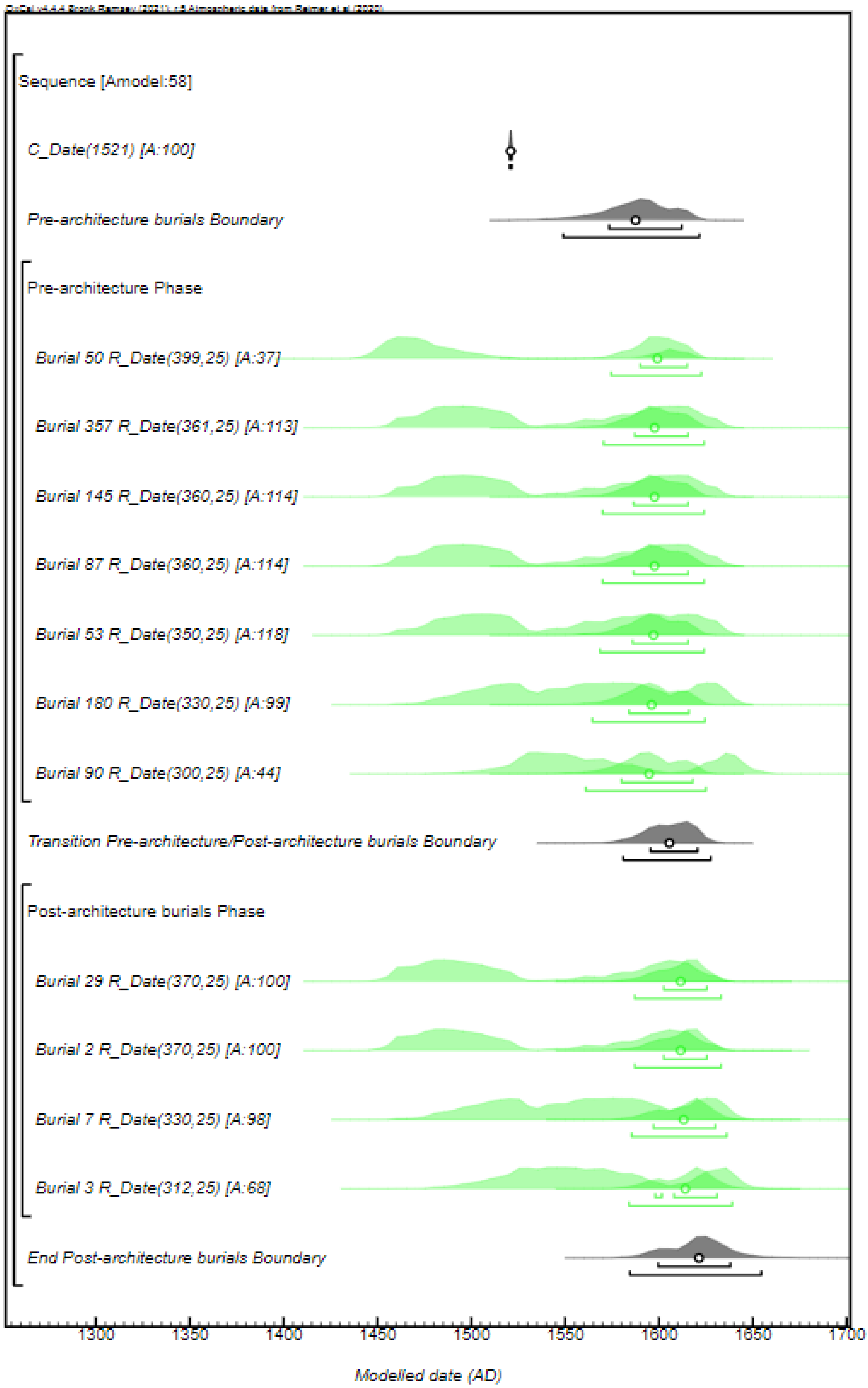
```
{
Outlier(“General”,0.05);
};
R_Date(“Burial 53”, 350, 25)
{
Outlier(“General”,0.05);
};
R_Date(“Burial 180”, 330, 25)
{
Outlier(“General”,0.05);
};
R_Date(“Burial 90”, 300, 25)
{
Outlier(“General”,0.05);
};
Interval(“Pre-architecture burials Interval”);
};
Boundary(“Transition Pre-architecture/Post-architecture burials”);
Phase(“Post-architecture burials”)
{
R_Date(“Burial 29”, 370, 25)
{
Outlier(“General”,0.05);
```

```
};
R_Date("Burial 2", 370, 25)
{
Outlier("General",0.05);
};
R_Date("Burial 7", 330, 25)
{
Outlier("General",0.05);
};
R_Date("Burial 3", 312, 25)
{
Outlier("General",0.05);
};
Interval ("Post-architecture burials Interval");
};
Boundary("End Post-architecture burials");
};
};
};
```

Model 5 Results

C_Date	Unmodelled				1521 Modelled			
	68.3%		95.4%		68.3%		95.4%	
	From	To	From	To	From	To	From	To
					1574	1612	1550	1622
Boundary, start	1449	1492	1441	1623	1590	1615	1575	1623
Burial 50	1473	1623	1457	1634	1587	1616	1570	1624
Burial 357	1475	1623	1457	1634	1587	1616	1570	1624
Burial 145	1475	1623	1457	1634	1587	1616	1570	1624
Burial 87	1482	1626	1465	1636	1586	1616	1568	1624
Burial 53	1505	1635	1485	1640	1584	1616	1565	1625
Burial 180	1523	1645	1500	1655	1580	1618	1561	1625
Burial 90					0	25	0	60
Interval, lower burials					1596	1620	1581	1628
Boundary, transition	1461	1619	1454	1632	1602	1626	1587	1633
Burial 29	1461	1619	1454	1632	1602	1626	1587	1633
Burial 2	1505	1635	1485	1640	1597	1630	1586	1636
Burial 7	1521	1640	1496	1646	1598	1631	1585	1639
Burial 3					0	21	0	51
Interval, upper burials					1606	1638	1585	1654

Model 5 Plot


Sequence [Amodel:58]
C_Date(1521) [A:100]
Pre-architecture burials Boundary
Pre-architecture Phase
Burial 50 R_Date(399,25) [A:37]
Burial 357 R_Date(361,25) [A:113]
Burial 145 R_Date(360,25) [A:114]
Burial 87 R_Date(360,25) [A:114]
Burial 53 R_Date(350,25) [A:118]
Burial 180 R_Date(330,25) [A:99]
Burial 90 R_Date(300,25) [A:44]
Transition Pre-architecture/Post-architecture burials Boundary
Post-architecture burials Phase
Burial 29 R_Date(370,25) [A:100]
Burial 2 R_Date(370,25) [A:100]
Burial 7 R_Date(330,25) [A:98]
Burial 3 R_Date(312,25) [A:68]
End Post-architecture burials Boundary
1300
1350
1400
1450
1500
1550
1600
1650
1700
Modelled date (AD)

Chapter 4. El Japón (San Gregorio Atlapulco, Xochimilco, Mexico): examining Colonial population continuity through dental nonmetric indicators of phenetic similarity [a]

a. Edgar Alarcón Tinajero [1, 2], Britney Kyle McIlvaine [3], Laurie J. Reitsema [1], Jorge A. Gómez-Valdés [4, 5], Lourdes Márquez Morfín [4]. To be submitted to the *American Journal of Biological Anthropology*.

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Abstract

Objectives

Archaeology, paleodemography, and historic records demonstrate long decline of Indigenous North American populations in the two centuries following initial European contact (Gibson 1964; Storey 2012; Márquez Morfín and Hernández Espinoza 2016). This study employs phenotypic indicators of biological relatedness to provide insight into population continuity in El Japón (ca. 1565–1650 CE) — a farming hamlet in the Xochimilco area of Mexico City — at a time when demographic decline and interethnic gene flow are documented.

Materials and Methods

Twenty-nine nonmetric dental traits were assessed in 143 adult skeletal remains of early colonial individuals from El Japón. Successively smaller subsets of eleven, nine, and seven traits with complete cases are used to compare phenotypic similarity of El Japón individuals to individuals from continental European, Asian, and North and South American archaeological human remains and to test the sensitivity of the model. Dental variation within the community of El Japón is compared to identify outliers and discuss diachronic change within the sample.

Results

The composite sample from El Japón presents low Mean Measures of Divergence (MMD) in comparison with other Indigenous communities of the Valley of Mexico that predate and postdate European contact. Variation in dental traits (Mahalanobis D^2) changed stochastically from the earlier to later period within El Japón with no significant changes.

Discussion

Based in the clustering of El Japón with other Basin of Mexico samples, gene flow from disparate populations was likely absent at El Japón in the decades following European contact to the eventual cease in use of the cemetery near 1640 CE. Outliers identified by Mahalanobis D^2 are of consistent magnitude in earlier and latter subsamples likely originating in other Indigenous populations rather than in previously isolated gene pools which include Europe.

Introduction

In colonial contexts, depressed autonomy of Indigenous inhabitants, encroachment on territory needed for sustenance, violence or the threat of violence are drivers of population relocation (Gibson 1964; Chuchiak 2006). Central Mesoamerica after Spanish contact is no exception as violent events are recorded within months of Spanish arrival in the central highlands (León-Portilla 2007). Epidemic diseases spread between North America and Eurasia where regular contact was near inexistent (Prem 1992; Newson 1993). Violence and disease of continental pandemic proportions influenced both voluntary and forced relocation (Stojanowski 2005; Chuchiak 2006; de la Torre Villar 2018). Mesoamerican populations declined in number due to health stress for more than a century after Spanish contact though (Storey 2012; Márquez Morfín and Hernández Espinoza 2016). The demographic context of the early colonial period in Mesoamerica was without a doubt one of population decline.

Bioarchaeological study of human remains is another approach towards understanding population history and this can be carried out via phenetics (Irish 2016) or study of similarities in predefined trait samples without a priori assumptions of descent or relatedness. In the context of colonial era Mesoamerica, two questions of population are central. These are when gene flow between Europeans and Indigenous Americans began and what the timing of population decline may be. Study of phenetic traits (including dental traits and cranial traits whether metric or nonmetric) provide evidence of diverse biological ancestries within individuals (admixture) and provide measures of population diversity within predefined population samples, e.g., a single archaeological site.

El Japón

El Japón archaeological cemetery site represents a hamlet settlement within the territory of the San Gregorio Atlapulco on the southern edge of Mexico City, Mexico (Figure 4. 1) occupied between *1565–1640* cal. CE (Chapter 3). Without a doubt, human habitation and resource extraction occurred in the area far earlier (McClung de Tapia and Acosta Ochoa 2015). The skeletal collection studied here proceeds from the colonial period cemetery area of the archaeological site (Supplemental Figure 4. 1). The early colonial origin presents an opportunity to examine hypothesized population change that may have occurred via gene flow or demographic decline due to colonization and the documented deleterious effects.

Like other marshland communities, El Japón was an agricultural town with secondary focus in craft production and collection of wild foods. Following Spanish contact, civil and religious authorities encouraged relocation of communities to aggregated locations: *congregaciones* (Cline 1949; Jalpa Flores 2008), facilitating proselytization, taxation and labor drafts (Ricard 1966; de la Torre Villar 1995; Zamudio Espinosa 2001; Megged 2020). The process of relocation lasted several decades generally occurring between 1530 and 1610 CE (Cline 1949; Jalpa Flores 2008). Nearby Xochimilco, and later San Gregorio Atlapulco would have been the *cabecera* or head town that held authority over smaller hamlets in its territorial jurisdiction including El Japón (Pérez Zevallos and Reyes García 2003). Legally recognized *pueblos de indios* (Rodríguez-Alegría 2010:55) or Indigenous towns, in the region included San Gregorio Atlapulco and Xochimilco (Conway 2014).

Figure 4. 1 Location of El Japón in the southern Basin of Mexico. Estimated maximum extent of chinampas in the southern Basin of Mexico (Armillas 1971) is filled iconographically. Major canals and causeways illustrated above are identified in multiple historical records (Palerm 1973). Map modified from an image with a Free Art License (YAVIDAXIU 2007).

In colonial New Spain, kinship and descent were the determinants of access to land and collective labor. Ethnohistoric accounts reveal geographically flexible kinship networks (Kellogg 1995). These regionally networks likely extended into the colonial period as marriage patterns between settlements were not directly manipulated by Spanish institutions (Kellog 1995). Postmarital residence norms were likely not strictly prescribed; women in early colonial Mesoamerica were as likely as men to inherit house plots and houses from a parent (Kellogg 1995). Though no prescriptive pattern of increasing interethnic marriage is assumed, interethnic gene flow (children from formal marriages and children of non-institutionalized marriages) in Mesoamerica seems to be low until an 18th century increase (Swann 1979; Pescador 1992).

The historical record of postcontact Mesoamerica is rich with detail of beliefs, genealogies, natural histories, and customs: including marriage and partnership customs (Soustelle 1956; Anderson and Dibble 1975). Formal marriages and procreation between European and Indigenous individuals are documented in the first years following Spanish arrival. Assessment of the biological remains of humans presents an independent opportunity to evaluate the process of gene flow. Gene flow through partnerships, formalized marriages and creation of nuclear families and new kin networks occurred throughout the Americas. That is undoubted. The rapidity of the process however is less explored.

Population Continuity and Skeletal Data

The study of phenetics is an approach toward exploring descent and gene flow between populations relying on observed and standardized biological traits (Irish 2016). These biological traits in skeletonized remains include metric cranial traits and nonmetric dental traits (Stojanowski, and Schillaci 2006). Nonmetric dental traits are selected for this study. Dental nonmetric traits are slight variations in tooth enamel and roots and are demonstrated stochastically expressed genetic bases (Scott and Turner 1997; Hubbard et al. 2015; Irish et al. 2020). Nonmetric dental traits in adult teeth reflect biological relatedness between individuals and populations (Pilloud et al. 2016; Hanihara 2008; Rathmann and Reyes-Centeno 2020). Populations that share biological ancestry, and therefore genes, are more likely to share similarity dental traits or dental traits in similar degrees of expression. Dental nonmetric traits are not driven by natural selection (Pilloud et al. 2016) and are therefore reliable indicators of relatedness. Comparison of population samples from multiple continents (e.g., Europe, Asia, North America) permits contextualization of other bioarchaeological proxies of lived experiences. For example, a sample of Mestizo individuals (persons of mixed Indigenous and European ancestry) would likely have traits intermediate between traits typically found in European and Indigenous American populations predating European contact.

Previous assessments of dental morphology from the 14th to 17th century Basin of Mexico identify geographic isolation (Willermet et al. 2013), overlapping biological populations (Aubry 2009; Willermet et al. 2013), as well as population replacement (González-José et al. 2007; Ragsdale et al. 2019). Ragsdale and collaborators (2017 and 2019) employ dental nonmetric traits to examine population affinities within Postclassic Mesoamerica (900–1520 CE) as well as to examine population affinity between late Postclassic (1300–1521 CE) and Colonial (1521–1821 CE) populations. Ragsdale et al.'s (2017 and 2019) findings support the interpretation of biological affinity and gene flow between communities and polities with close economic, political, and religious ties. Mesoamerica shared phenetic similarity rooted in high gene flow across political and linguistic boundaries (Ragsdale 2017).

Here, it is hypothesized that patterns of intraregional gene flow may have continued in the early decades of the colonial period in the Basin of Mexico. Nahuatl-speaking communities of Xochimilcan ethnic identity may have continued in patterns of regional gene flow and it is expected that the inhabitants of the El Japón area may have intermarried and recognized kin relationships between themselves. Because El Japón is sample that spans nearly a century, it is also possible to examine intrapopulation variation.

Assessing phenetic similarity within a community is one approach to identifying gene flow in a 16th century population experiencing sociopolitical change. Based in the kin-based social and kinship units that secured both land tenure and access to collective labor, it is hypothesized here that interethnic gene flow may have been undesirable to the chinampa agriculturalists of the Xochimilco area. The continuity of an Indigenous way of life, Indigenous agriculture, and land sovereignty may have gone hand in hand with closed kinship networks.

Materials and Methods

Twenty-nine dental traits (Supplemental Table 4. 1) were collected on 143 adult individuals from the San Gregorio Atlapulco/ El Japón bioarchaeological collection curated at the Escuela Nacional de Antropología e Historia. Burial depth information from the San Gregorio Atlapulco salvage project (Ávila López 1995) and radiocarbon chronology (Chapter 3; Alarcón Tinajero 2022) permit identification of an early and late El Japón sample that spans ca. *1565–1640 cal.* CE.

Nonmetric traits are scored as completely absent or in ordinal degrees of expression following standard methods (Edgar 2017; Scott and Irish 2017). Teeth from El Japón individuals were often preserved in alveolar bone making observation of root traits impossible without bioimaging or damage to skeletal remains. No dental root traits were used to compare El Japón individuals to each other or to other populations.

Unpublished data from Xochimilco, Santa Cruz y Soledad, Los Reyes/ La Paz and Tlatelolco was provided by Dr. Corey Ragsdale. Thirty-two comparative samples from Europe, Asia, the Pacific Islands, and the Americas spanning approximately 2500 BCE-1900 CE were collected from among 67 available published datasets (Scott and Irish 2017: 267-271). Published comparative data with broad age designations were avoided (e.g., prehistoric period).

Eleven traits that are found to have high utility estimates (sensu, Rathmann and Reyes-Centeno 2020) were selected as they offer greater discriminatory power between population samples. The dataset of thirty-two population samples was further narrowed to 23 population samples where 11 high-utility variables are present in all cases. A *battery* (Rathmann and Reyes-Centeno 2020) of eleven high-utility dental crown traits (identified in Table 4. 1) were selected for biodistance analysis between populations. An increasingly reduced battery of 9 and 7 traits (Supplemental Table 4. 1) was used to test the sensitivity of the dendrogram model to the selection of specific traits. The iterative datasets relied on the same 23 population samples. Intrapopulation analysis generally employed the same traits as interpopulation analysis with some necessary modification. When comparing El Japón individuals to each other, upper molar enamel extension (UMEE) was used in place of first upper molar enamel extension (UM1EE). UMEE (Edgar 2017) records the maximum expression of enamel extension on any upper molar.

Table 4. 1 Nonnmetric Dental Traits selected for Biodistance Analyses

Trait	Trait Abbreviation	Present	Absent
Upper first incisor double shoveling † ‡	UI1DS	2–6 §	0–1
Upper second incisor interruption groove † ‡	UI2IG	1–4 §	0
Upper canine distal accessory ridge † ‡	UCDAR	2–5 §	0–1
Upper second molar hypocone † ‡	UM2HC	2–5 §	0–1
Upper first molar Carabelli's cusp † ‡	UM1CB	2–7 §	0–1
Upper molar enamel extension ‡ ††	UMEE	1–3 ¶	0
Lower fourth premolar lingual cusp † ‡	LPM4LC	2–3 §	0–1
Lower first molar deflecting wrinkle † ‡	LM1DW	2–3 §	0–1
Lower first molar trigonid crest ‡	LM1TC	1 §	0
Lower first molar protostylid † ‡	LM1PS	2–7 §	0–1
Lower second molar groove pattern †	LM2GP	1 (Y) §	2–3 (+, X)
Lower second molar cusp number †‡	LM2CN	5–6 ¶	3–4
Lower second molar fifth cusp ‡	LM2C5	1–5 §	0
Lower first molar seventh cusp †	LM1C7	2–4 ¶	0–1

† 11 traits used in interpopulation analysis.
‡ 12 traits used in intrapopulation analysis.
§ Breakpoint source is Scott and Irish (2017).
¶ Breakpoint source is Edgar (2017).
†† Maximum expression on any upper molar, consistent with Edgar (2017).

Breakpoints to dichotomize presence and absence of traits were selected from relevant literature (Edgar et al. 2017; Scott and Irish 2017). Dichotomized data is used to calculate Mean Measures of Divergence (MMD) of each population sample pair using the R package AnthropMMD (Santos 2018). Multidimensional scaling graphically demonstrates the similarity of populations based on the MMDs.

Population-level presence/absence data was examined for correlation between traits using a correlogram of Spearman's rank correlation coefficients (Supplemental Figure 4. 2). Non-dichotomized data was used to calculate Spearman's rank correlation coefficients between traits within El Japón individuals (Supplemental Figure 4. 3). Pearson correlation coefficients were not used because sample sizes varied greatly between populations: multiple without normal distribution. Spearman's rank correlation coefficients of paired traits are identified as weakly correlated (ρ=0.01–0.25), moderately correlated (ρ=0.26–0.50), strongly correlated (ρ=0.51–0.75), or very strongly correlated (ρ=0.76–0.99). Strongly correlated traits are identified to prevent inclusion and positively biased estimation of phenetic similarity between population samples.

Second lower molar groove pattern (LM2GP) was removed from intrapopulation analysis since it displayed no variation, thus providing no power in estimating divergence of phenotypic traits between individuals (Supplemental Figure 4. 5). The degree of expression of the first lower molar trigonid crest and first lower molar protostylid correlate moderately negatively within El Japón individuals (Spearman's ρ=- .30). No stronger correlations were found, and the pair of traits was not excluded.

Interpopulation analysis was completed through the AnthropMMD interface that permits manual selection of traits and formulae. The default angular transformation formula for trait frequencies in AnthropMMD is used here: Anscombe's formula (Santos 2018). Fisher's exact tests in the AnthropMMD interface were selected to identify pairs of samples that did not differ at a an alpha significance level of 0.05, consistent with Harris and Sjøvold (2004). When dental traits vary little between population samples, the "contribution to the MMD will not be zero" (Harris and Sjøvold 2004:91) and may risk overestimating affinities. A minimal sample size of 10 individuals per population sample was used. Ward's D^2 method was used to group samples based on similarity.

Intrapopulation analysis for El Japón individuals is carried out via calculation of Mahalanobis distances (Mahalanobis D^2). Mahalanobis D^2 is a measure of the dissimilarity of samples with higher values indicating greater dissimilarity. "Pseudo" Mahalanobis' D^2 (McIlvaine 2014 after Konigsberg 1990) was not employed because strongly correlated traits were removed prior to calculation of Mahalanobis D^2.

Results

Interpopulation Comparison

In comparison of pairwise-complete observations among 64 populations (primarily Europe, Asia, and North American Indigenous) strong Spearman's rank correlations were found between the following variable pairs: UI1SS and UM1EE, UI1SS and LM2CN, UI1SS and LM1DW, and UI1DS and UM1EE, UCDAR and UM2HC, UCDAR and LM2CN, and UM2HC and UM1C5, UM1EE and LM1RN, UPM3RN and LPM4LC, UM2RN an LPM4LC (Supplemental Figure 4. 2). No very strong correlations were found among the samples. Identification of the strong correlations allowed for selection of traits to be excluded in graphics and further analysis.

The complete sample from El Japón clusters most closely with four samples from the southern Basin of Mexico that date to the Postclassic period (900–1520 CE) and colonial period (1521–1821 CE): Xochimilco, Santa Cruz y Soledad, Los Reyes/ La Paz, and Tlatelolco (Figure 2.2). The El Japón sample and four southern Basin of Mexico samples cluster separately from the Guasave (600–1400 CE) and Cuicuilco samples (Formative period, 2,000 BCE– 200 CE). The Guasave skeletal samples (600–1400 CE, (Ragsdale 2017)) are from northwestern Mexico and the Cuicuilco samples are from the southern Basin of Mexico but predate the other southern Basin of Mexico samples by at least 1,300 years. In comparison to the East Asian, Pacific Island, and European samples, the five southern Basin of Mexico samples (including El Japón) cluster most closely with six other Indigenous North and South American population samples (data from Scott and Irish 2017). The Indigenous North and South American samples in turn cluster farthest from European and Asian samples.

The results of the hierarchical cluster analyses based on 11 and 9 traits (Figure 4. 2 and Supplemental Figure 4. 4) are broadly consistent with global scale history of population movement. As such, Indigenous North American populations cluster with populations with more recent genetic links (i.e., East Asia). The hierarchical model based on 7 traits (Supplemental Figure 4. 4) performed notably worse than the model based on 11 and 9 traits implying greater similarity between Indigenous North American and Southeast Asian populations that are not known to have close genetic links, e.g. (20th c. Malay, 16th c. Iroquois, and Formative period Cuicuilco). Adequate performance of the 11 and 9 trait models justified the use of those trait batteries for intrapopulation analysis with only minor modification to include high-utility traits that may not have been used in interpopulation comparison due to absence in multiple cases.

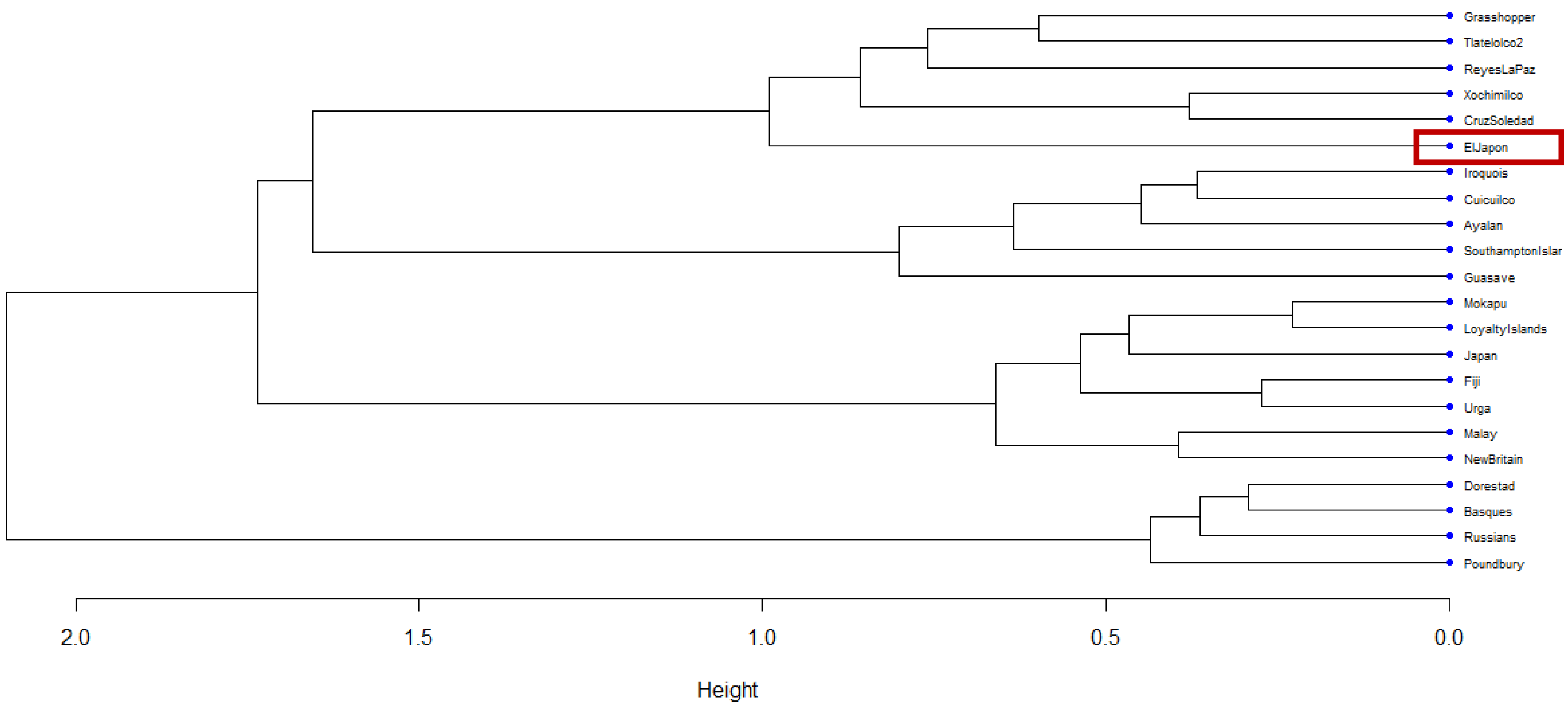

Figure 4. 2 Twenty-three population Hierarchical Cluster Diagram from 11 high utility traits. "Tlatelolco2" is labeled as such to differentiate from the Tlatelolco sample published by Scott and Irish (2017) which is not used here. Plot created using AnthropMMD in R (Santos 2018).

Intrapopulation Comparison

Individual scores of dental traits are presented in Supplemental Table 4. 2. Based in a battery of 12 traits, mean Mahalanobis D^2 of El Japón individuals decrease in more recent burials (Upper Stratigraphy, burial Layers 7–4) in comparison to burials of Lower Stratigraphy (burial layers 7.5–11). Statistical outliers (significance, $p<0.05$) in latter strata are all males while the earlier strata outliers are both male and females. Sex-based differences must be read with caution due to extreme difference in sample sizes between strata.

Table 4. 2 Summary of Mahalanobis D^2 Results

Group (*n*)	Battery	Mahalanobis D^2 Mean and Standard Deviation
Lower Stratigraphy (32)	11 Traits	11.2 ± 4.9
Upper Stratigraphy (5)	11 Traits	10.5 ± 6.4
Lower Stratigraphy (32)	12 Traits	12.7 ± 5.3
Upper Stratigraphy (5)	12 Traits	11.1 ± 6.7

A similar interpretation of decreasing variation is made from a battery of 11 traits as Mahalanobis D^2 within El Japón gradually decreases from earlier to later burials (Supplemental Figure 4. 6). As with the battery of 12 traits, decrease in calculated indicators of phenetic distance are not statistically distinct between the earlier and later burials. Statistical outliers are again all males in the more recent burial group.

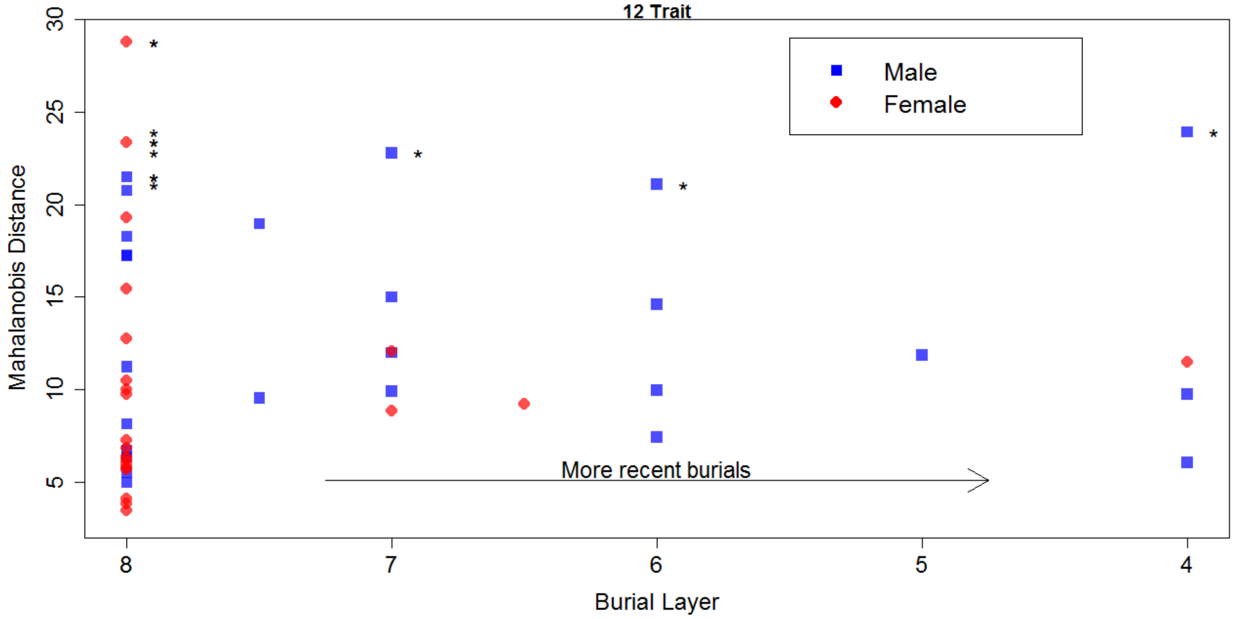

Figure 4. 3 Mahalanobis D^2 scores plotted against burial layers. Shallower stratigraphy is consistent with more recent burials while the deepest layers are consistent with older burials (Chapter 3; Alarcón Tinajero 2022). Asterisk-marked individuals are identified as outliers from the whole sample mean at significance level of $p<0.05$.

Discussion

Analysis of genetically determined nonmetric dental traits groups El Japón samples with Indigenous communities that predate and postdate European colonization (Figure 2.2) indicate the individuals buried at the early colonial El Japón cemetery (1565–1650 CE) were Indigenous individuals rather than persons of mixed European and Indigenous American ancestries. The results of hierarchical models based on phenetic relatedness are sensitive to the specific traits selected. An 11-trait model is favored over reduced models of 9 and 7 traits (Supplemental Figure 4. 4) based on inclusion of a more expansive comparative dataset of population samples using high-utility traits (Rathmann and Reyes–Centeno 2020).

The hierarchical models carried out in this project permit interpretation that individuals buried in the early colonial period cemetery had genetic links to local communities that survived the early Spanish empire, namely Tlatelolco. As an agricultural hamlet reliant on labor intensive methods, El Japón residents may have opted to continue idealized and executed regionally or ethnically endogamous patterns following European contact.

The distinct cluster of five southern Basin of Mexico samples in the hierarchical dendrogram model (Figure 2.2) is consistent with existing understanding that postclassic populations of central Mesoamerica shared phenetic similarity rooted in high gene flow across political and linguistic boundaries (Ragsdale 2017). The five population samples in question share phenetic similarity despite the early colonial origin of most samples. Patterns of primarily intraregional gene flow may have continued in the early decades of the colonial period in the Basin of Mexico.

The intrapopulation analysis demonstrates marginal decrease in phenotypic dental variation within the El Japón sample, seemingly at odds with the expectation of decline in phenetic and genetic diversity decline due to demographic decline of North American Indigenous populations following European contact (Prem 1992; Newson 1993; Storey 2012). Documented demographic loss following decades of epidemic pressure (Storey 2012) decreased genetic variation in Indigenous populations in the Valley of Mexico (Ragsdale et al. 2019). This pattern of genetic diversity decrease may not be adequately captured in the hamlet site of El Japón due to the sample size rather than to some intrinsic difference in genetic diversity.

Geographic consolidation of Indigenous towns was of interest to Spanish authorities (Jalpa Flores 2008). Population replacement or significant gene flow in the Xochimilco area is not supported by the 17th century narrative which emphasizes the lack of Europeans in the area compared to larger cities in the Valley of Mexico (Conway 2014). The presented dental phenetic analysis corroborates that historical understanding for a narrow chronological sample (1565–1640 CE, Chapter 3) of a farming hamlet: populations persistence prior to potential abandonment or relocation of the settlement in the mid-17th century. Genetic diversity, and concomitantly phenetic diversity, may have remained consistent at the geographically isolated site of El Japón for at least a few decades after the onset of European colonization.

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Chapter 4. Appendix. Supplemental Data.

Supplemental Table 4. 1 Twenty-nine Examined Nonmetric Dental Traits

Abbreviation	**Trait**
UI1WING	Upper first incisor winging
UI1SS	Upper first incisor shovel shape
UI1DS	Upper first incisor double shoveling †
UI2IG	Upper first incisor interruption groove † ‡ §
UI2TD	Upper second incisor tuberculum dentale
UCMR	Upper canine mesial ridge
UCDAR	Upper canine distal accessory ridge † ‡ §
UPM3DS	Upper third premolar distosagittal ridge
UM2HC	Upper second molar hypocone † ‡ §
UM1C5	Upper first molar 5th Cusp
UM1CB	Upper first molar Carabelli's Cusp †
UM3PS	Upper third molar parastyle
UMEE	Upper molar enamel extension
UPM3RN	Upper third premolar root number
UM2RN	Upper second molar root number
UM3PRM	Upper third molar peg-shaped, reduced size, or congenitally missing
LPM4LC	Lower fourth premolar lingual cusp † ‡
LM2GP	Lower second molar groove pattern † ‡ §
LM1CN	Lower first molar cusp number
LM2CN	Lower second molar cusp number † ‡
LM1DW	Lower first molar deflecting wrinkle † ‡ §
LM1TC	Lower first molar trigonid crest
LM1PS	Lower first molar protostylid † ‡ §
LM1C7	Lower first molar 7th Cusp † ‡ §
LM2C5	Lower second molar 5th Cusp
TOMES	Tome's Root
LCRN	Lower canine root number
LM1RN	Lower first molar root number
LM2RN	Lower second molar root number
ODONTOME	Odontome (any premolar)

† Included in 11 trait interpopulation comparison
‡ Included in 9 trait interpopulation comparison
§ Included in 7 trait interpopulation comparison

Supplemental Table 4. 2 Individual Nonmetric Scores for El Japón Individuals

Tooth	UI2		UC	UM2	UM1	UM	LPM4	LM1			LM2		
Trait	DS	IG	DAR	HC	CB	EE	LC	DW	TC	C7	GP	CN	C5
Burial													
1	4	3	1	3	6	3	0	1	0	0	2	6	3
3	-	-	-	-	0	0	1	-	0	0	2	4	0
6	0	0	-	-	-	-	1	0	0	0	2	5	3
7	3	1	0	-	5	-	6	3	0	0	2	4	0
25	-	-	-	-	-	-	1	2	1	0	2	5	3
19	0	0	3	0	0	1	1	1	0	0	2	4	0
22	0	2	0	2	1	0	1	2	0	1	2	5	4
33	-	-	-	-	-	-	-	-	-	-	-	-	-
33A	0	0	-	-	-	-	1	0	0	0	0	4	0
39	1	3	0	3	0	1	1	0	1	0	1	5	4
15	0	4	0	3	0	2	3	-	0	0	1	5	3
29	2	0	2	2	1	2	2	1	0	0	1	4	0
35	-	0	0	2	0	2	1	2	0	0	2	4	0
46	0	1	0	2	1	0	1	0	1	0	0	4	0
51	1	0	1	0	0	-	1	2	1	0	2	6	1
52	1	1	-	4	0	2	1	2	0	0	1	4	0
53	3	1	0	2	7	2	1	0	0	0	0	4	0
55	1	4	0	3	3	1	2	1	0	2	0	5	3
59	-	-	0	2	1	0	0	1	0	0	1	5	4
60	0	2	-	1	0	2	-	-	-	-	-	-	-
136	0	0	-	2	0	0	1	0	0	0	2	5	3
13	0	4	-	3	0	1	1	-	0	0	2	5	4
50	1	3	0	2	0	1	2	3	0	0	1	5	4
27	3	0	0	2	2	1	4	1	0	0	2	5	4

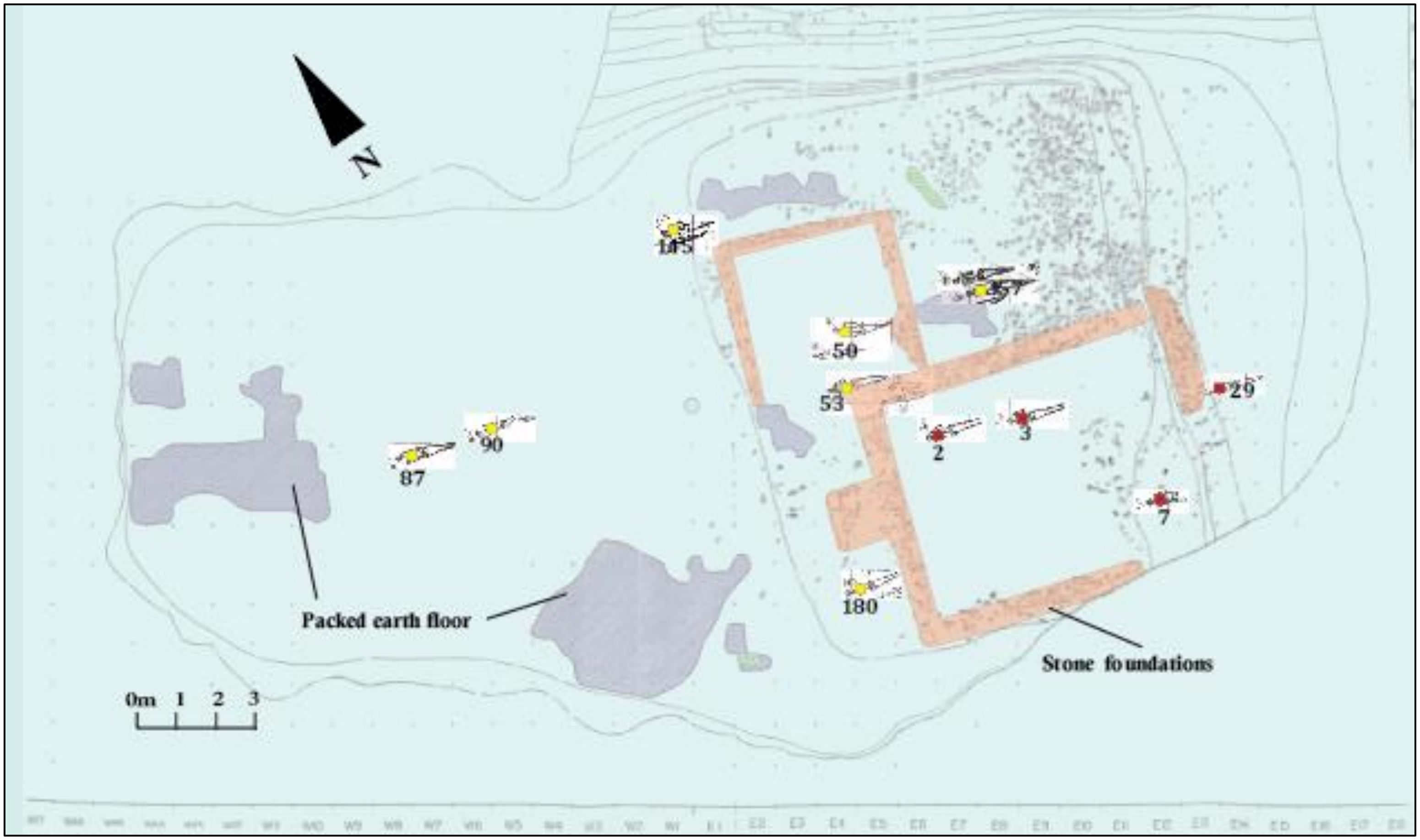
31	0	2	0	3	1	1	1	0	0	0	1	5	4
48	4	3	1	2	1	1	1	2	0	0	2	4	0
49	-	-	0	-	-	0	-	-	-	0	-	-	-
58	1	0	0	3	0	1	2	0	0	0	2	5	4
61	0	0	1	2	2	0	2	1	1	0	0	6	1
62	0	2	2	2	3	1	2	4	0	0	2	5	2
69	5	0	-	3	0	1	4	-	1	0	2	4	0
80	2	2	3	3	2	0	1	1	0	0	2	5	4
83	1	0	-	-	-	-	-	-	-	-	-	-	-
87	1	0	0	2	2	1	3	0	1	2	0	5	4
88	1	0	0	2	2	1	1	1	1	0	2	5	3
90	1	0	-	-	-	-	1	0	0	0	0	4	0
91	3	1	0	3	0	3	1	0	0	0	1	5	4
96	0	0	0	0	2	0	2	3	0	0	1	5	4
97	1	2	0	5	3	1	2	0	0	0	2	5	0
102	1	0	1	2	2	2	1	-	-	0	1	5	3
103	-	-	-	-	-	-	6	0	0	0	0	5	2
108	0	3	0	2	0	1	4	0	0	0	0	5	1
109	0	0	0	-	0	1	-	-	-	-	-	-	-
110	0	0	0	0	0	2	7	1	0	0	2	5	4
112	1	0	-	3	0	1	2	0	0	0	2	5	4
113	0	4	1	0	1	0	1	0	0	0	2	4	0
113A	-	-	-	-	-	-	1	1	0	0	1	4	0
116	0	0	-	-	-	-	1	-	-	0	-	4	0
117	1	2	-	3	0	0	1	-	-	0	0	4	0
119	1	1	1	3	2	1	2	0	0	0	2	4	0
120	2	0	0	5	6	0	1	0	0	0	0	5	4
126	5	0	3	3	0	1	1	3	0	0	2	4	0
127	5	0	2	0	1	0	1	0	0	0	2	4	0
129	0	2	0	0	1	2	1	1	-	0	0	5	4

138	1	0	0	2	1	2	1	3	1	0	2	5	2
139	-	0	-	-	-	0	4	-	0	-	-	-	-
142	1	1	-	0	-	-	1	-	0	0	-	4	0
143	-	-	-	-	-	-	1	-	-	0	2	5	4
153	0	0	0	2	1	0	1	1	0	0	2	4	0
156	0	4	0	3	0	0	2	1	0	0	1	4	0
162	1	2	-	0	0	1	4	-	1	0	2	4	0
170	-	-	-	-	-	-	-	-	-	-	-	-	-
171	-	-	-	-	0	1	-	-	-	-	-	-	-
180	1	0	0	3	0	1	1	0	0	0	2	5	4
181	-	-	-	-	-	-	-	-	-	-	-	-	-
184	0	0	4	2	0	0	1	0	0	0	2	5	3
185	-	-	-	2	1	1	1	0	-	0	1	4	0
192	0	2	0	2	0	2	-	-	-	-	-	-	-
194	-	-	-	-	-	-	6	0	0	0	1	4	0
197	-	-	-	-	-	-	2	0	0	0	1	5	3
202	0	0	0	2	0	0	2	-	0	0	2	4	0
208	0	3	0	2	0	0	1	-	-	0	-	-	0
212A	1	0	2	3	2	1	2	3	0	0	2	5	2
218	0	4	4	2	1	1	2	0	1	0	2	5	4
219	0	2	0	2	-	2	-	-	-	-	-	-	-
220	0	0	0	0	1	2	0	0	0	0	1	5	3
221A	-	-	-	-	-	-	1	0	0	0	2	5	4
221B	0	4	0	0	1	0	2	0	0	0	2	5	4
222	0	0	-	2	0	0	1	-	-	0	2	-	-
223	0	0	0	0	0	1	1	0	0	0	2	4	0
227	0	0	-	-	-	-	-	2	-	0	1	4	0
228	-	-	-	-	0	0	-	-	-	-	-	-	-
230	-	-	-	-	-	-	-	-	0	0	1	3	0
232	0	0	1	4	2	1	-	-	-	-	-	-	-

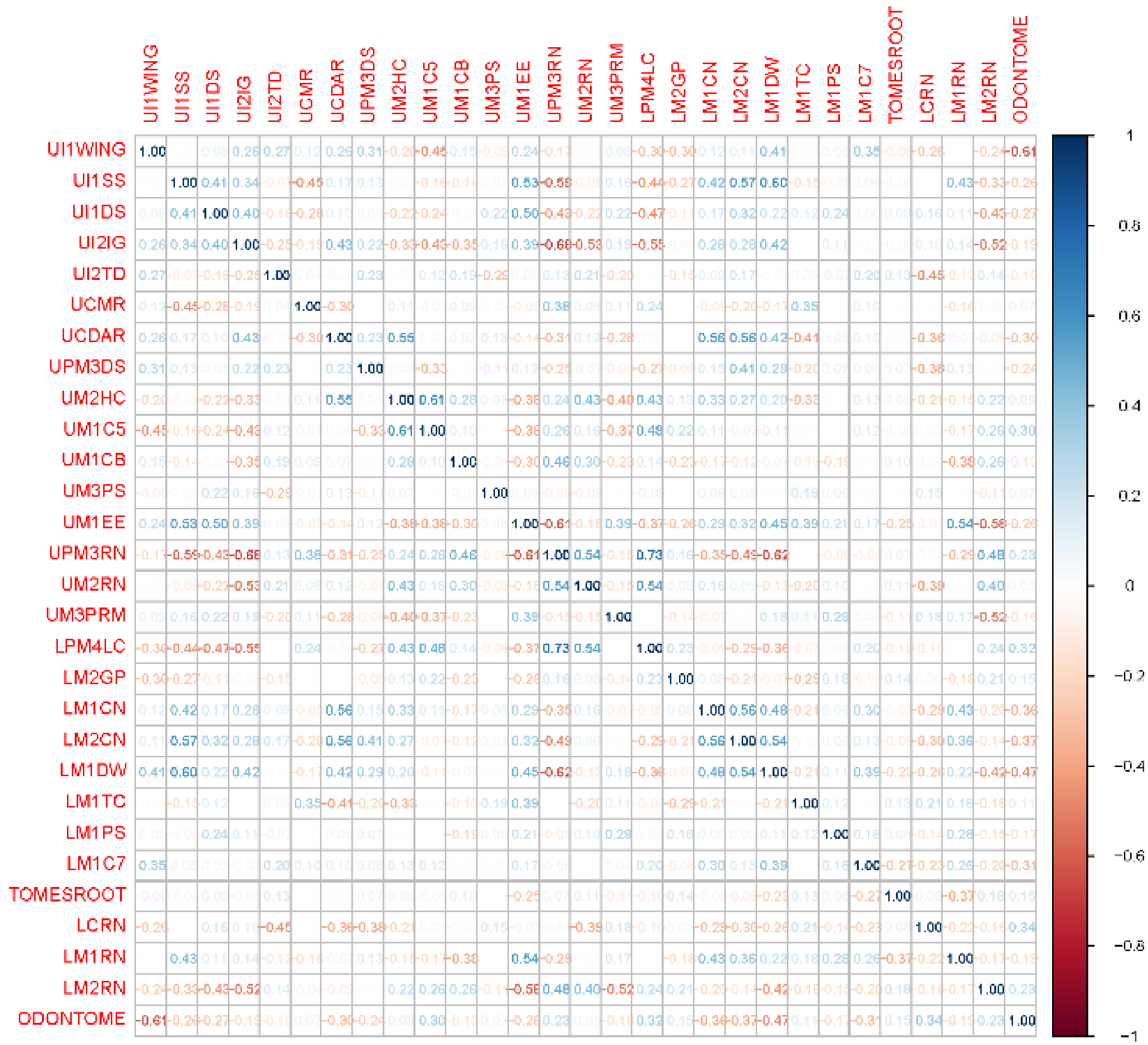
235	1	1	1	2	1	1	1	0	0	0	1	6	3
236A	0	1	-	0	0	1	1	2	0	0	2	6	3
237	1	0	3	5	1	1	1	0	0	0	1	5	5
238	2	1	0	4	2	1	2	0	0	0	1	4	0
243	1	0	-	2	0	0	-	-	-	0	2	5	4
244	0	2	0	3	0	1	1	1	-	0	2	5	4
251	0	3	0	0	0	0	1	0	0	0	0	5	2
255	0	0	-	0	0	0	-	-	-	-	-	-	-
256	1	0	2	0	2	2	6	2	0	0	2	6	4
257	2	0	0	3	0	1	1	-	-	0	2	5	5
258	1	0	0	3	0	2	4	0	0	0	2	5	4
262	-	-	-	-	-	-	1	0	0	0	1	4	0
267	-	-	-	-	-	-	-	-	-	-	-	-	-
272	1	0	1	3	1	1	1	-	0	0	1	5	4
273	0	1	0	0	1	0	6	0	1	0	0	5	4
276	1	0	0	3	2	1	3	0	0	4	2	4	0
279	-	-	-	-	-	-	-	-	-	-	-	-	-
280	-	-	-	3	-	-	-	-	0	0	2	4	0
290	0	1	0	0	-	0	-	-	-	0	2	5	4
293	-	-	-	3	1	1	2	-	0	0	2	4	0
306	0	0	-	3	0	0	1	-	-	0	1	5	0
310	1	0	0	2	0	2	-	-	-	-	-	-	-
311	-	-	3	2	0	0	8	-	0	0	2	5	4
341	1	-	0	0	0	0	1	-	-	0	1	4	0
76	-	1	-	2	0	2	-	-	-	0	-	-	-
78	1	1	2	2	1	2	2	1	0	0	1	4	0
79	0	0	1	3	1	1	1	0	0	3	2	5	2
86	1	0	0	0	1	0	1	0	0	0	2	5	1
124	0	2	0	3	1	2	1	0	0	0	1	4	0
125	-	0	0	4	-	1	2	-	-	0	2	4	0

145	4	0	-	0	0	1	1	1	0	0	-	4	0
260	-	-	-	-	0	1	-	0	0	-	-	-	-
260A	-	-	-	3	-	1	-	1	0	0	0	5	5
264	-	-	-	-	-	-	1	-	0	0	2	4	0
275	0	0	0	3	0	2	1	0	0	0	0	5	4
309C	0	4	0	3	-	0	1	1	0	0	2	5	4
315.1	1	0	-	3	-	0	0	-	0	0	-	5	-
316	-	-	-	2	0	0	1	-	-	0	2	4	0
320	0	0	-	2	-	1	1	0	0	0	2	5	4
325	0	2	-	3	-	0	3	-	-	0	1	4	0
333	1	4	-	0	1	1	4	-	-	0	0	4	0
345	1	1	0	2	1	0	1	0	0	0	1	4	0
346	1	4	0	3	3	1	1	1	0	0	2	5	4
347	0	2	-	-	-	-	-	-	-	-	-	-	-
348	0	1	-	5	0	2	1	-	0	0	-	4	0
350	0	0	0	2	0	2	8	0	-	0	0	5	4
353	1	2	0	0	0	1	1	1	0	0	1	4	0
356	1	2	-	-	-	-	1	-	0	0	0	5	4
357	0	0	-	0	0	2	2	1	0	0	2	5	1
358	0	2	0	3	0	1	1	1	0	0	2	5	4
359	1	1	0	3	0	2	1	1	1	0	1	5	4
360	-	-	-	-	-	0	-	-	-	-	-	-	-
362	1	0	0	3	3	2	1	0	0	0	1	4	0
363	0	0	0	3	1	1	1	0	0	0	1	4	0
376	0	1	-	0	0	2	6	-	0	0	2	4	0
379	0	2	0	2	0	1	1	0	-	0	1	5	4
380	2	4	0	3	2	1	1	1	0	0	1	4	0
384	1	0	9	0	1	2	1	9	0	0	2	4	0
381	1	2	0	5	2	1	3	-	0	0	2	6	3

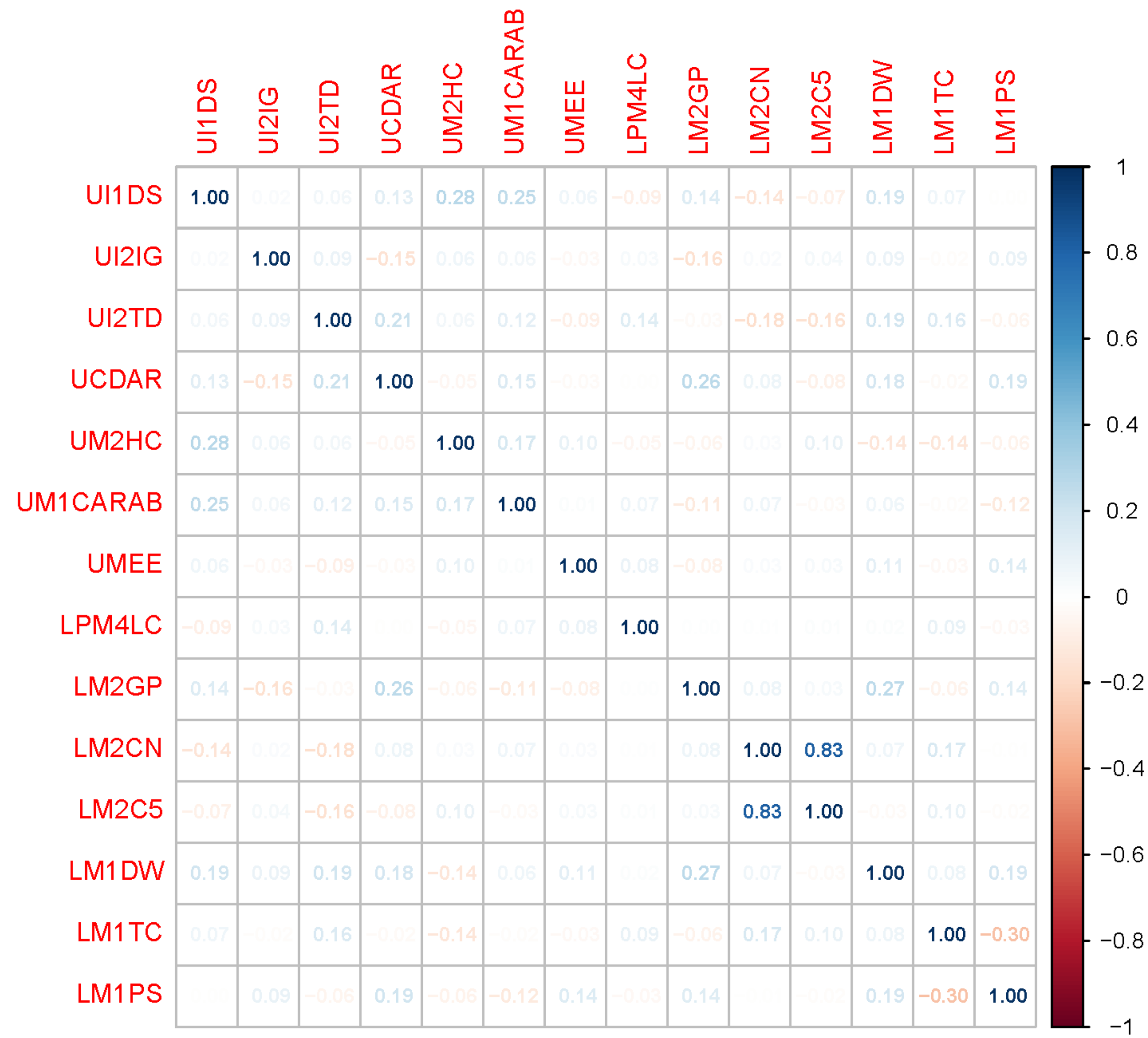
Chapter 4. Appendix. Figures.



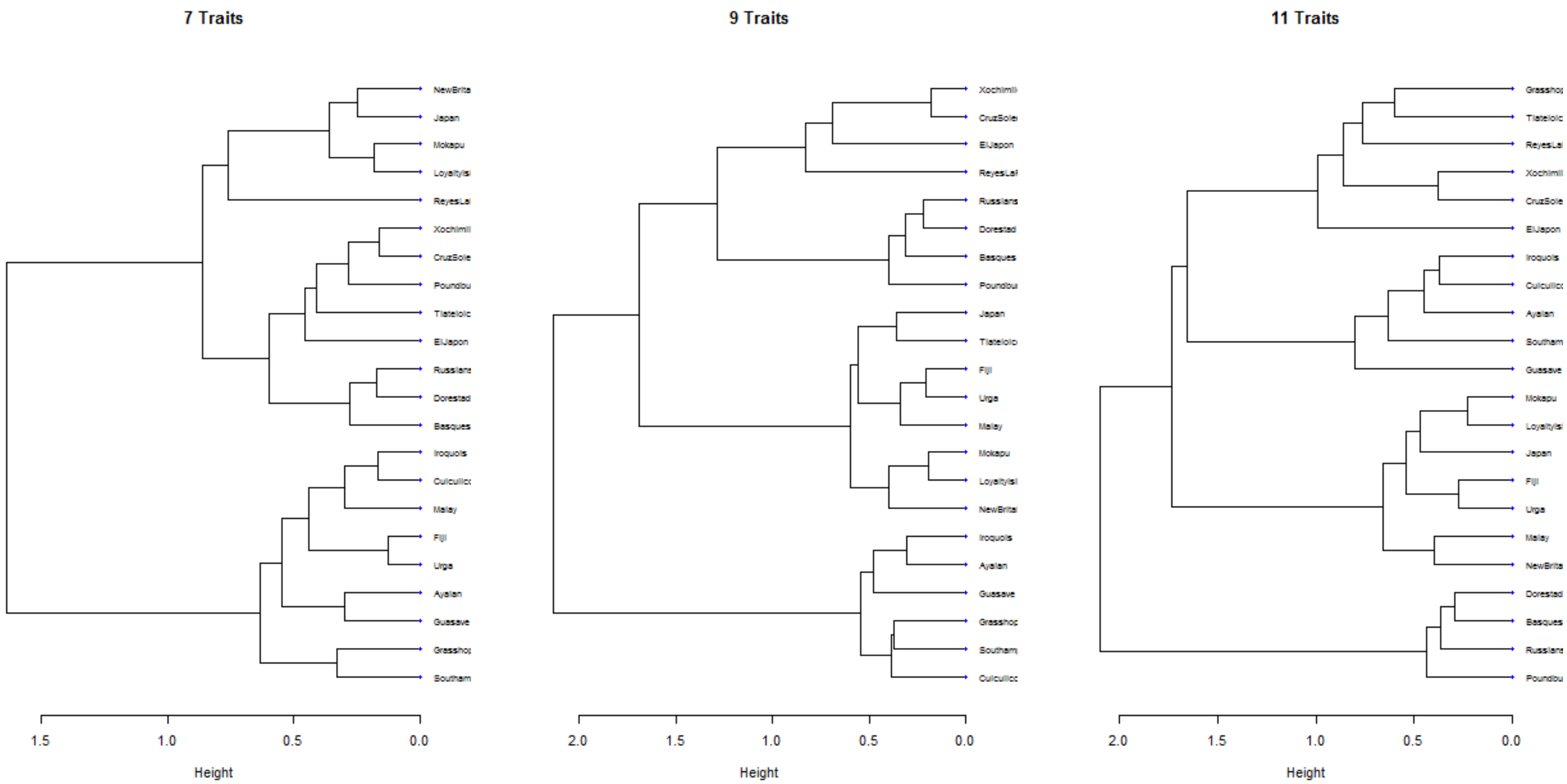
Supplemental Figure 4. 1 Map of El Japón cemetery with locations of radiocarbon sampled burials. Red squares are burials in upper levels and yellow squares are burials in lower levels. Map adapted from Ávila López (1995).



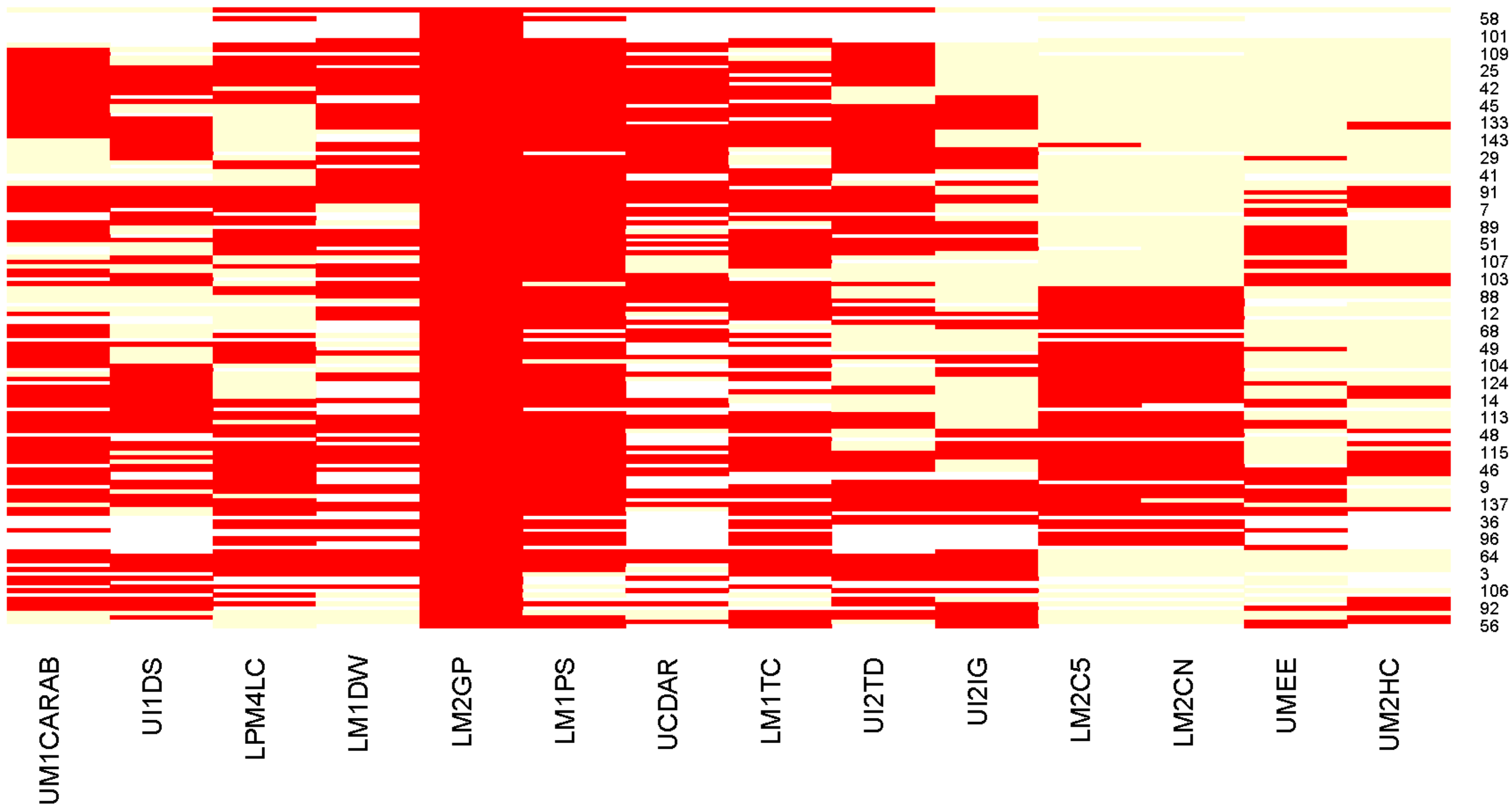
Supplemental Figure 4. 1 Correlogram of 29 Nonmetric Dental Traits from 64 Population Samples.



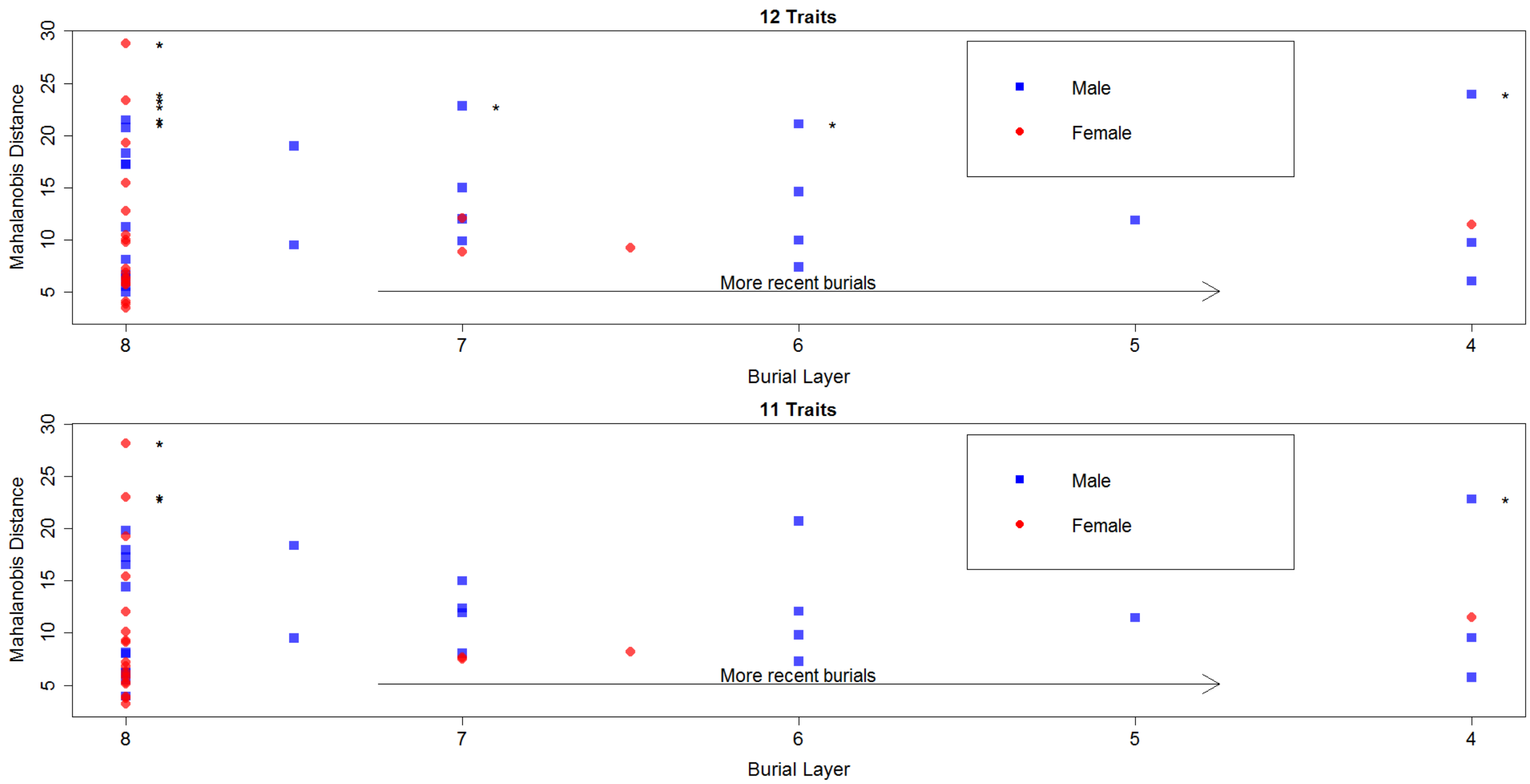
Supplemental Figure 4. 2 Correlogram of 14 Nonmetric Dental Traits for El Japón Samples.



Supplemental Figure 4. 4 Comparison of Hierarchical Dendrograms with 7, 9, and 11 High Utility Nonmetric Dental Traits



Supplemental Figure 4. 5 Heatmap of 14 High Utility Nonmetric Dental Traits for El Japón Individuals. Note Lower second molar groove pattern removed from intrapopulation analysis due to non-variation despite high utility in intrapopulation analysis. Red denotes absence of a trait for the individual in that row, beige denotes absence and white denotes missing data.



Supplemental Figure 4. 6 Biplot of Mahalanobis D^2 for El Japón Individuals based on 12 and 11 High Utility Traits.

Chapter 5. Structural Adaptation: Subsistence in early Colonial El Japón (San Gregorio Atlapulco), Mexico[a]

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Abstract

Sixteenth century European colonization in North America brought about deleterious results for Indigenous communities via epidemic disease and demographic decline (Gibson 1964; Storey 2012). Demographic decline in the Valley of Mexico strained agricultural systems that relied on communal labor to facilitate agriculture in the marshland environment (Rojas Rabiela 1991). El Japón (within San Gregorio Atlapulco territory) maintained traditional wetland agriculture similar to other Southern Valley of Mexico agriculturalists: the chinampa system. We infer that El Japón agriculturalists experienced quantitatively different physical strain compared to European agriculturalists relying on plow and draft animal use and hypothesize such a distinction will be evident in skeletal structure. Physical activity strains bone causing cellular-level response. Over time, bone response produces cross-sectional shape that varies with activity. This research uses cross-sectional properties from bone of adult individuals (ages 19–57, *n*=37) as indicators of individual physical activity (primarily subsistence activity) to test the distinguishability of physical labor regimes on the upper limbs. Eight cross-sectional properties from two humerus regions are calculated from periosteal measurements to quantify activity difference. Linear discriminant analysis of calculated properties separates El Japón individuals from 6 comparative late Medieval – early Modern European agricultural and urban communities (*n*=140 individuals). All sampled populations exhibit wide variation in individual properties making a true discriminant analysis difficult. The distal humerus however is most informative for population-level differences. This study highlights persistence in local subsistence methods in the first 150 years after Spanish contact.

Resumen

Se infiere que los agricultores de El Japón experimentaron fuerzas físicas diferentes a las experimentadas por agricultores europeos debido al uso de métodos agrícolas típicos de humedales en vez del uso del arado y animales de tiro. Este estudio resalta la persistencia en los métodos de subsistencia en los primeros 150 años tras el contacto español en Mesoamérica. La colonización de Norteamérica del siglo XVI conllevó retos para los pueblos indígenas incluyendo epidemias y declive demográfico. El declive demográfico en el Valle de México sobrecargó los sistemas agrícolas que se basan en labor comunal para llevar a cabo la agricultura en un entorno pantanoso. El Japón (dentro del territorio de San Gregorio Atlapulco) mantuvo el sistema tradicional agrícola: la chinampa. Esta investigación examina propiedades geométricas transversales en osamentas adultas (edades 19–57, n=37) como indicadores de actividad física y actividad de subsistencia individual. La actividad física presiona el hueso causando reacción a nivel celular. Al largo plazo, la reacción ósea produce geometría transversal que varía con la actividad. Ocho propiedades geométricas de dos regiones del húmero se calculan a partir de medidas perióseas para cuantificar las diferencias en actividad física. Un análisis discriminatorio lineal de las propiedades calculadas separa los individuos de El Japón de 6 muestras poblacionales de comunidades agrícolas y urbanas del periodo Medioevo tardío al Moderno temprano (n=140). Toda población incluida demuestra amplia variación en propiedades transversales dificultando un análisis veramente discriminatorio. El húmero distal es lo más informativo en cuanto a diferencias a nivel poblacional. Inferimos que los agricultores de El Japón experimentaron tensión física diferente a los individuos europeos debido a los métodos agrícolas de la chinampa en comparación al uso del arado y animales de carga. Este estudio resalta la persistencia en los métodos de subsistencia en los primeros 150 años después del contacto europeo.

Introduction

El Japón site represents the archaeological remains of a hamlet settlement within the traditional territory of the modern town of San Gregorio Atlapulco in Mexico City in the southern portion of the Basin of Mexico (Figure 5. 1). The early 17th century *Anales de San Gregorio Atlapulco* list 28 towns and hamlets from where households were relocated generally limited to a 6-kilometer radius. (Pérez Zevallos and Reyes García 2003). El Japón site is well within that radius but the Náhuatl name of the community has not been ascertained and the settlement is referred by the archaeological site name.

El Japón was occupied during the late Postclassic period (González 1996) and early colonial period (Alarcón Tinajero 2022; Chapter 3). Hamlet settlements during both the Postclassic period (900–1521 CE) and colonial period (1521–1810) were integrated into a network of settlements with both economic and political hierarchy (McAfee and Barlow 1952; Sanders et al. 1979; Parsons et al. 1983; Nichols 2017). Residents of El Japón focused on agriculture and like other marshland communities partially invested in craft production and collection of wild foods either for market or for personal use.

Upon colonization after 1521, Spanish civil and religious authorities encouraged relocation of communities to aggregated locations: *reducciones* or *congregaciones* (Cline 1949; Jalpa Flores 2008a; Aguirre Salvador 2021). The two terms are used interchangeably. Congregaciones facilitated proselytization and labor drafts (Ricard 1966; de la Torre Villar 1995; Zamudio Espinosa 2001; Megged 2020). The process of relocation lasted several decades generally occurring between 1530 and 1610 CE (Cline 1949). In many regions of central Mesoamerica including the Valley of Mexico (Lockhart 1992) and Valley of Toluca (Zamudio

Espinosa 2001; Santiago Cortez 2021), hamlet inhabitants concentrated into larger settlements because of force, duress, or by their own initiative.

As a congregated town, San Gregorio Atlapulco (Pérez Zevallos and Reyes García 2003) was not without legal recourse in the incipient colonial system. In 1555 San Gregorio Atlapulco secured self-governance through a royal charter (Pérez Zevallos and Reyes García 2003) reasserting claims to land and authority to control labor drafts for communal projects. Indigenous families and communities often utilized legal systems like courts (Pérez Zevallos and Reyes García 2003; Hicks 2005) and wills (Kellogg 1995; Díaz Serrano 2012) to ensure integrity of land rights. Elite native families often maintained access to political roles especially in formally recognized "pueblos de indios" (Rodríguez-Alegría 2010:55) or Indigenous towns. Xochimilco is one of these towns and as polity in the southern Basin of Mexico, has well documented history of continuity of elite families in colonial government (Pérez Zevallos 1984; Conway 2014).

Figure 5. 1 Location of El Japón in the southern Basin of Mexico. Estimated maximum extent of chinampas in the southern Basin of Mexico (Armillas 1971) is filled iconographically. Major canals and causeways illustrated above are identified in multiple historical records (Palerm 1973). Map modified from an image with a Free Art License (YAVIDAXIU 2007).

El Japón site consists of hundreds of relict farm fields and house plots atop *chinampas* that dotted the Lake Xochimilco marshlands (Parsons et al. 1983), similarly to other chinampa farming communities in the northern Valley of Mexico (Sanders et al. 1979). Throughout the Valley of Mexico, chinampas are anthropogenic islands of lakebed sediments built and reused over several generations (Morehart and Frederick 2014). Throughout the Postclassic and colonial periods, chinampa and canal building was carried out communally (Rojas Rabiela 1977; 1991; Cano Vallado 1992; Conway 2012) since agricultural labor and productivity were in the interest of each community for subsistence or tribute payment (Morehart 2016). Intensive agriculture in the marshland environments required methods and technologies specifically adapted to perennially wet soils and management of an excess water. These methods were maintained throughout the Postclassic (Armillas 1971) and colonial periods (Conway 2012). Chinampa agriculture was so productive that it extended throughout the Basin of Mexico: Lake Xochimilco and Chalco in the south, and Lake Texcoco, Xaltocan, and Zumpango in the north (Armillas 1971).

Chinampas were the foundation of agriculture and subsistence for marshland communities like El Japón. Though methods varied by microregion and period, chinampa fertility was maintained through dredging of lakebed sediment and composting (Frederick 2007). Maintenance of those chinampas and the infrastructure was costly and primarily relied on communal labor (González 1996) becoming over centuries paramount landesque capital (Morehart and Frederick 2014). Landesque capital (sensu, Blaikie and Brookfield 1987) becomes the object of multigenerational investment in infrastructure that permits subsistence. Beyond subsistence, it also provides a means for agricultural households to secure the ability to purchase or barter for goods in the markets and to meet tributary demands from political bodies (e.g., the Mexica empire or colonial New Spain).

Chinampa communal labor was organized and carried out via the calpulli in the postclassic (Soustelle 1956; Rojas Rabiela 1977; Lockhart 1992). Early colonial period authorities extracted labor for public projects via units that may have grouped individuals through calpulli membership. The term *tlaxilacalli* is often used interchangeably with *calpulli* (McAfee and Barlow 1952; Hicks 2012) in the southern Basin of Mexico including in historical documents most pertinent to the archaeological site of El Japón — *Los Anales de San Gregorio Atlapulco* (Pérez Zevallos and Reyes García 2003). In addition to labor, collection of material tribute like crops and manufactured crafts was also organized through the calpulli (Gibson 1964; Lockhart 1992). As a small hamlet, El Japón likely consisted of a single calpulli since larger towns and cities in the region consisted of various calpullis (Lockhart 1992; Smith 1993; Conway 2012).

Physical Activity

Though community-level coordination was important for maintenance of infrastructure, individual households and their constituent individuals pursued diverse economic activities of importance secondary to agriculture. Some northern lakeshore communities produced salt in addition to agricultural products (Gibson 1964). Colonial historical sources (Anderson and Dibble 1975) and zooarchaeological study of precontact and colonial sites attest to hunting, fishing, fowling, and collection of wild lacustrine foods by marshland inhabitants (Manzanilla and Serra 1987; Corona Martínez 2012; Valadez Azúa and Rodríguez Galicia 2013; McClung de Tapia and Acosta Ochoa 2015). Wild lacustrine foods like agricultural products were destined for rural households as well as for the markets (Gibson 1964). Sale and exchange in the markets of the Valley of Mexico facilitated diverse economic strategies for households (Rodríguez-Alegría and Stoner 2016), often involving specialization in tasks along gendered lines (Medrano Enríquez 2001). The ethnohistoric record of postclassic and early colonial Mesoamerica (Soustelle 1956;

Anderson and Dibble 1975) specifically discuss the economic roles of adult men and women and the early childhood instruction of these within the household.

Sixteenth century colonization of central Mexico involved directed proselytization, establishment or transformation of labor tribute systems, as well as new taxation systems. In some areas, including Chalco or Ixtapaluca in the Valley of Mexico, Spanish authorities encouraged or imposed agricultural and livestock production of European products including sheep, cattle, and wheat (Jalpa Flores 2008b). Jalpa Flores (2008b) identifies use of draft animals and plows in Chalco only kilometers from El Japón. Satellite-based survey of El Japón site identifies evidence of plows agriculture though precise timing is not established (León Soriano 2015) and is likely associated with desiccation of the lakebeds in the last two centuries postdating the period of focus defined in Chapter 3 (*1565–1650* cal. CE).

Indigenous communities of the chinampa region made concerted efforts to maintain hand-tool agricultural practices and production of local crops. Based in historical accounts of the mid-18th century, Conway (2012) identifies continuity of chinampa agriculture in a vast area from Xochimilco to Chalco which would include the hamlet settlements surrounding San Gregorio Atlapulco and contemporaneous hamlet settlements. Unsuitability of soil conditions for Spanish crops and livestock (Schwartz 2000) may have safeguarded an Indigenous economic niche in chinampa agriculture (Conway 2014) despite incentives or pressure to become involved with production of European crops and livestock or with European agricultural methods (Jalpa Flores 2008b). Roughly contemporaneous European agriculture was notably different for its general reliance on plow and draft-animal agriculture.

For late Medieval (1250–1500 CE) and early modern (1500–1800 CE) Europeans, physical activity was likely centered around subsistence activities or economic activities that generated wealth in cash economies (Ruff, ed. 2018). As such, the skeletal indicators of physical activity patterns are interpreted as indicators of subsistence practices. Differing subsistence and economic activities in Europe and Mesoamerica placed differing physical strain on human bodies. Urban communities in both Mesoamerica and Europe contained craft-producing households (Soustelle 1956; Ruff, ed. 2018) with highly specialized skills. Blacksmithing is one example of a medieval European economic specialization with repetitive and bilaterally asymmetrical patterns of limb use. Not all economic specializations however have such unique physical “signatures”. Plow agriculture reliant on draft-animals places physical tension on the upper limbs of individuals that is appreciably different from similar tasks with hand tools.

Medrano Enríquez (2001) identifies pronounced muscular insertion points in the humerii of the El Japón skeletal series and attributes this to the varied tasks in chinampa agriculture that relied on hand tools placing repetitive strain on the muscle insertions. Hand tools facilitated chinampa agriculture in the Basin of Mexico including dredging, turning soil, planting, and clearing canals (Rojas Rabiela 1984). Canals that separated chinampas not only facilitated crop irrigation, but also facilitated water level management (Palerm 1973), freshwater influx (Palerm 1973; Morehart and Frederick 2014), and efficient transport of fertile dredged sediment, crops, and non-food merchandise large wood canoes, *trajineras* (Conway 2012).

Cross-sectional Properties

Cross-sectional properties (CSPs) measure the resistance of bone to deformation or fracture due to repetitive physical activity and are indicative of specific mechanical strains: shearing, bending, compression, or torsion (Frost 1988). Everyday activities, including agricultural labor or food processing, place those mechanical strains on bone. Bone tissue responds to physical activity at the cellular level. In adults with repetitive physical activity, osteoclast cells resorb bone in areas of low mechanical strain and osteoblast cells redeposit in areas of higher strain (Pearson and

Lieberman 2004). Experimental studies in animals demonstrate the effect of consistent mechanical activity on the CSPs of bone (Mosley et al. 1997; Mosley and Lanyon 1998; Robling et al. 2001). Study of 20th century athletes (varsity-level cricket players and swimmers) provides a quantifiable demonstration of CSPs resulting from documented patterns of intensive and repetitive physical activity (Shaw and Stock 2009). The impact of physical activity on CSPs is interpreted to be most substantial when activity patterns begin prior to skeletal maturity (Bass et al. 2002; Pearson and Lieberman 2004) which has variability ranging from 19 (Hedges et al. 2007) to 35 years of age (Zioupos 2001).

Bone responds to mechanical stress in patterned ways: increased cortical thickness, enlarged diaphyseal breadth, and diaphyseal shift (Maggiano et al. 2015). Cortical thickness cannot be gauged without bioimaging or invasive cross-sectional cutting of bone. This study gauges two responses of bone to physical activity through noninvasive methods. Calculated platymeric indices quantify the intensity and direction of diaphyseal change in relation to standard planes: anteroposterior and mediolateral (Pomeroy and Zakrzewski 2009). Diaphysis ratios (e.g., Figure 5. 2) provide a measure of the robusticity of bone while standardizing for body size (Wescott 2006) using estimates of body mass or stature or measurements correlated to these (not CSPs in themselves). The humerus head and femur head diameters are understood to be strongly correlated to anthropometric measures in life: stature or body mass (Grine et al. 1995; Auerbach and Ruff 2010) and this is demonstrated in a preliminary study of El Japón adults (Alarcón Tinajero and Gómez-Valdés 2021).

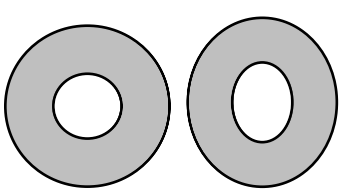

Figure 5. 2 Schema of low and high platymeric index cross-sections. The right, more oval, cross-section has a higher platymeric index due to the difference in anteroposterior diameter compared to the mediolateral diameter.

Patterns of physical activity, rather than genetics or body size, explain differences in bone CSPs allowing for interpretation of past physical activity. In human limbs, CSPs reflect patterns of mechanical pressure in the years before death permitting exploration of topics that include sexual division of labor (Ruff 1987; Soares et al. 2008), differences in activity between population subsets (Maggiano et al. 2008), and changes in activity over time (Sládek et al. 2006; Marchi 2008; Ruff et al. 2015). CSPs calculated from noninvasive periosteal measurements (O'Neill and Ruff 2004; Stock and Shaw 2007; Sparacello et al. 2011) present comparable results to studies using bioimaging methods, including computed tomography (Macintosh et al. 2013).

Four platymeric indices in two regions of the humerus quantify the regularity and intensity of movement in x/y planes in relation to the midline of the body. Repetitive mechanical pressure for the upper limb includes flexion, supination, abduction, and adduction. The diaphysis ratios in the same region of the humeri (50% length and 35% length) quantify the size of cross-sectional shape as a response to activity. By observing periosteal measurements on both upper limbs and calculating geometric properties for both sides, platymeric indices and diaphysis ratios capture information about asymmetrical use of limbs. Asymmetric use of limbs may be informative — but not diagnostic — of specific tasks and broad subsistence regimes (Auerbach and Ruff 2006).

Hypotheses

Based in the archaeological chinampa context of El Japón we infer that chinampa agriculture was practiced well into the colonial period. We posit that CSPs should be sufficiently different from roughly contemporaneous European individuals with urban and rural labor specializations. The ethnohistoric record of postclassic and early colonial period Mesoamerica, as well as interpretation of the entheseal effects of activity patterns (Medrano Enríquez 2001) support the interpretation that household and economic labor was divided along gendered lines. We posit that males and females at El Japón specialized in different tasks and expect to observe differences in CSPs.

Materials and Methods

Periosteal measurements from the El Japón collection were taken according to standard methods (Buikstra and Ubelaker, eds. 1994; Moore-Jansen et al. 1994). Adult individuals were selected if they had at two complete humeri, radii, ulnae, and femora. Periosteal measurements consist of diameters, lengths, and circumferences taken on dry bone (Table 5. 1). Osteometric boards were used to take lengths of long bones. Digital sliding calipers were used to take smaller measurements. Age at death and sex estimates for El Japón individuals were incorporated from lab records previously calculated in the *Laboratorio del Posgrado en Antropología Física* of the *Escuela Nacional de Antropología e Historia* (Márquez Morfín and Hernández Espinoza 2005).

Periosteal dimensions from 140 individuals of European archaeological collections were accessed from a published database (Ruff, ed. 2018). European urban or agricultural communities where draft animals and plows were used were selected (identified in Figure 5. 3 and Table 5. 2). Late Medieval (1250–1500 CE) and early Modern (1500–1800 CE) samples were chosen to be roughly contemporaneous with the postclassic and colonial context of chinampa agriculture. Similar periosteal measurements have previously been collected on Native American remains from North America. That data is not available due to ethical concerns about how data and human remains have been treated has been collected over several decades, especially in American institutions (Buikstra 2006).

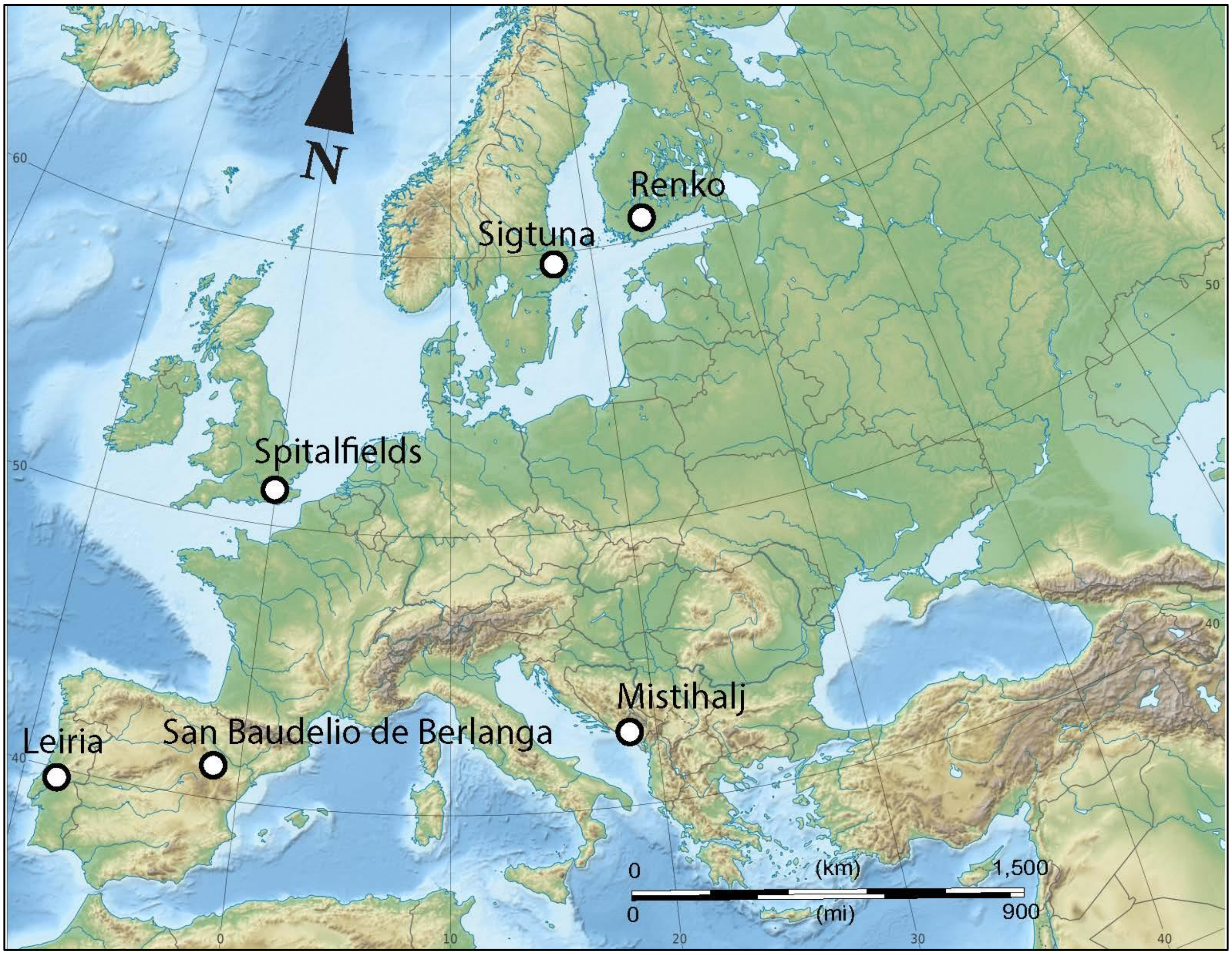

Figure 5. 3 Location of European sites included in text. Map adapted a Creative Commons Attribution-Share Alike 3.0 Unported license image (TUBS, no date).

Midshaft diaphysis diameters correspond to measurements at 50% of the diaphysis length while distal diaphysis diameters are taken at 35% of the diaphysis length beginning from the distal end of the bone. Platymeric indices (at 50% and 35%) of diaphysis length follow the formula:

anteroposterior diameter × *100/ mediolateral diameter* (Pomeroy and Zakrzewski 2009).

Diaphysis ratios (at 50% and 35% length) are modified from femur midshaft ratios (Wescott 2006; Watson and Stoll 2013) and follow the formula:

100 × (anteroposterior diameter + mediolateral diameter)/ *femur head diameter*

Table 5. 1 Periosteal Measurements and their Calculated Cross-sectional Properties

Humerus Periosteal Measurements	Cross-sectional Property
Diaphysis diameters at 50% length (Anteroposterior, Mediolateral, l. and r., *n*=4)	Humerus platymeric index (50%) (left and right, *n*=2)
Diaphysis diameters at 35% length (Anteroposterior, Mediolateral, L. and r., *n*=4)	Humerus platymeric index (35%) (left and right, *n*=2)
a. Superoinferior head diameters, l. and r., *n*=2) b. Diaphysis diameters at 50% length, (Anteroposterior, Mediolateral, l. and r, *n*=4)	Humerus diaphysis ratio (50%) (left and right, *n*=2)
a. Superoinferior head diameters, l. and r., *n*=2) b. Diaphysis diameters at 35% length, (Anteroposterior, Mediolateral, l. and r., *n*=4)	Humerus diaphysis ratio (35%) (left and right, *n*=2)

Anthropometric estimates and CSPs were calculated using R (R Core Team 2017) using continental population-appropriate methods for body mass (Grine et al. 1995) and stature (Auerbach and Ruff 2010). Body mass and stature estimations for the comparative European populations were incorporated through the available data set (Ruff, ed. 2018). A dataset of 107 European individuals without missing data points was selected for comparison to El Japón preferentially selecting sites with economic and subsistence described in the historical and archaeological literature.

Table 5. 2 Comparative Populations

Sample	Chronology (CE)	Geography	Economic Context
El Japón, *n*=37 (Ávila López 1995)	1565–1650 [a]	Central Mesoamerica, inland marshland	Rural, agricultural
Spitalfields, *n*=27 (Ruff et al. 2018)	1700–1850 [a]	Britain, major city	Urban, craft specialists
Renko, *n*=16 (Niskanen et al. 2018)	1500–1859 [a]	Scandinavia, inland	Rural, agricultural
Mistihalj, *n*=46 (Ruff and Holt 2018)	1400–1500 [b]	Balkans, mountainous	Rural, herding and transhumance
Leiria, *n*=18 (Ruff and Garvin 2018)	1200–1550 [b]	Iberia, coastal plain	Urban, economically heterogenous
San Baudelio de Berlanga, *n*=12 (Ruff and Garvin 2018)	1100–1200 [b]	Iberia, inland	Rural, livestock farming
Sigtuna, *n*=21 (Niskanen et al. 2018)	1080–1300 [b]	Scandinavia, coastal plain	Urban, economically heterogenous

[a] Early Modern period.
[b] Late Medieval period.

Dimensionality Reduction

Linear Discriminant Analysis (LDA hereafter) in R software is carried out to compare these disparate populations using the eight cross-sectional variables. All R functions hereafter are italicized. LDA is a statistical method applied to datasets of more than two categorical variables to calculate a linear combination of traits that best groups individual into known categories (Ripley et al. 2022). The LDA categories are the archaeological sites from which the osteological samples are taken. An LDA reduces the dimension and direction of skeletal adaptation to graphically present the differences between individuals and groups. LDA methods quantify a difference in CSPs of the upper limb in humans expecting overlap as skeletal plasticity is not infinite.

Dimensions of the midshaft and distal humerus were selected for this study as a focused subset based on earlier work that demonstrated wide variation in CSPs in both in El Japón and comparative European communities (Alarcón Tinajero and Gómez-Valdés 2021). The eight humerus CSPs have low correlation with estimates of stature, weight, and the interaction of both (Alarcón Tinajero and Gómez-Valdés 2021). Low correlation to anthropometric estimates justifies use of the CSPs as proxies of activity.

All CSPs were natural log-transformed to achieve normal distribution prior to incorporation into the LDA. Humerus diaphysis ratios at 50% length are the only non-normal subsets within the El Japón sample after log-transformation. Sex-based differences for those variables are tested by a Wilcoxon signed-rank test — all other variables by *t*-tests. Variables were tested for equality of variances using F-tests. 80% of the dataset was randomly sampled as a training set while the remainder 20% is designated as a test set using the *lda* function in the R package *MASS* (Ripley et al. 2022)

Results

Individual results of anthropometric estimates and CSPs are presented in Supplemental Table 5. 1 and Supplemental Table 5. 2. Significant differences are observed in seven of eight CSPs comparing El Japón individuals to the combined European samples (Table 5. 3). Significant differences are observed between El Japón males and females in only two of eight cross sectional properties: the left platymeric index at the midshaft and 35% length.

Table 5. 3 Summary Statistics of Cross-sectional Properties

Humerus CSP	El Japón Males		El Japón Females		El Japón combined		Europeans combined	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Right platymeric index, 50% length **	104.4	6.5	106.0	5.9	105.2	6.2	100.7	9.1
Left platymeric index, 50% length * / *	101.9	4.8	107.6	7.3	104.7	6.7	102.0	7.5
Right platymeric index, 35% length **	99.5	5.7	102.6	5.8	101.0	5.9	111.3	8.3
Left platymeric index, 35% length ** / *	99.0	5.6	102.9	5.3	100.9	5.7	113.4	7.9
Right diaphysis ratio, 50% length *	100.0	5.0	99.2	6.5	98.6	5.7	96.3	6.5
Left diaphysis ratio, 50% length *	96.2	6.8	99.2	5.6	97.6	6.3	95.0	6.6
Right diaphysis ratio, 35% length	89.0	5.3	89.2	4.6	89.1	4.9	88.3	5.3
Left diaphysis ratio, 35% length *	88.5	6.1	89.0	4.2	88.7	5.2	86.8	4.7

* Difference between El Japón and combined European sample, $0.05>p>0.01$.
** Difference between El Japón and combined European sample, $p<0.01$.
* Difference between male and female El Japón sample, 0.05>p>0.01.

Linear Discriminant Function

The *lda* function calculates a *proportion of trace* equitable to a percentage of how much total variation can be explained by the linear discriminant. Linear Discriminant 1 (LD1) is calculated as:

*0.640 * log(R. Diaphysis Ratio 50%) + -0.016 * log(L. Diaphysis Ratio 50%) + 0.651 * log(R. Platymeric Index 50%) + 0.336 * log(L. Platymeric Index. 50%) + -0.450 * log(R. Platymeric Index 35%) + -0.960 * log(L. Platymeric Index 35%) + -0.607 * log(R. Diaphysis Ratio 35%) + 0.086 * log(L. Diaphysis Ratio 35%).*

Linear Discriminant 2 (LD2) is calculated as:

*-0.0530 * log(R. Diaphysis Ratio 50%) + 0.735 * log(L. Diaphysis Ratio 50%) + 0.979 * log(R. Platymeric Index 50%) + -0.763 * log(L. Platymeric Index. 50%) + -0.210 * log(R. Platymeric Index 35%) + 0.517 * log(L. Platymeric Index 35%) + 0.651 * log(R. Diaphysis Ratio 35%) + -0.702 * log(L. Diaphysis Ratio 35%).*

LD1 separates 78% of the variation in the multi-population sample while LD2 separates 11% of the sample. Kruskal-Wallis statistics are not significantly different among the Linear Discriminants in three of four sex-based and stratigraphic comparisons (Table 5. 4). Males and females from El Japón do not differ statistically in either Linear Discriminant 1 or 2. Comparison between lower and upper stratigraphy should be read with caution as the sample sizes are very uneven (lower stratigraphy n=34 and upper stratigraphy n=4). Model Accuracy is calculated using the *mean* function in R — the model accurately classifies 42% of samples.

Table 5. 4 Kruskal-Wallis Statistics of Linear Discriminants

Linear Discriminant	$\chi 2$	*p*	$Group_1$	Trend	$Group_2$
			El Japón vs. Europeans		
LD1	41.9	<0.01	El Japón	>	Rural European
LD2	0.01	0.91	El Japón	≈	Rural European
LD1	19.9	<0.01	El Japón	>	Urban European
LD2	3.4	0.06	El Japón	≈	Urban European
			El Japón		
LD1	3.3	0.06	Male	≈	Female
LD2	2.3	0.12	Male	≈	Female
LD1	1.3	0.26	Lower stratigraphy	≈	Upper stratigraphy
LD2	1.5	0.22	Lower stratigraphy	≈	Upper stratigraphy

Discussion

El Japón individuals included in this research were born and died decades after Spanish contact maintaining patterns of physical activity substantially different from agriculturalist and urban Europeans. LDA of humerus CSPs distinguish El Japón from Europeans where semi-mechanized plow agriculture was common. These individuals were active in the chinampa economy as members of often nested institutions: local calpullis, settlements dependent of larger towns, regionally extended kin networks, and religious communities. Environmental and political change are not new subjects in the Valley of Mexico and current archaeological scholarship accounts for the institutional and political transformations that helped to maintain agricultural systems (Morehart 2018) despite the challenges of political and demographic change in the Postclassic and Colonial periods.

Rooted in the political ecology framework, this research concludes that subsistence and dietary patterns were strategic Indigenous choices (Rodríguez Alegría 2010), rather than European directives. The hamlet community likely carried out maintenance of agricultural infrastructure: causeways, irrigation canals, and drainage canals (Soustelle 1956; Rojas Rabiela 1977). Communal in landesque capital facilitated agriculture and by extension facilitated tax payment and participation in the regional markets. Shared tasks likely contributed to within-population similarity of cross-sectional results.

The chinampas were farmed, replenished, and expanded for a minimum of 600 years (14^{th}–20^{th} centuries). Chinampa agriculture persisted throughout the colonial period (Gibson 1964) and into the present despite environmental constraint, sociopolitical pressures, and long demographic decline beginning with Spanish contact (Newson 1993; Storey 2012). Chinampa dimensions and sizes varied within subregions of former Lake Texcoco (Frederick 2007). However, there seems to be regularity within communities since households were responsible for predictable amounts of tribute crops or raw products: this is known through historic texts (Berdan and Rieff Anawalt 1992; Durán 1994).

Commoners in the colonial period, like those of El Japón, did not persist in chinampa agriculture as unquestioned tradition. Rather, El Japón residents remained in a geographically remote settlement and continued investing in landesque capital reliant on specialized knowledge, regular maintenance, and communal coordination. Skeletal study of the adult individuals allows us to understand that persistence in local agriculture likely happened with local tools.

Chinampa agriculture may have secured some independence for Indigenous commoner and elite agriculturalists away from direct influence (i.e., direction in choice of crops or methods of production) of most Europeans in the initial colonial period (Conway 2014). Examination of the historical record in nearby Culhuacán cites the dearth of European interest in chinampas (Cline 1984). The households of El Japón maintained economic agency by investing in shared landesque investments: canals, causeways, and chinampa islands. El Japón was likely depopulated by 1650-1660 CE when many Indigenous populations reached a nadir (Newson 1993) brought on by multigenerational epidemic assault. Evidence of early and mid-colonial period changes in land tenure (Cline 1984) and inheritance (Kellog 1995) substantiate an understanding that the workings within communities changed as Indigenous kin and economic networks and Indigenous settlements became more entwined with regional economic networks that permitted monetization, extraction, sale, and purchase of both land and labor.

The linear discriminants find no significant differences between adult males and females at El Japón (Table 5. 4), likely reflecting some shared labor in chinampa agriculture. Adult males and females at El Japón generally shared some tasks of the chinampa agricultural cycle, especially tasks that may have been more asymmetrical and right-hand dominated. Dredging lacustrine soils for chinampa maintenance and movement of large canoes with crops or merchandise are two examples of largely asymmetrical tasks that took place in the southern Valley of Mexico until recent decades. Sex-segregated tasks identified in ethnohistoric accounts (Anderson and Dibble 1975) may have been limited to domestic tasks. Intensive agriculture specializations like the chinampa system may have taken precedence over idealized economic specializations that divided households and settlements along gendered lines.

Few early El Japón individuals plot distinctly from others of the same and later stratigraphy (Figure 5. 4). The four lowest in LD1 are all adult males. Female individuals from El Japón cluster much more closely between the earlier and later stratigraphy in the same plot. Bending, flexion, and extension in the upper limps in those four male individuals differed substantially over years prior to death in comparison to other males and females in the El Japón sample — likely due to physical activity with different methods or in an entirely different physical context.

In addition to material tribute, precontact and early colonial communities provided tributed labor like collection of firewood or domestic cooks for elite households (Gibson 1964). Therefore, labor extracted as tribute was not new in the colonial period. Labor divorced from traditional calpulli and ad-hoc kin-based reciprocity may have grown as the colonial period advanced. Wage labor for example, is documented in early colonial New Spain as Indigenous markets became more entangled (*sensu*, Jordan 2009) with European concepts of partible and marketable land. Indigenous tribute was claimed by *encomenderos* (Gibson 1964; Lockhart 1992; Chuchiak 2006) and in some cases divided by individuals in communities like Indigenous towns and villages.

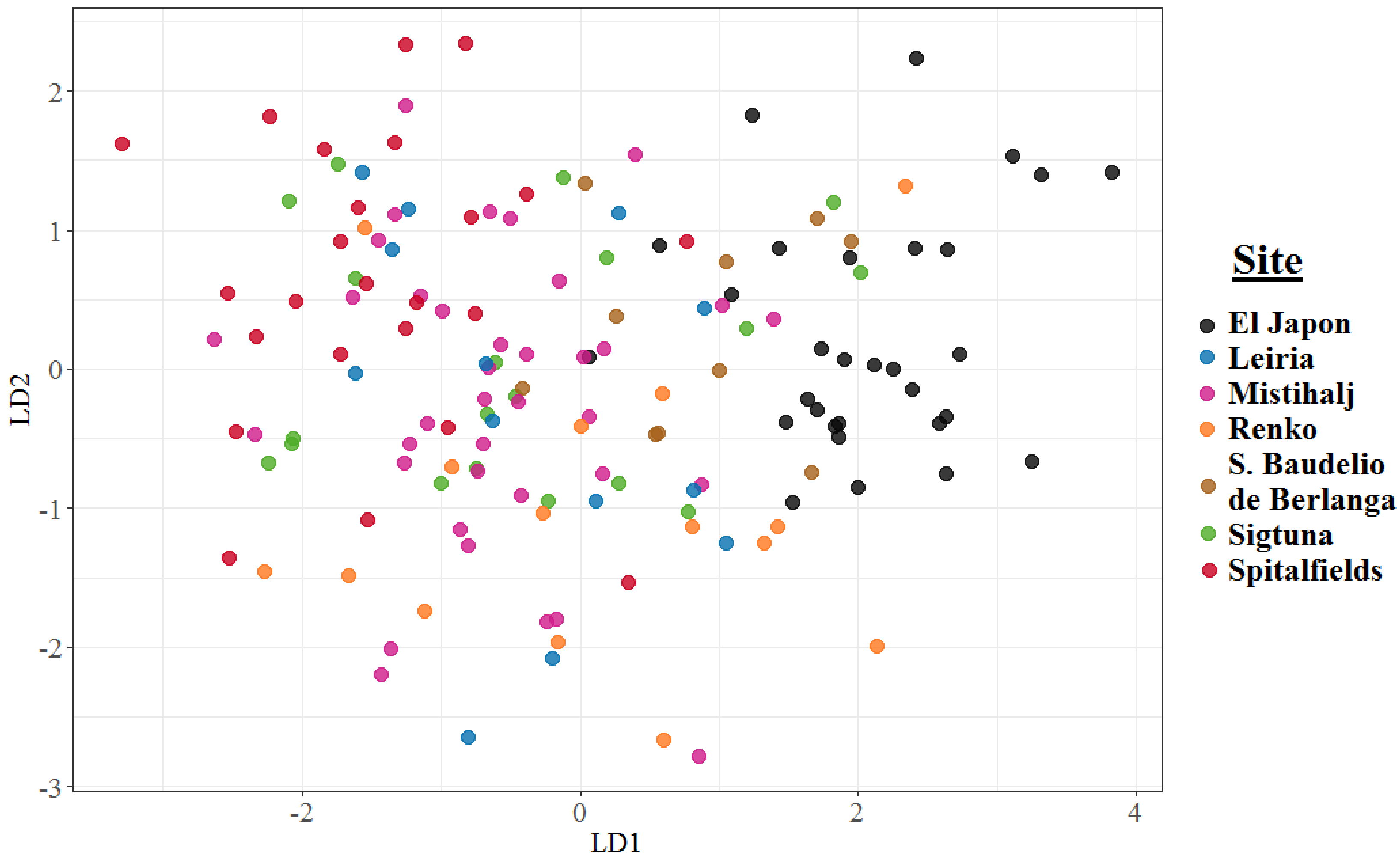

Figure 5. 4 LDA Biplot of El Japón and Comparative European Samples.

The individual El Japón males who plot distinctly could have carried out physical labor outside chinampa agriculture from early age or with higher frequency than males who plot distinctly from Europeans along Linear Discriminant 1. It is worth repeating that the cross-sectional shape and orientation of these five individuals is substantially due to years of physical activity different from counterparts buried in the same rural cemetery. Indigenous males provided renumerated and unremunerated services carrying items by foot, transporting goods by trajinera along canals, collecting and transporting fodder, and herding European livestock for both European and Indigenous people (Gibson 1964; Jalpa Flores 2008b). These diverse economic activities could have been carried out by El Japón males with differential time investment leading to differential skeletal architecture.

Within-population similarity of activity patterns and the relatively small size of El Japón supports the interpretation of persistence in pooled labor as a means of production: likely both for staples, and for market or tribute. Morehart (2016) identifies chinampa agricultural based craft producing households in the northern Basin of Mexico that temporarily survived imperial political change in the middle Postclassic (1200–1350 CE). Increased imperial Mexica demand of household agricultural and craft good production was a major detriment to postclassic Xaltocan (Morehart 2016). This example in the regional context of El Japón demonstrates the balance between agricultural economies and the importance of political contextual interpretation.

Upon advance of the colonial period, European crops, draft animals, and plow technology were certainly present in Mesoamerica. Based in political ecological assumptions, diffusion of new goods and technologies at times of significant transition will continue to be unequal unless addressed directly (Blaikie and Brookfíeld 1987). Postcolonial economic differences likely increased in the southern Basin area as in other regions, e.g., Morelos (Smith et al. 2014) and it can therefore be connected that the lack of diffusion of novel technologies and goods may have been rooted in entrenched status differences with economic results. These findings support a generalized hypothesis that diffusion of new Eurasian crops, livestock and technologies among the rural commoner Mesoamerican communities was probably gradual and not present in the chinampa area until after the use of El Japón as a hamlet site.

Conclusion

Intensive agriculture in the marshland environments of the Valley of Mexico required unique methods and technologies in comparison to the generally dryland farming of European communities sampled for comparison. Population-level differences are evident in the CSPs of the upper limb and are attributed to appreciably different methods of agricultural labor and transportation. El Japón residents maintained the chinampa system with techniques and tools similar to precontact ancestors and transported nutrient dense sediment, supplies, and crops using trajineras.

LDA parses out the single Mesoamerican sample from roughly contemporaneous eastern and western European agriculturalist communities. LDA also demonstrates ample variation in the osseous result of diverse physical activity within all communities. Discernable difference in the skeletal record is linked to historically and archaeologically documented subsistence patterns in the marshlands of the Valley of Mexico. This study demonstrates the possibility of identifying change or consistency in physical activity in other postcontact Mesoamerican contexts to inform understanding of diachronic subsistence patterns. The methods of agricultural production persisted for at least 150 years following European contact in the region despite political and economic change with colonization. Documented change in governance and tribute demands may have played a role in persistence of high-yield high-investment agricultural methods in the Xochimilco marshlands.

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Chapter 5. Appendix. Individual Cross-sectional Results.

Supplemental Table 5. 1 Demographic Data and Periosteal Measurements of El Japón Individuals, Femora

Demographic Data					Femur Periosteal Measurements			
Burial	Sex [a]	Mean age [a]	Stature (cm) [b]	Body mass (kg) [b]	Bicondylar length [b]	Superoinferior Femur head diameter [b]	AP[c] Diaphysis diameter, 50% length [b]	ML[c] Diaphysis diameter, 50% length [b]
2	F	32.5	146.4	50.5	380.5	38.4	22.8	19.9
88	F	27.5	149.9	55.9	393.5	40.7	24.5	20.6
91	F	19.5	143.3	47.1	369.0	36.9	23.0	21.2
110	F	25.5	143.9	46.2	371.0	36.5	22.9	21.3
185	F	27.5	147.6	48.9	385.0	37.7	22.0	20.6
202	F	37.5	151.6	49.2	400.0	37.8	25.8	23.0
255	F	27.5	143.6	46.6	370.0	36.6	25.6	21.7
325	F	32.5	148.3	52.5	387.5	39.2	25.8	21.3
333	F	32.5	145.6	53.1	377.5	39.5	24.0	22.0
124	F	21.5	151.1	47.9	398.0	37.2	26.5	24.3
145	F	32.5	144.3	51.0	372.5	38.6	27.4	23.2
358	F	20	147.6	47.4	385.0	37.0	23.5	21.5
359	F	27	149.1	48.7	390.5	37.6	23.6	22.8
360	F	47.5	150.8	55.1	397.0	40.4	24.7	21.9
362	F	27.5	144.1	49.5	372.0	37.9	23.3	20.2
363	F	22.5	148.9	51.2	390.0	38.7	24.4	22.8
380	F	24	148.9	52.6	390.0	39.3	26.9	22.0
381	F	42.5	142.4	54.1	365.5	40.0	26.9	21.7
13	M	32.5	149.8	50.8	384.0	39.4	24.3	21.9
19	M	27.5	148.7	51.2	379.5	39.1	24.6	22.0
55	M	22.5	159.5	69.7	422.0	46.8	26.1	25.5
162	M	32.5	160.2	59.7	425.0	42.4	26.7	26.0
181	M	32.5	162.4	67.6	433.5	45.9	28.3	24.5
238	M	27	161.9	58.4	431.5	41.9	28.3	24.0

244	M	37.5	159.3	63.4	421.5	44.0	26.8	26.0
256	M	25	164.0	69.3	440.0	46.7	26.6	23.4
258	M	25	160.0	64.8	424.0	44.7	27.3	22.7
262	M	32.5	168.6	67.3	458.0	45.8	28.6	29.5
79	M	27.5	156.0	65.1	408.5	44.8	25.1	24.1
125	M	57.5	162.8	73.0	435.0	48.3	29.7	25.6
275	M	22	149.2	58.7	381.5	42	24.26	25.03
320	M	22.5	155.3	64.1	405.5	45.8	22.79	25.72
346	M	27.5	151.3	57.6	390	41.5	23.5	22.5
353	M	27.5	160.0	62.2	424	43.5	26	26
356	M	53.5	162.0	59.9	432	42.5	26	25.5
357	M	53.5	162.8	61.0	435	43	27	24
384	M	42.5	158.6	62.1	418.5	43.5	27.97	21.8

a. Age and sex estimates calculated by Márquez Morfín and Hernández Espinoza (2005).
b. Original data of this project. Stature estimations follows Auerbach and Ruff (2010). Body mass estimations follow Grine (1995).
c. AP, anteroposterior. ML, mediolateral.

Supplemental Table 5. 2 Periosteal Measurements of El Japón Individuals, Humeri [a]

Burial	Right Humerus					Left Humerus				
	Diaphysis				Head	Diaphysis				Head
	AP [b], 35% length	ML[c], 35% length	AP [b], 50% length	ML[c], 50% length	SI [d] diameter	AP [b], 35% length	ML[c], 35% length	AP [b], 50% length	ML[c], 50% length	SI [d] diameter
2	16.6	15.5	19.1	18.2	36.7	16.4	15.3	18.7	16.8	37.4
88	16.3	17.3	19.7	18.4	36.5	16.6	17.0	18.4	18.5	36.7
91	16.0	14.6	17.7	15.5	35.2	15.8	14.5	18.6	14.9	35.2
110	15.3	16.2	17.4	16.0	36.2	15.7	16.0	17.7	16.4	36.3
185	14.7	15.0	15.8	16.6	37.3	15.0	15.1	17.7	16.6	36.7
202	16.2	15.8	18.6	17.7	36.3	16.8	15.2	18.5	17.5	36.5
255	17.5	16.5	18.4	17.0	35.6	17.1	16.3	18.4	17.3	35.4
325	17.0	17.2	19.6	17.9	40.9	17.7	16.8	21.3	18.1	41.2
333	17.7	18.4	20.6	19.3	40.0	17.3	17.7	19.4	19.5	39.0
124	18.3	17.3	19.3	17.9	38.4	18.6	17.4	19.3	17.6	38.6
145	18.0	17.3	20.7	18.0	39.3	18.1	16.2	20.9	17.7	37.4
358	17.7	17.4	20.5	20.5	36.0	17.3	16.8	20.2	20.4	34.5
359	16.6	15.2	18.3	18.7	34.0	16.0	15.8	18.0	17.1	35.5
360	16.5	16.5	18.8	19.7	37.9	16.5	17.1	18.5	19.2	38.3
362	17.7	15.8	19.8	17.9	37.0	17.1	16.5	20.1	18.0	37.3
363	16.9	15.1	19.2	17.1	39.3	17.1	15.9	19.8	18.1	39.1
380	15.6	15.6	17.5	16.4	34.2	15.9	16.5	17.6	16.7	35.3
381	16.1	16.9	19.4	18.4	36.3	15.9	16.7	19.9	19.2	37.4
13	16.6	15.6	18.8	18.0	35.9	16.4	17.1	18.8	18.8	35.1
19	17.9	18.9	20.4	18.9	39.1	17.3	19.4	20.2	19.3	37.6
55	20.8	20.7	23.1	23.5	46.3	20.3	19.8	21.5	21.3	45.6
162	18.7	18.6	20.8	18.9	41.2	18.4	18.0	19.8	19.1	41.5
181	19.5	20.7	22.7	24.6	46.5	18.5	20.7	22.4	22.7	45.8
238	20.8	20.6	22.8	20.4	42.9	20.3	20.3	21.3	21.9	43.1
244	19.8	18.5	22.9	21.0	47.0	19.5	18.4	20.9	21.3	45.7

256	20.0	19.1	21.0	21.2	45.1	19.7	18.3	20.3	19.8	47.7
258	19.4	18.2	21.8	19.5	43.6	19.4	18.3	21.8	19.6	44.4
262	19.3	20.2	21.7	23.5	46.2	20.2	21.2	22.6	21.4	46.4
79	19.9	18.2	21.3	19.3	43.8	19.5	18.6	21.7	21.4	45.2
125	20.3	21.0	24.3	22.9	51.0	19.9	20.9	23.2	24.5	52.2
275	17.3	18.7	19.9	19.0	39.0	18.0	18.7	19.1	19.1	41.1
320	19.2	19.0	22.7	20.9	46.9	18.8	18.9	20.8	20.4	46.6
346	18.3	19.5	21.2	21.5	42.5	19.4	19.7	20.9	22.5	42.0
353	19.5	19.3	21.7	19.2	43.0	20.1	21.4	21.8	19.8	44.4
356	19.2	21.8	22.4	20.9	42.5	19.0	20.5	21.6	20.0	42.0
357	19.6	19.5	20.7	21.4	45.5	19.5	18.9	20.2	20.2	45.5
384	20.7	21.7	23.8	23.3	42.2	21.1	20.7	24.0	22.8	42.3

a. All data in this table is original product of this research.
b. AP, anteroposterior.
c. ML, mediolateral.
d. SI, superoinferior.

Chapter 6. Early Colonial Diet in El Japón, Xochimilco, Mexico: examining dietary persistence through stable isotope analysis of bone collagen and bioapatite[a]

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Abstract

Objectives — Early colonial documents from central Mesoamerica details raising and planting of European livestock and crops alongside native ones. The extent to which Indigenous people, especially of the rural commoner class, consumed newly introduced foods is less known.

Materials and Methods — Stable isotope analysis of bone collagen and bioapatite is applied to 74 skeletal samples representing early colonial individuals from El Japón — a farming hamlet in the Xochimilco area — to provide insight into long-term individual dietary practices in the context of a rapidly transforming Mesoamerican world.

Results — Carbon isotope ratios in collagen ($\delta^{13}C_{collagen}$) average -8.1 $^{0}/_{00}$ PDB (SD 0.55), while $\delta^{15}N$ averages 8.9 $^{0}/_{00}$ AIR (SD 0.50). $\delta^{13}C_{bioapatite}$ averages -2.6 $^{0}/_{00}$ PDB (SD 0.69). Modest increase in carbon isotopic diversity is observed among more recent males from El Japón when compared to earlier males and females.

Discussion — Relying on multivariate comparison to animal samples of known dietary composition and human samples from European and North American archaeological contexts, it is estimated that the individuals of El Japón consumed maize or other C_4 plants as a central source of carbohydrates. Dietary protein was largely domestic maize-fed fauna but potentially supplemented by wild terrestrial and aquatic fauna, and fowl. Similarity in skeletal isotopic composition between precontact Mesoamericans from other sites and El Japón individuals of both earlier and later stratigraphy is interpreted as persistence in local diets and foodways despite potentially available European alternatives.

Introduction

Stable isotope analysis has been applied over several decades to human remains from archaeological contexts to better understand lived experiences of health and diet. In Mesoamerica, specifically, stable isotope analyses paint a picture of long-term commitment to agriculture with maize-centered diets but with variation between individuals based on geography, biological sex, and social status (White et al. 2001; Williams et al. 2017; Alcantara-Russell 2020). This study applies individual level stable isotopic analyses to a skeletal collection from the early colonial period cemetery of El Japón (1565–1650 CE, Chapter 3) with the objective of comparing this postcontact sample to those of published precontact Mesoamerican samples, European samples of known differing diets and a constructed faunal and botanical baseline.

El Japón archaeological site and the southern Basin of Mexico

The archaeological site of El Japón represents a hamlet settlement in the southern Basin of Mexico (Figure 6. 1). The original Náhuatl name of the hamlet is not identified in the historical literature (Pérez Zevallos and Reyes García 2003) but the site is known to be within the traditional territory of the modern town of San Gregorio Atlapulco. San Gregorio Atlapulco aggregated from multiple farming hamlets in the decades following Spanish contact in Mesoamerica (Pérez Zevallos and Reyes García 2003) securing self-governance through a royal charter in 1555 (Pérez-Zevallos 1984). Legal recognition under an incipient colonial Spanish regime may have helped to reassert autonomy in modes of production and by extension, continuity of foodways.

Figure 6. 1 Location of El Japón in the southern Basin of Mexico. Estimated maximum extent of chinampas in the southern Basin of Mexico (Armillas 1971) is filled iconographically. Major canals and causeways illustrated above are identified in multiple historical records (Palerm 1973). Map modified from an image with a Free Art License (YAVIDAXIU 2007).

El Japón, like other postclassic Mesoamerican hamlets, likely consisted of households interrelated through kinship and corporate membership (Parsons 1991; Lockhart 1992). Settlements within the Lake Xochimilco lakebed, rested atop *chinampa* islands. These were built from lacustrine sediment throughout the Basin of Mexico since at least the 14th century (Morehart and Frederick 2014). The exact timing of chinampa construction is not well known. It is inferred here that chinampa ubiquity may have increased both with population (Parsons et al. 1982) and Postclassic agricultural surplus production destined for markets (Parsons 1976; Blanton 1996; Hirth 1998; Morehart 2016) or tribute (Gibson 1964). The chinampas were central to Postclassic and colonial agricultural production influencing economic organization, land tenure, and foot options available in the markets (Lockhart 1992; Nichols 2017).

Historic sources identify individuals or households as owners of agricultural land (Lockhart 1992) including chinampa fields (Cline 1984). Multi-household communal labor, however, maintained the infrastructure (Gibson 1964; Rojas Rabiela 1977) that permitted abundant harvests. That infrastructure included: canals carrying freshwater from springs or streams, dikes and levees that controlled water levels, and causeways that allowed travel by foot (Armillas 1977). Canals also connected the lakes of the Lake Texcoco system facilitating transport of merchandise and people via *trajineras* (large wood canoes) to the regionally interconnected markets of the Postclassic and colonial periods (Rojas Rabiela 1984).

By the time of Spanish contact in the 1520s, communally oriented chinampa agriculture is documented throughout the Basin of Mexico (Durán 1994; Frederick 2007). The *calpulli* or *tlaxilacalli* (used interchangeably) in the Nahua sphere of influence was a source social and economic organization which included labor organization and organization of tribute payment among its roles (Gibson 1964). Neighborhoods of large settlements, like Xochimilco or Texcoco in the Valley of Mexico, consisted of multiple calpullis (Lockhart 1992; Smith 1993; Pérez Zevallos and Reyes García 2003). As a small hamlet, El Japón was likely a single calpulli.

The archaeological site of El Japón includes hundreds of relict farm fields and house plots on chinampas that dotted the shallow Lake Xochimilco marshlands over about 200 ha (Ávila López 1995). The cemetery of El Japón was excavated in the early 1990s (Ávila López 1995) and found to be similar to European churchyards in layout and includes adult and subadult individuals. Interred individuals likely lived and died in the marshland hamlets around El Japón. Bayesian modeling of bioapatite and collagen radiocarbon dates from El Japón human skeletal samples places burials between *1565–1640* cal. CE (Chapter 3), during the first century after Spanish contact. Within El Japón cemetery, burial depth correlates with relative age (Chapter 3). Burials in the lower layers occupied most of the area of a single mound identified as cemetery while burials in shallower layers reoccupy space previously used for burials. Based on mortuary treatment consistent with Christian cemeteries, no individuals were likely buried prior to European contact.

Migratory and endemic fowl, game animals, freshwater invertebrates and fish were likely among the C_3 organisms contributing to adult nutrition at El Japón as these are identified archaeologically (Corona Martínez 2012). The crafted chinampa landscape in the Basin of Mexico was primarily maintained to secure abundant harvests. However, the opportunity to exploit aquatic species of vertebrates and invertebrates did not go unused and this is documented through the Postclassic and colonial periods. Zooarchaeological evidence of European and local animals exists in household middens at El Japón site (Corona Martínez 2012). Native wild taxa identified includes migratory and non-migratory fowl, turtles, and fish. It is difficult to estimate what fraction these wild taxa occupied in colonial rural diets.

Contemporaneous historical documents, however, point toward the economic value of local aquatic species. A variety of fish were regularly collected, purchased, traded, and consumed in the Valley of Mexico: *xohuilin*, *izacmichin*, and *charales* (Gibson 1964; Díaz del Castillo 2003). Though folk taxonomies vary, these may correspond to: *Algansea tincella* (xohuilin), *Chirostoma spp.* (iztacmichin), and *Evarra spp.* (charales). These taxa occupied a variety of ecological niches in geographically isolated lakes of central Mesoamerica, including the Lake Texcoco system. The maximum size of curated specimens is 34 cm: *Chirostoma estor* (Lyons 2000). The largest of these Basin of Mexico fishes is far smaller than economically important marine fishes, *e.g.* tuna or cod.

Stable Isotope Analysis

Carbon in natural systems exists as ^{14}C, ^{13}C, and ^{12}C isotopes. ^{12}C and ^{13}C are the most abundant isotopes in organisms and facilitate the tracing energy movement through foodwebs beginning with producers (Tieszen 1991). The most important producers in temperate environments like Mesoamerica are terrestrial plants which are classified as C_3 and C_4 based on differing photosynthetic pathways (Smith and Epstein 1971).

C_4 plants are generally adapted to dryer or warmer climates (Tieszen 1991) and comprise maize and amaranth, and as such are often important in archaeological consideration of food production and consumption in Mesoamerica. In regional surveys of domestic and wild plants in Oaxaca (Warinner et al. 2013) and western Argentina (Gil et al. 2009; Gil et al. 2010), $\delta^{13}C$ averaged -14$^0/_{00}$ PDB in contrast to C_3 plants of the same regions averaging -23$^0/_{00}$ PDB (Smith and Epstein 1971). Crassulacean (CAM) plants form a third subgroup of plants with intermediate $\delta^{13}C$ averaging -16$^0/_{00}$ PDB (Szpak 2013). CAM species may approach the isotopic ratios of C_4 plants due to adaptation to arid environments (O'Leary 1988) and this phenomenon is identified in Mesoamerica (Warinner et al. 2013).

Nitrogen and carbon ratios ($\delta^{15}N$ and $\delta^{13}C$) are altered as molecules or amino acids pass from consumed plant foods, through a digestive tract, and on to body tissues (carbon: DeNiro and Epstein 1978; Schoeninger and DeNiro 1983, nitrogen: DeNiro and Epstein 1981; Minagawa and Wada 1984). Both bone collagen and bone bioapatite are enriched in heavy isotopes of carbon and nitrogen compared to consumer's diet and that difference in isotopic ratios is quantified as a diet-tissue spacing (Δ, DeNiro and Epstein 1978, 1981). When observing terrestrial organisms, bone collagen $\delta^{15}N$ is expected to increase 3–5‰ from one trophic level to the next (Minagawa and Wada 1984; Hedges and Reynard 2007). Isotopic study of nitrogen isotope ratios in human bone collagen facilitates estimates of individual trophic position relative to plants and animal sources. The term *spacing* is also used to describe systematic difference between the protein and mineral fractions of bone: collagen and bioapatite respectively.

$\delta^{13}C$ and $\delta^{15}N$ isotope ratios in human bone collagen primarily reflect the mix of isotope ratios in dietary protein (Ambrose and Norr 1993; Fernandes et al. 2012) with secondary input from dietary carbohydrates and lipids. $\delta^{13}C_{bioapatite}$ reflect the isotopic variation of the whole diet. A minimum $\Delta_{bioapatite\ -collagen}$ of 4‰ (Lee-Thorp et al. 1989) for $\delta^{13}C$ is expected between consumed organisms and humans due to differential routing and assimilation during formation and remodeling of tissues.

Spacing higher than 4‰ is indicative of substantially different sources of carbohydrates and protein in an individual's diet: a common observation in human diets due to omnivory. Simultaneous isotopic study of $\delta^{13}C_{collagen}$ and $\delta^{13}C_{bioapatite}$ permits inference of the isotopic variability of macronutrients: carbohydrates, proteins, and lipids (Ambrose and Norr 1993; Fernandes et al. 2012). All macronutrients are necessary for human sustenance, but individual foods that meet those needs vary immensely across geography, historical and economic contexts. Protein, for example, can be supplied by legumes, mushrooms, meat, or animal byproducts.

Dietary Consistency and Change

This study examines isotopic variation of human bone collagen and bioapatite to identify variation in diet in the decades following European contact. Though agriculture continued as the main source of sustenance, environmental, political, and economic change modified the incentives and context under which intensive agriculture was carried out in central Mesoamerica. The relationship between that economic and political control and diets in a rural hamlet is worth exploring as an indicator of the lived effects of political change.

Mesoamerican societies primarily relied on agriculture for sustenance since at least the Formative Period (2,000 BCE–250 CE). By the Classic (250–900 CE) and Postclassic (900–1521 CE) periods, market systems circulated finished and unfinished goods (Schwartz 2000), including specialty foods (Hirth 1998) in addition to staple grains and domestic animals (Durán 1994;

Blanton 1996). Both rural and urban communities engaged in local and long-distance trade through the public markets that set up on a regular schedule in geographically central places (Durán 1994; Motolinía 2014; Smith 2017). Individual and household ability to acquire nonlocal foods and goods varied since Classic and Postclassic societies were stratified by social status (Gibson 1964; Lockhart 1992; c). Households — elite and nonelite — traded for foods they did not produce. Elite households not only had greater ability to acquire market goods but also occupied hereditary and nonhereditary political offices (Gibson 1964; Inoue 2007) that entitled them to "payment in kind" (Lockhart 1992: 132) of staple grains, e.g., maize and beans (Gibson 1964).

Stratified economic resources and interests continued into the colonial period (1521–1810 CE). For farming households of the early colonial period, experimentation with introduced Eurasian food sources was possible through participation in the markets (Gibson 1964; Lockhart 1992; Jalpa Flores 2008). Indigenous commoners raised European livestock and crops in lower rates than Indigenous and Spanish elites in Chalco (Jalpa Flores 2008; Lockhart 1992) 15 km from El Japón. It can be inferred that European livestock production may have been uncommon in the decades after Spanish contact in Indigenous communities where most households occupied a relatively low social rank — namely agricultural hamlets inhabited by *macehuales*. El Japón like other agricultural hamlets subject to San Gregorio Atlapulco was likely inhabited by tax-paying non-elites: macehuales. Commoners of the late Postclassic and early Colonial period had similar economic means and acquired goods and non-local foods through the same markets (Gibson 1964).

Land access for agriculture was a central resource for families of economic non-elite standing and protection of this resource was crucial. Ecological deterioration from raising cattle as opposed to smaller European livestock (i.e., sheep and goat) was a concern in the 16th and 17th century Valley of Toluca (González Reyes 2009). Similar concerns were echoed in San Gregorio

Atlapulco in 1595 (McAfee and Barlow 1952) in documented complaints against a single European rancher. Variation in food sources existed not only in agricultural production, but also in collection of wild foods. Lacustrine communities hunted, fished, and fowled before European colonization (Manzanilla and Serra 1987; McClung de Tapia and Acosta Ochoa 2015) and after (Gibson 1964). Those products were commonly found in markets and available beyond the shores of the Lake Texcoco system (Gibson 1964).

In the chinampa landscapes of Lakes Chalco and Xochimilco (the southern end of the Lake Texcoco system), raising European livestock may have been a less desirable economic activity in comparison to traditional agricultural methods (Sluyter 1997). Indigenous people in colonial Mesoamerica almost exclusively carried out chinampa agriculture (Gibson 1964; Conway 2014) despite changing economic dynamics (Hassig 1985), and demographic decline due to successive epidemics (Prem 1992; Newson 1993; Storey, 2012). By some accounts, direct environmental engineering for the purpose of agriculture similar to European methods (i.e., marshland desiccation) came late to the Xochimilco area in the 18th century (Conway 2014).

Unsuitability of soil for Spanish crops and livestock (Schwartz 2000) may have safeguarded an Indigenous economic niche in chinampa agriculture. The chinampa agricultural niche may have also been safeguarded by the ecological productivity offered by the lakebed and flow of freshwater from local springs. Lakebed sediment was dredged to replenish chinampa islands: mitigating lake levels and providing crops with fertilizer (Frederick 2007). Early colonial Indigenous persistence in chinampa systems however did not imply absolute continuity or resistance to all European foods and food production methods. Isotopic study of skeletal samples provides the opportunity to directly examine the dietary patterns in individuals who lived in the transformative 16th and 17th centuries in central Mesoamerica.

Materials and Methods

Seventy-four human bone samples (Table 6. 1) were collected from the El Japón skeletal collection located in the *Escuela Nacional de Antropología e Historia* (ENAH) in Mexico City, Mexico. Fifty-six adult individuals were selected at random from throughout the stratigraphic proveniences of the site cemetery. Twenty additional individuals were selected strategically to include stratigraphically superimposed individuals for chronological constraint and estimation of cemetery use via radiocarbon dating (Chapter 3; Alarcón Tinajero 2022).

Chemical pretreatment and analysis for all samples was carried out at the University of Georgia Center for Applied Isotope Studies. Ribs were preferentially selected for analysis. Bone isotope ratios reflect the ratios in diet for up to more than ten years prior to death, varying with remodeling rates (Hedges et al. 2007). More vascularized bone (including trabecular bone or relatively thin elements like ribs) has short turnover periods. Denser bone tends to turnover at a slower rate though exact rates are not known. Rib, fibula, or radius bone was preferentially sampled. Only two samples were taken from femora due to absence of thinner skeletal elements with adequate preservation.

Table 6. 1 Osteological Samples

Burial	Sex estimate†	Age estimate†	Cemetery Stratum
1	M	21	Upper
2	F	20	Upper
3	F	42	Upper
4	-	10	Upper
5	F	-	Upper
6	M	25	Upper
7	M	19	Upper
8	-	10	Upper
9	-	5	Upper
13	M	35	Upper
15	F	25	Upper
19	M	35	Upper
23	F	17	Upper
26-A	M	27.5	Lower
27	F	18	Lower
29	F	12	Upper
31	M	27.5	Lower
33	M	25	Upper
35	M	18	Upper
37	-	4	Upper
39	F	20	Upper
50	M	22	Lower
53	F	20	Lower
55	M	22.5	Upper
58	F	30	Lower
62	F	15	Lower
73	-	8.5	Lower
86	F	19	Lower
87	F	24	Lower
88	F	27.5	Lower
90	M	25	Lower
91	F	19.5	Lower
96	M	37.5	Lower
97	F	21	Lower
102	F	17.5	Lower
108	M	27.5	Lower
110	F	25.5	Lower
112	M	21	Lower
113	F	24.5	Lower
119	M	15	Lower
125	M	39	Lower
126	F	26	Lower
143	F	43	Lower
145	M	35	Lower
156	F	18	Lower
162	M	32.5	Lower
174	-	5	Lower
180	F	23	Lower
202	M	37.5	Lower
219	M	21.5	Lower
222	F	38	Lower
227	M	30.5	Lower
228	F	65	Lower
237	M	17	Lower
238	M	38	Lower
244	M	35	Lower
255	F	35	Lower
256	M	25	Lower
262	M	37	Lower
275	M	25	Lower
290	M	25	Lower
293	M	32.5	Lower
301	-	8.5	Lower
325	F	32.5	Lower
330	-	5	Lower
333	F	35	Lower
348	F	37.5	Lower
357	M	39	Lower
358	F	20	Lower
360	F	47.5	Lower
376	F	22.5	Lower
379	M	27	Lower
381	F	32	Lower
384	M	35	Lower

† Age and sex estimates calculated by Márquez Morfín and Hernández Espinoza (2005).

Collagen preparation

Collagen isolation for stable isotope analysis was carried out with a modified Longin (1971) procedure. Inspection for adhesives was carried out with UV light. If necessary, samples were sonicated in three consecutive acetone baths, then rinsed and soaked in ultrapure water to neutrality. Acetone pretreated samples were evaporated for a minimum of 12 hours prior to further pretreatment. Cortical bone surface was removed from all samples to prevent inclusion of adsorbed compounds. Samples were demineralized in a 1 N hydrochloric acid (HCl) solution at 4º C for 24 hours after an initial vacuum pump. Samples were probed with sanitized metal tools after 22–24 hours in solution to test the degree of malleability. Demineralized samples were decanted and rinsed to neutrality before a 5-minute sodium hydroxide (NaOH) wash. The base solution step modifies the procedure and is consistent with multiple studies isolating collagen for isotope analysis (Haynes 1968, Berglund et al. 1976, and Gurfinkel 1987).

Samples were then rinsed to neutrality and placed in a second HCl wash for 30 minutes. Samples were decanted and rinsed to be slightly acidic (pH 3–4) and dissolved on a hotplate at 80º C for 12 hours. Samples were filtered using a glass fiber filter and vacuum pump and placed in pre-weighed beakers for evaporation at 80º C. Evaporation times varied between samples. Samples were briefly cooled at room temperature and placed in -80º C freezer for 30 minutes. Samples were then placed in a freezer dryer for 15 hours. One milligram collagen subsamples were encapsulated in tin to measure elemental concentrations (%C and %N) and stable isotope ratios ($\delta^{13}C$ and $\delta^{15}N$) using a Thermo Fisher elemental analyzer isotope ratio mass spectrometer (EA-IRMS).

Isotopic ratios are expressed as $\delta^{13}C$ with respect to the Vienna Pee Dee Belemnite carbonate standard (VPDB) and $\delta^{15}N$ with respect to Atmospheric Nitrogen (AIR). National Institute of Standards and Technology standards 1570a (spinach) and 1577C (bovine liver) were included in stable isotopic analyses of bone collagen and modern botanical samples. Standard deviation of 1570a $\delta^{13}C$ (n=27) was 0.22‰ and standard deviation $\delta^{15}N$ was 0.14‰. Standard deviation of 1577C $\delta^{13}C$ was 0.07‰ and $\delta^{15}N$ was 0.09‰. Fisher and A1296 internal calcite standards (n=14 each) were included in gas bench analysis of bioapatite samples. $\delta^{13}C$ standard deviation of Fisher standard was 0.004‰, while $\delta^{13}C$ standard deviation of A1296 was 0.005‰. Carbon-nitrogen atomic ratios and percent collagen yield were calculated for each collagen sample. Carbon-nitrogen atomic ratios (C:N, van Klinken 1999) was calculated using $({}^{total\ \%C}/_{12})/({}^{total\ \%N}/_{14})$. Percent collagen yield (van Klinken 1999) was calculated by dividing the freeze-dried purified collagen sample by the weight of the sample after acetone pretreatment and evaporation but prior to HCl dissolution.

Bioapatite Preparation

Bone samples for bioapatite analysis were sonicated three times in ultrapure water in 30-minute increments to remove sediment and organic materials in pores not removed by abrasive cleaning. The remaining procedure for bioapatite samples follows Cherkinsky (2009). Samples were demineralized for 24 hours in a 1 N acetic acid (CH_3COOH) solution and pumped under vacuum every 6 hours to incite reaction. Samples were decanted at 24 hours and soaked in ultrapure water for 30 minutes to better release absorbed acetic acid, then rinsed to neutrality. Samples were placed in a 60º C oven for 12 hours for evaporation. 3 mg of crushed pretreated bone samples were placed in borosilicate glass exetainers and purged with helium for 20 minutes. Samples were subsequently acidified with 100% phosphoric acid (H_3PO_4) and heated for 12 hours at 50º C before analysis in a Thermo Gas Bench coupled to a Delta V isotope ratio mass spectrometer (IRMS).

Four modern comparative maize samples were collected in San Francisco Cuautlancingo, Puebla state, Mexico and chemically pretreated for stable isotope analysis. Whole kernels that showed no visual sign of fungus or insect boring were selected at random from four cobs of the

2020 harvest (three of *Cacahuazantle* and one of *Maíz azul*). During pretreatment, kernels were placed in HCl and heated at 80° C for 1 hour to remove potential contaminants (Brock et al. 2010). Samples were decanted, rinsed with ultrapure water, and placed in a NaOH soak for 5 minutes. Samples were rinsed to neutrality and placed in a second heated HCl soak for 30 minutes to remove potential atmospheric carbon introduced during the base step. Maize samples were soaked in ultrapure water for 30 minutes, rinsed to neutrality, and dried in a 60º C oven for a minimum of 12 hours.

Baseline Selection from Published Sources

Isotopic data from European, North American, South American, and Asian faunal and human archaeological skeletal samples was compiled systematically to compare with stable isotopic findings in this research and calculated isotopic variation in macronutrients. Carbon isotope ratios ($\delta^{13}C$) from modern comparative botanical samples were corrected for a Suess effect by adding 1.6‰ (Ambrose et al. 1997). Persistent fossil fuel use since the late Modern period has shifted atmospheric $\delta^{13}C$ (Keeling 1979) making modern plants of similar geography and taxa systematically more negative than premodern counterparts. A Suess correction of measured $\delta^{13}C$ makes modern isotopic data comparable with premodern archaeological samples.

Stable isotope data for comparative plants and animals was compiled using identical criteria from modern and archaeological contexts in Africa, Asia, Europe, North and South America to select appropriate comparative materials. Drastic postcontact changes to the Lake Texcoco system in water chemistry, volume and flow challenge the creation of a faunal isotopic baseline relying on modern or more recent samples. In place of Lake Texcoco specimens, comparative archaeological and Suess-adjusted modern fishes from multiple regions (Supplemental Table 6. 5) are employed to provide faunal isotopic baseline for interpretation of human isotopic data.

Maize from a variety of geographic, cultural, and climatic contexts provides a range of isotopic variation to explore human diet. Supplemental Tables 6. 2- 6. 5 provide summary statistics, geographic and chronological origin, as well as bibliographic sources of the faunal and botanical isotopic data. Most botanical and faunal samples are from archaeological contexts (see individual supplemental tables for counts and references). Modern samples were adjusted for Suess effect by adding 1.6‰ to measured $\delta^{13}C$ (Ambrose et al. 1997) prior to calculation of $\delta^{15}N$ and $\delta^{13}C$ statistics relied on for comparison in text or in figures.

Macronutrient Calculation

Isotopic ratios of two dietary components were calculated using regressions (Kellner and Schoeninger 2007) that compared stable isotope ratios in bone collagen and bioapatite with isotopic composition of animals fed controlled diets. $\delta^{13}C_{\text{diet energy}}$ is examined as a component rather than individual macronutrients (carbohydrates and lipids) since bulk isotope analysis on bioapatite and collagen do not permit more precise calculation. $\delta^{13}C_{\text{bioapatite}}$ and $\delta^{13}C_{\text{whole diet}}$ (protein, carbohydrates, and lipids) have the strongest correlation with controlled diets (Kellner and Schoeninger 2007) and strongest predictive capability. Collagen and bioapatite isotopic ratios in the experimental studies had weaker correlations with individual macronutrients (r^2= .54–.65, Kellner and Schoeninger 2007:1119). Isotopic estimates of dietary components from collagen and bioapatite facilitate inference of food sources and comparison published isotopic data of food sources elsewhere. $\delta^{15}N_{\text{whole diet}}$ is calculated via $\delta^{15}N - 3.30$ (Minagawa and Wada 1984), which was based on several terrestrial mammals. $\delta^{13}C_{\text{whole diet}}$ is calculated using $-1.04 \times \delta^{13}C_{bioapatite} - 9.20$ (Kellner and Schoeninger 2007). The difference between $\delta^{13}C_{\text{collagen}}$ and $\delta^{13}C_{\text{bioapatite}}$ is known as bioapatite -collagen spacing ($\Delta_{\text{bioapatite -collagen}}$, Lee-Thorp et al. 1989). $\delta^{13}C_{\text{protein}}$ is calculated using $-0.94 \times \delta^{13}C_{collagen} - 6.90$ (Kellner and Schoeninger 2007). $\delta^{13}C_{\text{diet energy}}$ is calculated using $-1.10 \times \delta^{13}C_{bioapatite} - 8.40$ (Kellner and Schoeninger 2007).

Isotopic results from El Japón are compared to archaeological human individuals from Europe (not mapped) and Mesoamericans from the Central highlands and the Mayan cultural region (Figure 6. 2). Data was systematically collected via literature searches where sample sizes were greater than 15 individuals and individual data was accessible: quality indicators (C:N and percent collagen yield), $\delta^{15}N$, $\delta^{13}C_{collagen}$, and $\delta^{13}C_{bioapatite.}$ Altun Ha (White et al. 2001), Calakmul (Price et al. 2018), Chinikiha (Negrete et al. 2020), Ka'kabish (Smith 2020), Minanha (Williams et al. 2017), Nakum (Rand et al. 2020), Xcambo (Sierra Sosa et al. 2014) are employed as *Mayan Comparative Set 1*.

Mayan Comparative Set 2 differs from the first set in that interpretation of social status is offered by the respective authors based on burial locations, household contents, and burial goods. Mayan Comparative Set 2 includes: Altar de Sacrificios (Wright 2006), Altun Ha (White et al. 2001), Cahal Pech (Ebert et al. 2019), Calakmul (Price et al. 2018), Chinikiha (Negrete et al. 2020), Itzan and Seibal (Wright 2006), Ka'kabish (Smith 2020), Minanha (Williams et al. 2017), Nakum (Rand et al. 2020), and Xcambo (Sierra Sosa et al. 2014).

Three Neolithic Iberian sites (Los Cascajos and Paternabidea (Fernández-Crespo et al. 2019), and Tossal de les Basses (Salazar-García et al. 2016)) are employed as a comparison outside Mesoamerica. A *Central Mesoamerican Comparative Set* (Chalcatzingo (Streuli 2016); Cholula and Tepeticpac (Alcantara-Russell 2020); Ecatepec (Moreiras Reynaga et al. 2020); Tlailotlacan (White 2004) and Tlajinga, Teotihuacan (Storey et al. 2019) permit broad comparison of subregional Mesoamerican foodways. Ecatepec and Cholula span the Postclassic period while Tepeticpac dates to the early colonial period, contemporaneous with El Japón. The Campeche City churchyard (Price et al. 2012) is discussed independent of the Mayan comparative sets since it is radiocarbon dating to after European contact and is demonstrated to contain the remains of

European, African, and local born individuals unlike precontact sites. The varied contexts of the comparative sites permit inference of food sources and discussion of their economic importance in El Japón where isotopic methods cannot be matched to zooarchaeological materials.

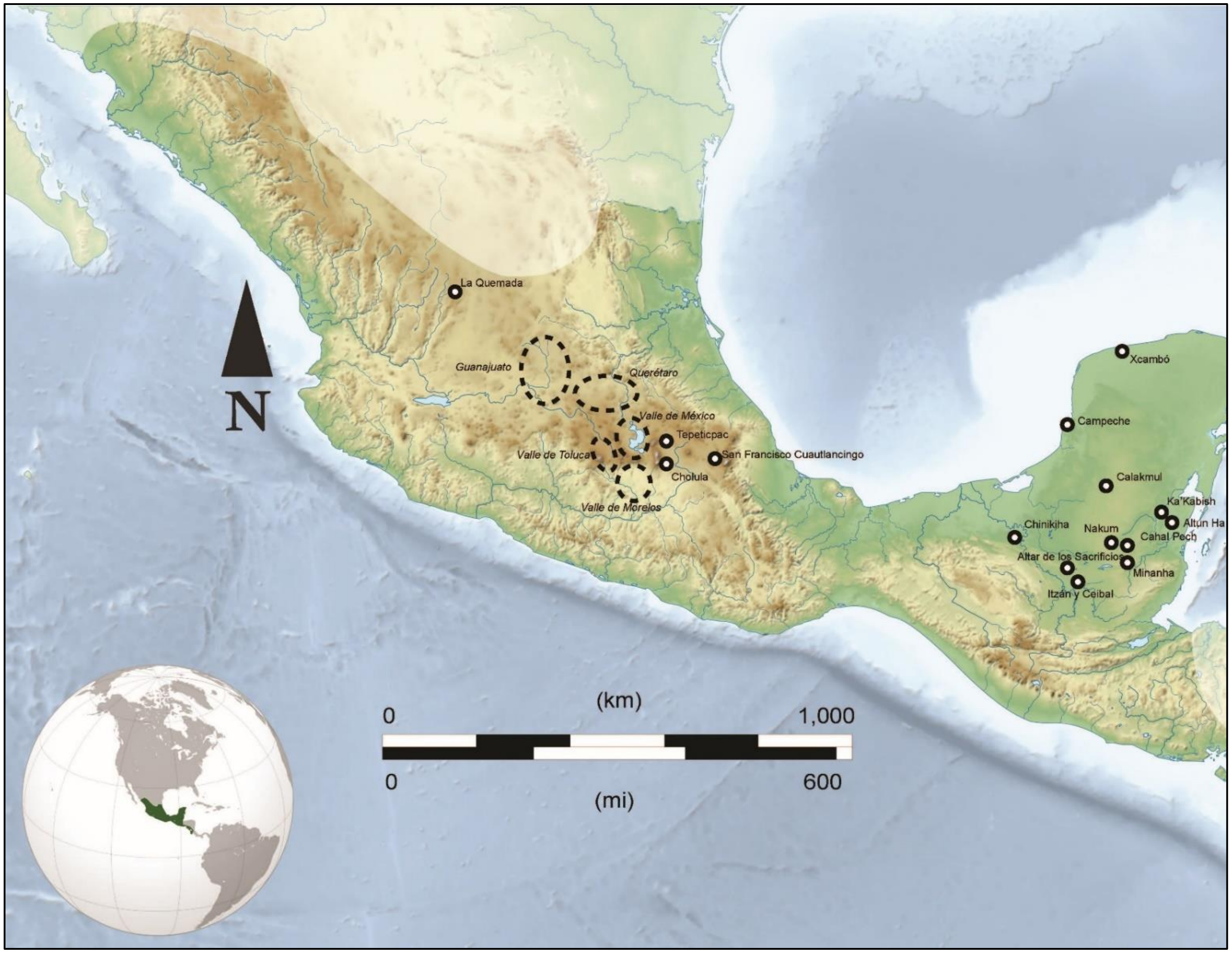

Figure 6. 2 Location of Mesoamerican sites included in text. Map modified from an image with a Free Art License (SÉMHUR 2011).

Results

Tables 6. 2 and 6. 3 present isotopic results of El Japón subsamples — both chronological and sex-based. Due to the size of the dataset, individual results are presented in Supplemental Table 6. 1. $\delta^{13}C_{collagen}$ averages -8.1‰ PDB (SD 0.55), while $\delta^{15}N$ AIR averages 8.9‰ (SD 0.50). $\delta^{13}C$ in bone bioapatite averages -2.6‰ PDB (SD 0.69). All samples had an atomic C:N between 2.9-3.3. Kruskal–Wallis were used to analyze the data as not all subsets are normally-distributed. Significant differences are observed in both $\delta^{13}C_{collagen}$ and $\delta^{13}{}_{bioapatite}$ when the El Japón sample is divided by sex (p<.01). No significant change over time is observed $\delta^{13}C_{collagen}$ when the El Japón individuals are divided by upper and lower stratigraphy (p=0.57). Significant change between burial strata, however, is evident in $\delta^{13}C_{bioapatite}$ (p=<.01).

Table 6. 2 $\delta^{13}C$ Isotopic Summary Statistics†

Sex and Stratigraphy	Fraction	Mean (‰)	S.D.	Median (‰)	Min. (‰)	Max. (‰)
Upper Males	Collagen	-7.7	0.3	-7.7	-8.1	-7.2
	Bioapatite	-2.7	0.6	-2.8	-3.4	-1.6
Upper Females	Collagen	-8.2	0.4	-8.4	-8.5	-7.7
	Bioapatite	-3.0	0.5	-2.8	-3.9	-2.5
Lower Males	Collagen	-7.7	0.4	-7.7	-8.5	-7.0
	Bioapatite	-2.2	0.6	-2.3	-2.3	-0.2
Lower Females	Collagen	-8.4	0.5	-8.4	-9.2	-7.3
	Bioapatite	-2.6	0.5	-2.5	-3.9	-1.7
All‡	Collagen	-8.1	0.6	-8.0	-9.4	-7.0
	Bioapatite	-2.6	0.7	-2.5	-4.6	-0.2

† Individual isotopic results are presented in Supplemental Table 6. 1.
‡ Includes 10 subadults (age estimates <15 years).

Table 6. 3 $\delta^{15}N$ Isotopic Summary Statistics †

Sex and Stratigraphy	Mean (‰)	S.D.	Median (‰)	Min. (‰)	Max. (‰)
Upper Male	8.7	0.6	8.8	7.5	9.3
Upper Female	8.9	0.3	8.9	8.4	9.2
Lower Male	9.1	0.4	9.0	8.2	9.7
Lower Female	9.0	0.5	9.0	7.9	10.3
All‡	9.0	0.5	9.0	7.5	10.3

† Individual isotopic results are presented in Supplemental Table 6. 1.
‡ Includes 10 subadults (age estimates <15 years).

No significant difference in $\delta^{15}N$ is observed when comparing sexes (*p*=.35). No significant differences are evident between sexes even when divided into upper (*p*=0.9) and lower stratigraphy (*p*=0.29). A significant — but marginal — difference in $\delta^{15}N$ is observed between lower and upper burials (*p*=.04). This statistic will be interpreted with caution as upper and lower samples are of unequal numbers (19 and 55, respectively).

Table 6. 4 Kruskal-Wallis Statistics of Stable Isotopic Data

Isotopic Fraction	$\chi2$	*p*	$Group_1$	Trend	$Group_2$
$\delta^{13}C_{collagen}$	25.6	<.01	Male	>	Female
$\delta^{13}C_{bioapatite}$	4.5	<.01	Male	>	Female
$\delta^{13}C_{collagen}$	0.9	0.6	Lower Stratigraphy	≈	Upper Stratigraphy
$\delta^{13}C_{bioapatite}$	14.5	<.01	Lower Stratigraphy	<	Upper Stratigraphy
$\delta^{15}N$	0.9	0.4	Male	≈	Female
$\delta^{15}N$	4.1	0.04	Lower Stratigraphy	>	Upper Stratigraphy

$\delta^{13}C_{collagen}$ shows no significant change between earlier and later individuals. Secular change towards more negative $\delta^{13}C$ occurs in both males and females (Table 6. 4). $\delta^{13}C_{collagen}$ demonstrates no change over time when comparing lower and upper burials. Only modest change in the range of $\delta^{15}N$ is observable in comparing the same lower and upper burials. $\delta^{13}C_{bioapatite}$ at El Japón became more negative for both males and females over time.

Discussion

Secular Change

Considering $\delta^{13}C_{collagen}$ and $\delta^{15}N$ together supports an interpretation that consistency in isotopic ratios over time is indicative of diachronic reliance on similar dietary sources. Only minor shifts in $\delta^{13}C$ are observed over time at El Japón (Figure 6. 3) with a minor shift indicating relatively more C_3 plant consumption. Based $\delta^{13}C_{collagen}$ and slight decrease in $\delta^{15}N$, dietary protein sources in El Japón changed little through time but what change did occur implies slight decrease in human trophic position implicating higher plant protein consumption through time as opposed to a reliance on animal meat and products as protein sources.

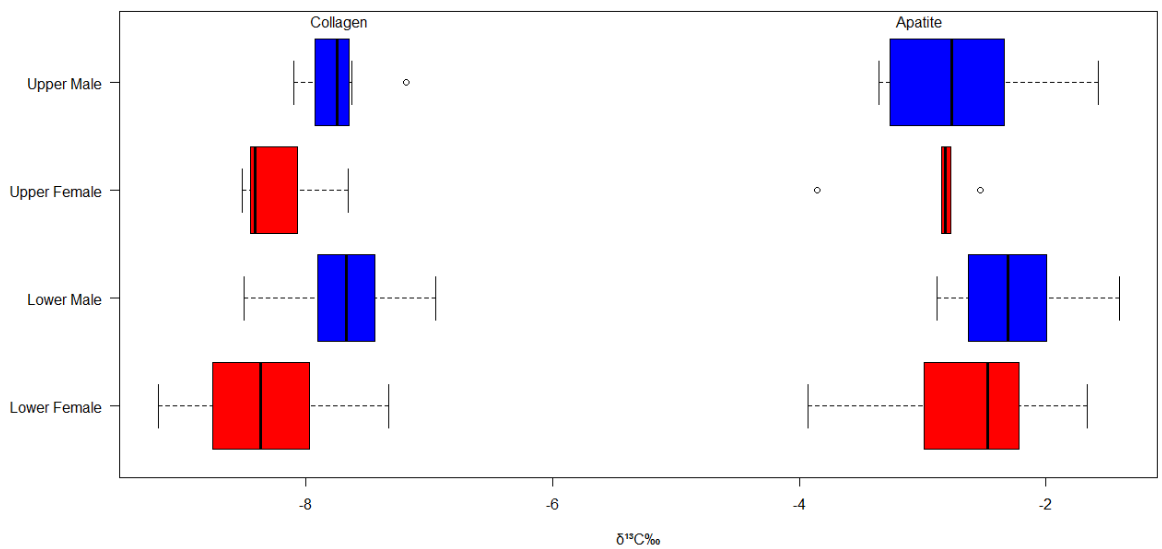

Figure 6. 3 $\delta^{13}C_{bioapatite}$ and $\delta^{13}C_{collagen}$ by stratigraphy and sex. Plot excludes male individual 384 as it is suspected to have undergone diagenetic alteration.

Sex-based variation is observed in both $\delta^{13}C_{bioapatite}$ and $\delta^{13}C_{collagen}$ but no concomitant difference in $\delta^{15}N$ follows. The absence of paired variation in $\delta^{13}C$ and $\delta^{15}N$ is interpreted in sex-based differences in $\delta^{13}C_{diet\ energy}$ sources that maintained a relatively high proportion of plant-based proteins and carbohydrates as opposed to animal products for both sexes. A marginally significant difference is observed between earlier and later $\delta^{15}N$ (Figure 6. 4). Males interred in latter stratigraphy may have consumed a smaller share of animal protein as a share of whole diet.

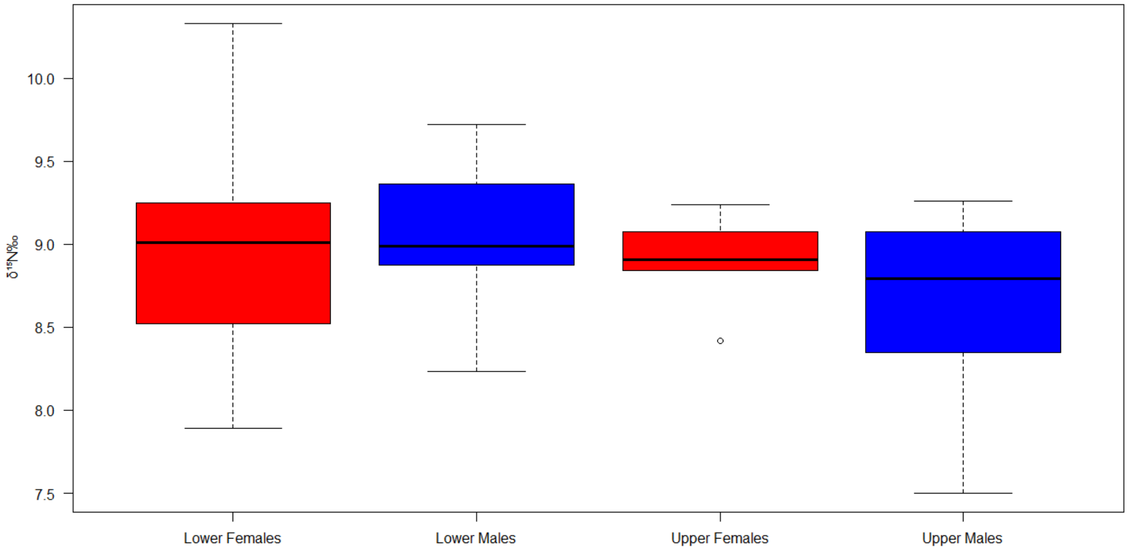

Figure 6. 4 Bone collagen $\delta^{15}N$ by stratigraphy and sex. Plot excludes male individual 384 as it is suspected to have undergone diagenetic alteration.

Specific Food Sources

Maize was a major component of individual diets at early colonial El Japón based in the Mesoamerican cultural context and the relatively high $\delta^{13}C_{bioapatite}$ and $\delta^{13}C_{collagen}$. No archaeological maize samples were secured from El Japón but newly acquired botanical isotopic data (Supplemental Table 6. 2) and compiled published data (Supplemental Table 6. 3) facilitate a botanical isotopic baseline. $\delta^{13}C_{diet\ energy}$ places all individuals from El Japón in a range consistent with C_4 diets (median -11.2$^0/_{00}$, SD 0.8). Median $\delta^{13}C_{whole\ diet}$ (-11.8, SD 0.7), though consistent with C_4 foods, is indicative of some supplementation with C_3 plants and animals. CAM plants (e.g., *opuntia ficus-indica*), legumes, C_3- feeding animals are some examples known in the region.

Comparative freshwater fishes (Supplemental Table 6. 5) oscillate near -21$^0/_{00}$ δ^{13}C PDB consistent with the theoretical expectation that freshwater aquatic foods consumption would weigh carbon isotope ratios in human bone collagen and bioapatite towards more negative δ^{13}C. The same samples average 8.8$^0/_{00}$ δ^{15}N AIR. In paleodietary studies, freshwater food consumption generally implies heightened δ^{15}N in comparison to terrestrial-centered diets (DeNiro and Epstein 1981; Minagawa and Wada 1984). Freshwater food consumption in the Basin of Mexico may have occurred without driving appreciable δ^{15}N increase since economically important species documented for the Postclassic and colonial periods tend to be of small body size and low trophic position — this is tentatively inferred from the variation of curated samples which postdate European contact (Lyons 2000).

Sex-based Differences

Sex-based differences in diet that were instilled at early age (Berdan and Anwalt 1992) according to informants and authors of the early colonial Codex Mendoza. Variation in amount and frequency of maize consumption is among those sex-based differences. Differences in portion size, meals per day, or other culturally designated distinctions likely took place at El Japón like other Nahua communities, and thus influenced isotopic ratios. Among the sex and chronological subgroups, females in the earlier stratigraphy demonstrate the greatest isotopic variation (Figures 6. 3 and 6. 4).

Maize was a central component of diet for all individuals but lower quartile $\delta^{13}C_{bioapatite}$ is consistently lower for females than males within the same chronological proxy. Adult women may have consumed larger portions of plant protein (e.g., C_3 legumes) or freshwater fish in place of meat from domestic maize-fed animals. Diets of adult males and females were varied. Reduced dietary richness (Reitz and Wing 2008) — for example in an almost exclusively animal-product reliant pastoralist context — would justify the expectation of concomitant high correlation between

$\Delta_{bioapatite\text{-}collagen}$ spacing and mean macronutrient isotopic ratio. In contrast low animal protein consumption is interpreted at El Japón based on weak correlations, especially among females. $\Delta_{bioapatite\text{-}collagen}$ is negatively correlated with dietary protein $\delta^{13}C$ of (Figure 6. 5).

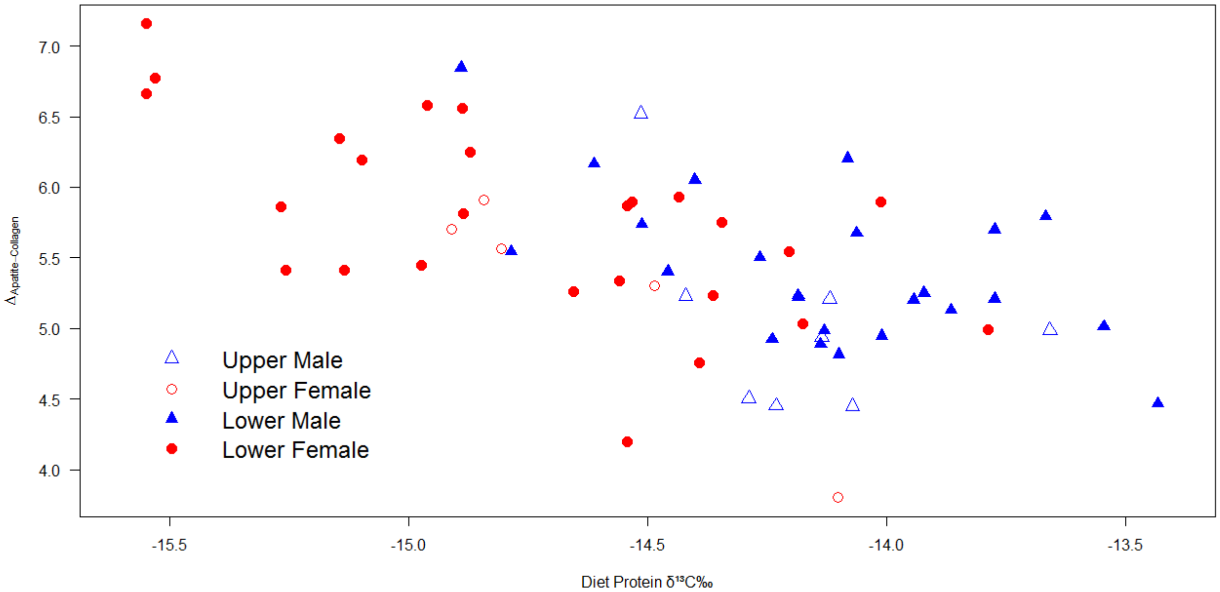

Figure 6. 5 Adult $\Delta_{bioapatite\text{-}collagen}$ and $\delta^{13}C_{protein}$ Biplot. Males $\Delta_{bioapatite\text{-}collagen}$ and $\delta^{13}C_{protein}$: ρ=-0.36, p=0.04. Females $\Delta_{bioapatite\text{-}collagen}$ and $\delta^{13}C_{protein}$: ρ=-.51, p<0.01. Combined sexes: ρ=-.47, p=<0.01

Median $\delta^{13}C$ of protein sources for adults at El Japón oscillates near -14.8$^{0}/_{00}$ and as such is intermediate between C_3 and C_4 plant sources. Coupled with the data on $\Delta_{bioapatite\text{-}collagen}$, however, it is evident that individuals with $\Delta_{bioapatite\text{-}collagen}$ greater than 5$^{0}/_{00}$ have greater diversity of calculated dietary protein δ^{13} C (SD 0.5, n=54). Those individuals (primarily females) with relatively high $\Delta_{bioapatite\text{-}collagen}$ may have relied on richer diversity of plant and animal sources for dietary protein when compared to individuals with $\Delta_{bioapatite\text{-}collagen}$ of less than 5$^{0}/_{00}$ (SD 0.4, n=20).

Population Comparison — Protein Sources

The observed sex-based differences are largely insignificant when interpreted mathematically. Adult males and females within El Japón households may have experienced and aimed for relative uniformity in the contents of meals. The household is a fundamental economic and social unit in postclassic and colonial Mesoamerica. Labor for gardening, farming, and wild food collection were likely pooled within households or kin-related households within the settlement. Chinampa production substantiated the economic means of a household — including bartering or purchasing ability in the markets — homogenizing the diets of household constituents and hamlet households of similar economic status. Spanish settlement and involvement in the markets may have played a minor role in changing the access or interests of hamlet dwellers.

$\delta^{13}C_{protein}$ and $\delta^{15}N_{protein}$ consistent with local flora and fauna, namely *opuntia sp. and z. mays, m. gallopavo, and o. virginianus* (Figure 6. 5). $\delta^{13}C_{collagen}$ and $\delta^{15}N$ for El Japón individuals display weak correlation between carbon isotopic values of food and collagen tissue with $\Delta_{bioapatite\text{-}collagen}$ (Figure 6. 5) and with $\delta^{15}N_{collagen}$ (Figure 6. 6), an indicator of trophic position. Low correlation between $\delta^{13}C_{whole\ diet}$ and $\Delta_{bioapatite\text{-}collagen}$ at El Japón is linked to low trophic level protein sources for the pooled male and female sample. In contrast, strong correlations between $\delta^{13}C_{whole\ diet}$ and $\Delta_{bioapatite\text{-}collagen}$ are observed in compared Neolithic Iberians (Figure 6. 6) where zooarchaeological evidence indicates high animal product consumption (Fernández-Crespo et al. 2019). European-introduced domestic taxa (even those feeding on C_4 crops) plot distinctly from colonial period Mesoamericans (Figure 6. 6).

Median $\delta^{15}N$ from El Japón adults are lower by $3^{0}/_{00}$ than Postclassic Ecatepec adults (Figure 6. 6) only a few kilometers north. Lake Texcoco (where Ecatepec was located) is a saltwater to brackish system (Alcocer and Hammer 1998; Moreiras Reynaga et al. 2020). Lower $\delta^{15}N$ at El Japón despite similar ethnic identity, dietary traditions, crops, and economic standing may be rooted in differing ecologies. El Japón $\delta^{15}N$ is more comparable with contemporaneous Cholula, Puebla individuals (Figure 6. 6) who centered maize- and plant sources as dietary staples supplemented with C_3 foods (Alcantara-Russell 2020).

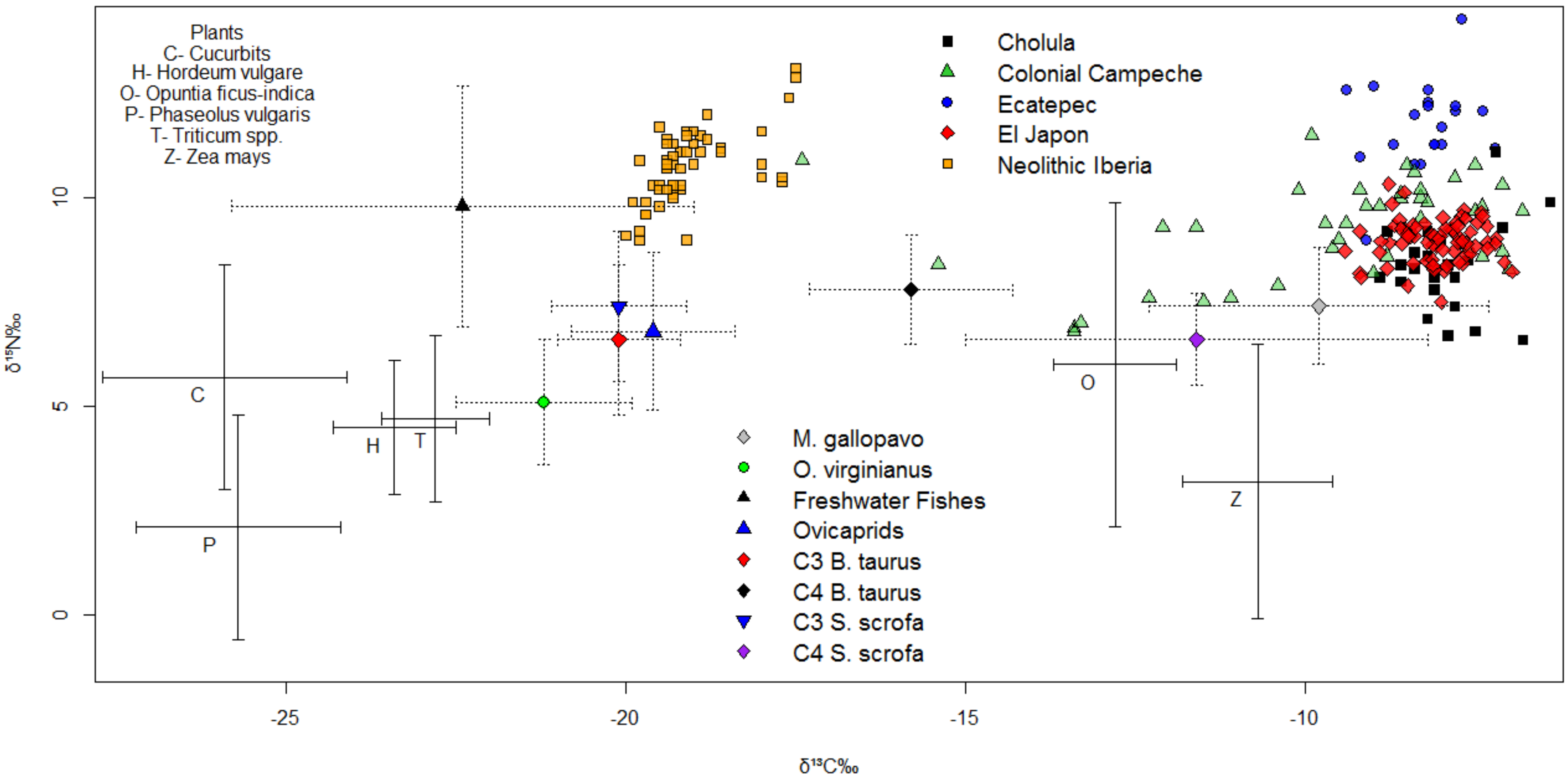

Figure 6. 6 Comparative δ^{13}Ccollagen and δ^{15}N Biplot. Summary statistics, selection criteria, and sources of faunal and botanical samples used as proxies are presented in Supplemental Tables 6. 2 - 6. 5. Human isotopic data: Cholula (Alcantara-Russell 2020), Campeche (Price et al. 2012), Ecatepec (Moreiras Reynaga et al. 2020), and Neolithic Iberia (Fernández-Crespo et al. 2019).

Non-agricultural foods (terrestrial game, reef and freshwater fish, and freshwater invertebrates) formed a substantial supplementary portion of human diets in the Mayan cultural region from the Preclassic (2000 BCE–250 CE) to Postclassic periods (900–1521 CE) (Wright 2006). Extremely low correlation of $\Delta_{\text{bioapatite-collagen}}$ and $\delta^{13}C_{\text{dietary protein}}$ ($\rho=0.004$, $p<.05$) is calculated for a comparative sample of 272 individuals from seven site clusters in *Mayan Comparative Set 1*. This supports an argument for high dietary richness at precontact Mayan diets (White et al. 2001; Williams et al. 2017) and low dietary richness for El Japón inhabitants.

Social status as a driver of dietary difference between households and settlements is also argued in that region (White et al. 2001; Williams et al. 2017). Both in the Mayan region and in Central Mesoamerica, urban centers were home to elite households, political offices, and geographically central marketplaces while smaller settlements fell into politically and economically secondary status (Sanders et al. 1979; Blanton 2012) often with less frequent of markets (Hassig 1985). Isotopic indicators of status-based dietary differences are also evident: $\delta^{13}C_{\text{dietary protein}}$ differs substantially between low and high-status individuals (SD 1.55 and 1.93, respectively) in a large comparative sample: *Mayan Comparative Set 2*.

Dietary protein sources may have been more limited in the *Central Mesoamerican Comparative Set* in comparison to the Mayan cultural region. It is important to interpret this cautiously as the samples that represent large populations are not as complete as in the Mayan region. $\delta^{13}C_{\text{collagen}}$ in the *Central Mesoamerican Comparative Set* and El Japón are higher than collagen ratios from the *Mayan Comparative Set 1*: (Welch's t-test, means -7.76 and -10.3 respectively, $p<.01$). Protein sources in the central Mesoamerican subregion are much closer to C_4 plant sources without concomitant increase in $\delta^{15}N$ which again implies consumption of plant sources over animals: C_4 plants as opposed to C_4–feeding animals.

Mean $\delta^{15}N$ AIR is consistent between the regions (means 9.62 and 9.64, p=.91) despite substantive variation in chronological contexts, climatic conditions, and types of social stratification. Variation in dietary patterns between communities likely came about through variation in plant protein and protein from low trophic level animals in contrast to domestic maize-fed protein.

Trophic level may have varied little due to consistent portion of animal products in comparison to plant foods (Alarcón Tinajero et al. 2022), especially maize. Based on modeling with controlled-feeding studies (Froehle et al. 2012), more than 50% of dietary protein and more than 70% of dietary carbohydrates for El Japón adults came from C_4 sources (Alarcón Tinajero et al. 2022). The role of maize in human diet is substantiated not only by isotopic study but by documentation of its consumption, preparation, trade, and payment as tribute (Gibson 1964; Berdan and Anawalt 1992; Durán 1994).

Social Significance of Dietary Results

El Japón, individuals from earlier and later interments present largely consistent isotopic indicators of diet through time which indicate postcontact diets may have shifted only gradually in the first century and a half after Spanish contact. Historical evidence of the late Postclassic indicates intensive agricultural production as a primary economic activity among commoner households in central Mesoamerica (Morehart 2016). Households likely invested less time in the acquisition of wild (C_3) foods in comparison to the ecologically more productive environments of the Mayan cultural region.

El Japón was legally an Indigenous community, making household relations to land use, land tenure, and the markets relatively more uniform than those in large contemporaneous urban settlements like Campeche City in the Yucatan peninsula. The economic role as multigenerational agricultural producers beyond subsistence and into important tributing and marketing roles contextualizes consumption of agricultural foods beyond individual or household preferences. It is thus unsurprising to find relative uniformity in adult diets at El Japón when compared to an urban population where individuals came from across continents and neighboring regions by force or by choice, i.e., Campeche city (Figure 6. 6). Individuals of mixed ancestry and diverse socioeconomic strata commingled in the colonial port city (Price et al. 2012).

The early colonial Campeche churchyard is contemporaneous with El Japón cemetery, but its individuals display higher variation in $\delta^{13}C_{diet\ energy}$ and $\delta^{13}C_{protein}$ estimates (Campeche $\delta^{13}C_{protein}$ SD=2.3, Campeche $\delta^{13}C_{diet\ energy}$ SD=2, 0.5 and 0.8 for El Japón respectively). Without a doubt, El Japón individuals had less dietary richness (*sensu*, Reitz and Wing 2008) when compared to an urban population. Archaeological and historical evidence for the introduction of European crops and livestock is almost immediately present in postcontact Mesoamerica (Sluyter 1997; Motolinía 2014; Dávila Moreno 2014). The ubiquity of those species in rural Indigenous diets however is not adequately quantified and their consumption at El Japón is demonstrated to be minimal via the analyses carried out in this study.

Continuity in El Japón and the Xochimilco area is identified in dietary staples, chinampa agriculture, and kinship as the basis of land access and calpulli membership. Settlement-site hierarchies are known to have transformed during the colonial period (Hassig 1985) yet persisted and demanded the production of domestic plant and animal foods, their transport to markets, and exchange or sale. Under new conditions, preexisting inequalities are often reified if not directly challenged (Robbins 2004) and the role of medium level organization (the calpulli), and the household as agricultural producers and tribute payers was purposefully reified by a new state. Supported by the findings of Chapter 3, agriculture continued to be the principal subsistence method rooted in the multigenerational landesque investments of the chinampa system (sensu, Blaikie and Brookfield 1987).

Variable rates and later standardized rates (*tasación*) of taxed material goods often had the form of crops in the colonial period (Lockhart 1992; Gibson 1964). Incentivized production of portable, durable, and high yield crops like maize indirectly influenced the food choices of commoner-status producing households by the volume that was produced in comparison to less portable and less durable crops or animal products.

Incentivized surplus production of time-tested local crops as opposed to introduced crops may be linked to the "entangled" (Jordan 2009) production modes of agricultural communities with tribute demands of a growing colonial administration. If this is the case, interpretation of the motives for production and consumption of local crops may not rest solely on dietary preferences but may be linked to pragmatic decisions that aligned with production of grains required for taxation or market participation where exchange and sale of nonlocal goods and foods continued following European contact (Gibson 1964). Everyday choices regarding food production and consumption were within the purview of local norms which may have been contested or reified within communities without direct manipulation of foreigners. Access to new goods including crops and livestock was ultimately determined in the early colonial period in ways similar to precontact time — through class-mediated ability to acquire these in the markets.

Conclusion

Carbon and nitrogen stable isotopes in bone collagen and bioapatite from El Japón burials are consistent with prehispanic central Mesoamerican individuals implying consistency in food sources with shifts in the share of staple crops rather than replacement with newly introduced European foods. Furthermore, isotopic data demonstrate relatively low trophic position of individuals implicating little anima product consumption in comparison to plant foods. The presented analyses indicate modest diachronic changes in isotopic indicators of carbohydrate and lipid sources at El Japón. Consistency however is not interpreted as a lack of change or a lack of European pressure and influence on subsistence practices and dietary components.

The historical record of early New Spain includes legal concessions to natives and Europeans for production of European grains and livestock (Jalpa Flores 2008). It is demonstrated here that evidence for production or sale of European foods Is not equitable to generalized accessibility, preference, or adoption. Jalpa Flores (2008) identifies the class-based drivers of access that are expected in novel environmental situations consistent with the political ecology framework (Blaikie and Brookfield 1987). Multiple generations persisted in food sources and foodways in the context of colonially entangled modes of seemingly unaltered chinampa production systems. The effects of European contact cannot be overstated. Epidemic disease, catastrophic depopulation, and new legal structures placed demands on traditional ways of labor organization, tribute payment, and settlement.

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Chapter 6. Appendix. Individual Stable Isotope Results and Comparative Data

Supplemental Table 6. 1 Individual Human Stable Isotopic Results

Burial	Element	UGAMS	Collagen yield (%)	%C	%N	C:N Atomic	Collagen		Bioapatite
							$\delta^{13}C$	$\delta^{15}N$	$\delta^{13}C$
1	Fibula	51803	0.22	44.34	15.93	3.25	-7.68	8.43	-2.47
2	Rib	47577-2	0.20	44.44	16.15	3.21	-8.41	8.42	-2.85
3	Rib	47578-2	0.21	44.38	16.19	3.20	-7.66	8.91	-3.86
4	Fibula	50246	0.13	43.95	15.91	3.22	-8.69	9.33	-3.98
5	Rib	50231	0.20	41.86	15.21	3.21	-8.11	8.36	-3.40
6	Fibula	50247	0.18	45.73	16.58	3.22	-7.63	8.62	-3.18
7	Radius	47057	0.17	42.90	15.30	3.30	-8.00	7.50	-2.77
8	Tibia	50248	0.11	45.34	16.34	3.24	-7.96	8.24	-3.69
9	Fibula	50249	0.16	45.27	16.44	3.21	-8.62	9.48	-4.60
13	Rib	49495-2	0.18	44.43	15.99	3.24	-7.70	8.96	-3.29
15	Radius	51807	0.16	44.17	15.65	3.29	-8.52	9.24	-2.82
19	Rib	50250	0.15	45.77	16.70	3.20	-8.10	8.27	-1.58
23	Fibula	51808	0.23	44.92	16.28	3.22	-8.07	8.84	-2.77
26-A	Rib	50237	0.10	42.51	15.66	3.17	-7.66	9.72	-2.85
27	Rib	50262	0.11	42.82	15.71	3.18	-8.13	8.86	-3.93
29	Fibula	47058	0.14	42.70	15.20	3.30	-8.80	8.30	-4.08

31	Rib	50263	0.21	42.38	15.56	3.18	-7.70	9.55	-2.81
33	Rib	50238	0.16	42.80	15.75	3.17	-7.19	9.02	-2.20
35	Rib	49496-2	0.17	43.48	15.52	3.27	-7.80	9.13	-3.35
37	Tibia	50239	0.11	42.26	15.76	3.13	-9.42	8.73	-3.08
39	Rib	49497	0.13	44.01	15.96	3.22	-8.45	9.08	-2.54
50	Fibula	47579-2	0.11	42.18	15.00	3.28	-7.56	8.68	-2.62
53	Fibula	47580-2	0.21	41.02	14.99	3.19	-8.50	7.89	-2.68
55	Rib	50241	0.18	42.17	15.84	3.11	-7.86	9.26	-3.36
58	Fibula	50252	0.26	44.30	16.08	3.21	-8.77	10.33	-2.43
62	Rib	50260	0.27	45.37	16.36	3.24	-7.33	9.31	-2.34
73	Femur	50256	0.07	42.85	15.45	3.24	-8.22	8.49	-2.42
86	Rib	51812	0.17	44.37	16.00	3.24	-9.20	9.20	-2.54
87	Radius	47059	0.21	44.20	15.80	3.30	-9.20	8.20	-2.04
88	Rib	50267	0.22	43.32	16.05	3.15	-7.92	8.36	-2.17
90	Fibula	47581-2	0.16	41.20	15.02	3.20	-7.49	8.85	-2.29
91	Rib	49499-2	0.17	45.81	16.58	3.22	-7.57	9.18	-1.67
96	Ulna	50290	0.21	44.43	15.93	3.25	-7.84	9.23	-2.33
97	Rib	51813	0.24	44.82	16.19	3.23	-7.94	9.25	-2.71
102	Rib	50264	0.21	41.90	15.42	3.17	-8.76	8.92	-3.34
108	Rib	50268	0.16	42.15	15.33	3.21	-7.62	8.91	-1.95
110	Rib	50265	0.18	42.14	15.49	3.17	-8.89	8.95	-3.48
112	Rib	50274	0.20	43.32	15.91	3.18	-7.07	8.46	-2.06

113	Rib	50266	0.18	42.64	15.68	3.17	-9.18	8.09	-2.41
119	Radius	50280	0.21	41.16	15.65	3.07	-8.50	9.21	-1.66
125	Rib	51814	0.22	45.02	16.28	3.23	-7.41	9.65	-2.28
126	Rib	49500-2	0.14	44.86	16.03	3.27	-7.74	8.46	-2.71
143	Rib	50281	0.15	44.77	16.13	3.24	-7.77	9.40	-2.22
145	Fibula	47582-2	0.12	39.77	14.32	3.24	-7.81	8.73	-2.89
156	Radius	50257	0.09	41.64	14.92	3.26	-8.58	8.90	-2.00
162	Rib	50261	0.15	42.18	15.48	3.18	-7.75	8.93	-2.52
174	Tibia	50285	0.21	45.07	16.23	3.24	-8.53	10.14	-3.13
180	Rib	47060	0.20	44.20	15.90	3.20	-8.90	8.70	-3.04
202	Radius	50286	0.21	45.08	16.27	3.23	-8.39	9.09	-2.85
219	Fibula	50258	0.24	45.02	16.56	3.17	-8.20	8.94	-2.04
222	Rib	50232	0.16	42.86	15.75	3.17	-8.25	9.38	-2.99
227	Femur	50278	0.21	42.37	15.63	3.16	-7.47	9.41	-2.22
228	Fibula	50253	0.26	44.44	16.25	3.19	-8.15	9.11	-2.81
237	Rib	50269	0.13	42.05	15.55	3.15	-7.64	9.51	-1.44
238	Fibula	50243	0.16	44.79	16.23	3.22	-6.95	8.23	-2.48
244	Rib	51815	0.12	43.74	15.60	3.27	-7.75	9.32	-2.53
255	Ulna	50244	0.19	45.33	16.43	3.22	-8.02	9.08	-2.08
256	Fibula	50282	0.12	44.25	15.78	3.27	-8.10	9.09	-2.36
262	Rib	50287	0.22	44.20	16.05	3.21	-7.31	8.93	-1.62
275	Rib	50275	0.21	42.59	15.82	3.14	-7.20	8.90	-1.41

290	Rib	50283.5	0.12	44.44	15.74	3.29	-7.69	8.97	-2.71
293	Rib	50288	0.15	44.21	16.01	3.22	-7.98	9.52	-1.93
301	Fibula	51816	0.21	44.45	15.82	3.28	-8.42	9.35	-2.72
325	Radius	49505	0.15	41.31	14.91	3.23	-8.59	9.27	-3.14
330	Tibia	50284	0.17	45.22	16.36	3.22	-8.37	9.29	-2.20
333	Rib	50234	0.19	43.04	15.81	3.17	-8.72	9.85	-2.53
348	Rib	50270	0.22	43.30	16.02	3.15	-8.13	8.52	-2.26
357	Rib	47583-2	0.21	44.14	16.22	3.18	-7.31	8.78	-2.10
358	Rib	50271	0.22	42.98	15.87	3.16	-7.97	8.76	-3.21
360	Fibula	50259	0.17	44.69	16.26	3.21	-8.50	9.14	-1.94
376	Rib	50272	0.22	42.46	15.75	3.15	-8.12	8.38	-2.22
379	Rib	49506	0.22	42.42	15.46	3.20	-8.04	9.01	-2.64
381	Rib	50276	0.22	43.65	16.20	3.14	-8.48	9.09	-2.23
384	Rib	50277	0.19	42.91	15.86	3.16	-7.39	9.56	0.49

Supplemental Table 6. 2 Maize Stable Isotopic Results

UGAMS and Subsample †	Land Race	%C	%N	$\delta^{15}N_{AIR}$	Measured $\delta^{13}C$	Adjusted $\delta^{13}C$‡
53983 A	Cacahuazantle	40.54	2.04	1.3	-11.3	-9.7
53983 B	Cacahuazantle	41.14	3.00	1.5	-11.4	-9.8
53983 C	Cacahuazantle	40.23	1.74	0.5	-11.0	-9.4
53984 A	Cacahuazantle	38.88	1.24	2.2	-11.4	-9.8
53984 B	Cacahuazantle	38.84	-	-	-11.3	-9.7
53984 C	Cacahuazantle	38.51	-	-	-11.1	-9.5
53985 A	Cacahuazantle	39.63	1.01	1.7	-11.1	-9.5
53985 B	Cacahuazantle	39.86	1.07	1.3	-11.3	-9.7
53985 C	Cacahuazantle	39.64	1.01	1.5	-10.4	-8.8
53986 A	Maíz azul	44.98	3.29	0.6	-11.5	-9.9
53986 B	Maíz azul	41.59	2.02	0.3	-10.6	-9.0
53986 C	Maíz azul	39.92	0.78	-3.4	-11.7	-10.1
53986 D	Maíz azul	42.01	2.15	0.1	-11.4	-9.8

† All samples are kernels.
‡ $\delta^{13}C_{PDB} + 1.6^{0}/_{00}$ (Ambrose et al. 1997).

Supplemental Table 6. 3 Summary Statistics of Comparative Maize Isotopic Data

Estimate	$\delta^{13}C$		$\delta^{15}N$		Criteria
	Median Mean	SD	Median Mean	SD	
1	-9.5 -9.9	1.2	4.8 4.9	2.0	Modern and archaeological, (n=143) †
2	-9.1 -9.2	0.6	4.7 4.7	1.5	Archaeological only, (n=84) ‡

† Gulf Coast and highland Oaxaca (Warinner et al. 2013), Ontario, Canada (Hart et al. 2020), Tlaxcala (Alcantara-Russell 2020), highland Peru (Szpak et al. 2013), northeast Brazil (Colonese et al. 2020), western Mesoamerica (Jácome 2012), Yucatan (Wright 2006), and Puebla (this study).
‡ Ontario, Canada (Hart et al. 2020), highland Oaxaca (Warinner et al. 2013), western Mesoamerica (Jácome 2012).

Supplemental Table 6. 4 Summary Statistics of Comparative Crops

Taxa	$\delta^{13}C$		$\delta^{15}N$		Criteria
	Median Mean	SD	Median Mean	SD	
Amaranthus spp.	-12.7 -12.3	1	4.0 4.2	2.2	Mesoamerican, modern (n=4). *Amaranthus hybridus and Amaranthus spp.* †
Cucurbits	-26.5 -25.9	1.8	5.2 5.7	2.7	Mesoamerican, modern (n=25). *Cucurbita sp., C. maxima, C. mixta, C. moschata, C. pepo, and Sechium edulis* ‡
Opuntia ficus-indica	-12.9 -12.8	0.9	5.8 6.0	3.9	Mesoamerican, modern (n=9) §
Phaseolus spp.	-26.0 -25.7	1.5	1.2 2.1	2.7	Similar elevation (1,000-3,000 *masl*), modern and archaeological (n=29) *Phaseolus sp., P. coccineus, P. lunatus, and P. vulgaris* ¶
Hordeum vulgare	-23.6 -23.4	0.9	4.4 4.5	1.6	European, archaeological (n=30) ††
Triticum spp.	-22.8 -22.8	0.8	4.7 4.7	2	European, archaeological (n=77). *Triticum sp. T. aestivum, T. diccocum, T. monoccocum, and T. spelta* ‡‡

† Oaxaca Market (Warinner et al. 2013), Tepeticpac (Alcantara-Russell 2020).
‡ Altar de Sacrificios and Nacimiento (Wright 2006), Oaxaca Market and Villhermosa, Tabasco Market (Warinner et al. 2013), Tepeticpac (Alcantara-Russell 2020).
§ Oaxaca Market and Villhermosa, Tabasco Market (Warinner et al. 2013), Tepeticpac (Alcantara-Russell 2020).
¶ Ampu, Carhuaz, Jesús, Jesús II, Shuto and Yungay (Szpak et al. 2013), Oaxaca Market (Warinner et al. 2013), Tepeticpac (Alcantara-Russell 2020).
†† Danebury Hillfort (Lighfoot and Stevens 2012), Bailly, Houdan, Jouars Pontchartrain and Mareuil Les-Meux (Aguilera et al. 2017), and Stanwick (Lodwick et al. 2021).
‡‡ Danebury Hillfort (Lighfoot and Stevens 2012), Bailly, Bonneuil, Epais les Louvres, Houdan, Jouars Pontchartrain, Mareuil Les-Meux, Morigny Champigny, Palaiseau, Roissy, and Varennes sur Seine (Aguilera et al. 2017), Vráble-Veľké Lehemby (Gillis et al. 2020), and Stanwick (Lodwick et al. 2021).

Supplemental Table 6. 5 Summary Statistics of Comparative Animal Food Sources

Taxa	$\delta^{13}C$		$\delta^{15}N$		Criteria
	Median Mean	SD	Median Mean	SD	
Bos taurus, C_3 diet [†]	-20.3 -20.1	0.9	6.6 6.6	1.8	24 European and Asian sites, premodern (n=112) [‡].
Bos taurus, C_4 diet [†]	-15.9 -15.8	1.5	7.7 7.8	1.3	6 European and Asian sites, premodern (n=14) [§].
Meleagris gallopavo	-9.1 -9.8	2.5	7.6 7.4	1.4	15 sites in Mesoamerica and the southwest United States. Primarily prehispanic (n=35) [¶].
Sus scrofa domesticus, C_3 diet [†]	-20.0 -20.1	1.0	7.3 7.4	1.8	15 European sites and one African site, Neolithic – early Modern (n=58) [††].
Sus scrofa domesticus, C_4 diet [†]	-10.1 -11.6	3.4	6.6 6.6	1.1	2 sites, Neolithic China (n=17) [‡‡].
Odocoileus virginianus	-21.2 -21.2	1.3	4.7 5.1	1.5	5 sites in Mesoamerica (n=36). Primarily prehispanic, two modern samples [§§].
Freshwater Fishes	-22.2 -22.4	3.4	9.8 9.8	2.9	12 sites in the Amazon, central Europe, Mesoamerica, and Eastern North America, Medieval – Modern periods. (n=153) [¶¶].
Asian Ovicaprids	-18.9 -18.7	0.8	7.6 7.5	1.5	12 sites, Neolithic – Medieval (n=126) [†††].
European Ovicaprids	-20.1 -20.0	1.1	6.3 6.4	1.9	26 sites, Neolithic – early Modern (n=51) [‡‡‡].
Ovicaprids, combined	-19.8 -19.6	1.2	6.6 6.8	1.9	European and Asian sites, Neolithic – early Modern (n=177).

† Taxa was divided into C_4 and C_3 when bimodal distribution was observed and cited literature postulated C_4 diet of domestic animals (generally millet in Europe and Asia).

‡ Thebes, Greece (Vika 2011), Bozshakol 6, Kanar Bulak 1, Kenelkel 18, and Lisakovsk, Kazakhstan (Motuzaite Matuzeviciute et al. 2015), Vráble-Veľké Lehemby, Slovakia (Gillis et al. 2020), Leptiminus, Tunisia (Keenleyside et al. 2019), Apigliano and Quattro Macine, Italy (Rolandsen et al. 2019). Iberia: Dulantzi, Zaballa, and Zornoztegi (Lubritto et al. 2017), Marroquies Jaén (Beck et al. 2018), Visigothic, Islamic and Christian period Valencia (Alexander et al. 2019), Los Cascajos (Fernández-Crespo et al. 2019), San Baudelio de Berlanga (Jiménez-Brobeil et al. 2020).

§ Karatuma, Kazakhstan (Motuzaite Matuzeviciute et al. 2015), Dongying, China (Chen et al. 2016) Nustar, Croatia (Vidal-Ronchas et al. 2019), and Vráble-Veľké Lehemby, Slovakia (Gillis et al. 2020). Spain: Marroquies Jaén (Beck et al. 2018), Arroyal I, El Hornazo, and Fuente Celada (Jones et al. 2019), Islamic period Valencia (Alexander et al. 2019).

¶ 13 sites in the Southwest United States (Rawlings and Driver 2010), Altar de Sacrificios (Wright 2006), Ceibal (Sharpe et al. 2018), Tepeticpac (Alcantara-Russell 2019), 12 Mesoamerican archaeological sites (Manin et al. 2018).

†† Thebes, Greece (Vika 2011), Kaldus, Poland (Reitsema et al. 2013), Leptiminus, Tunisia (Keenleyside et al. 2019), Apigliano and Quattro Macine, Italy (Rolandsen et al. 2019). Iberia: Aistra, Dulantzi and Zaballa (Lubritto et al. 2017), Marroquíes Jaén (Beck et al. 2018), Santa Catalina Belmonte (Sarkic et al. 2019), Visigothic, Islamic and Christian period Valencia (Alexander et al. 2019), Los Cascajos (Fernández-Crespo et al. 2019), San Baudelio de Berlanga (Jiménez-Brobeil et al. 2020).

‡‡ Donying and Wayaogou, China (Chen et al. 2016).

§§ Altar de Sacrificios (Wright 2006), El Tropel (Jácome 2012), Ceibal (Sharpe et al. 2018), Tepeticpac (Alcantara-Russell 2019), Nakum (Rand et al. 2020).

¶¶ Puerto Ayacucho and San Carlos de Rio Negro (van der Merwe and Medina 1991), Altar de Sacrificios (Wright 2006), Lajas River, Mexico (Mercado-Silva et al. 2009), Essequibo River Basin (Watson et al. 2013), Kaldus, Poland (Reitsema et al. 2013), Ball, Draper, Kelly-Campbell, Moatfield, and Parsons sites (Pfeiffer et al. 2016), San Pedrito Lagoon, Mexico (Sepúlveda-Lozada et al. 2015), lower Missouri River and tributaries (Wang et al. 2018), and Nakum (Rand et al. 2020).

††† Donying and Wayaogu, China (Chen et al. 2016). Kazakhstan: Bozshakol 6, Butakty, Kainar Bulak 1, Karatuma, Konyr Tebe 1, Kyzyl Bulak, Lisakovsk, Oi Dzailau VII, Shimkent, Teirlanovka (Motuzaite Matuzeviciute et al. 2015).

‡‡‡ Velia, Italy (Craig et al. 2009), Kaldus and Giecz, Poland (Reitsema 2010 and 2013), Thebes, Greece (Vika 2011), Zemunica, Croatia (Guiry et al. 2017), Nustar, Croatia (Vidal-Ronchas et al. 2019), Apigliano and Quattro Macine, Italy (Rolandsen et al. 2019), Vráble-Veľké Lehemby, Slovakia (Gillis et al. 2020). Iberia: Aistra, Dulantzi, Treviño, Zaballa, and Zornoztegi (Lubritto et al. 2017), Marroquíes Jaén (Beck et al. 2018), La Lámpara, Los Cascajos, and Paternabidea (Fernández Crespo et al. 2019), Santa Catalina Belmonte (Sarkic et al. 2019), San Baudelio de Berlanga (Jiménez-Brobeil et al. 2020).

Chapter 7. Conclusion

Only through study of human biological remains does this study uncover that the inhabitants of El Japón did not participate in the trends of cultural and genetic mestizaje that are often presupposed to have begun with Spanish colonization of southern North America. Absence of evidence for postcolonial change in the diet and subsistence patterns (lifeways) and genetic profile of the hamlet inhabitants should not be equated to absolute continuity in lifeways or resistance to all Spanish interaction. Intrapopulation variation in the skeletal data support an interpretation of colonial entanglement despite the absence of centralized acculturation efforts.

Entanglements occurred even in places of indirect Spanish influence — the chinampa region of Xochimilco, Tláhuac, and Chalco — where Spanish persons settled in minor numbers and Indigenous persons constituted legally-recognized governments called *pueblos de indios.* In these Indigenous-majority spaces, sublimated colonial entanglements formed through cascading pressures on locally determined and household-mediated engagement with political-economic structures that influenced food production, labor-as-tribute, and food acquisition beyond local production (the markets). A central premise of applying an entanglement approach is that parties in colonial encounters must have relatively equal power in a given situation — and this is interpreted in the early colonial period of El Japón and the San Gregorio Atlapulco subregion.

Substantive evidence exists for a patronizing view of Indigenous people in the dominant legal and religious philosophies of the time and for ethnic identity-based access to economic and political roles (MacLachlan 2015) painting an image that is hardly equative. However, in the chinampa region Spanish influence came not through presence of Spanish persons but through more sublimated postcontact manipulation of the political and economic structures that permitted Indigenous communities to create opportunities to exercise varying levels of autonomy.

This reading of large-scale happenings influencing the daily lifeways of Indigenous people and eventually leaving skeletal results in a remote hamlet settlement demonstrates the pervasiveness of not only the Spanish colonial efforts but also of the mestizaje process at large: entanglements occurred despite the absence of biological mestizaje via gene flow. This tailored reading of entanglements in cultural practices and human biology was only possible through examination of human physical remains. Ergo, entanglement and skeletons were needed to know the true diversity and process of mestizaje beyond the concepts of swift mestizaje that tends to circulate in public and nationalist discourse (Robles García 2012; Castillo Ramírez 2014). Entanglement approaches like the one taken here can elicit ways in which human lives and societies at large transformed after engagement with Europeans even if gene flow was not central.

The decline of Indigenous populations in absolute numbers in the century and a half after Spanish contact cannot be ignored. Exercise of Indigenous political agency, like that identified in the ethnohistoric record of the Xochimilco area (e.g., McAfee and Barlow 1952), occurred in a context of practical difficulties for Indigenous communities that included needs and demands for productivity despite persistent demographic decline. Acculturation or cultural assimilation occurred in limited Indigenous populations elsewhere in the Basin of Mexico, e.g., the northern Basin (Rodríguez-Alegría 2010). Evidence for adoption of limited European foodways and production schemes is evident also in the southern Basin among hereditary and non-hereditary elite families (Jalpa Flores 2008). Based on that evidence, acculturation to Spanish ways of production and consumption was interpreted by some Indigenous persons and households as beneficial or advantageous. Acculturation in the broadest sense as an effort to change the culture or majority of lifeways of the Indigenous population however may have had a very limited role among the methods of achieving colonization of the region. This interpretation of a lack of broad acculturation is possible in the sum of the constituent analyses of this thesis with application of a refined chronology and with the perspective of entanglement which specifically seeks out explanation in the political and economic context when a simpler reading of the data may only indicate continuity or change from pre-contact time.

Summary of Findings

This research presented four independent datasets and analyses to provide insight into hypothesized changes and continuities in population variation, food production and consumption in an early Colonial skeletal sample from the southern Basin of Mexico. Radiocarbon dating of burials and by extension an estimate of archaeological site occupation (Chapter 3) and comparison of biological traits to other populations (Chapter 4) narrowly contextualized the skeletal sample of El Japón in the early colonial period as opposed to previous broad designations in published literature — a late Postclassic to early colonial designation. Relying on the concepts of entanglement (Jordan 2009) and political ecology (Blaikie and Brookfield 1987; Robbins 2004), interpretations of continuity in food production (Chapter 5) and food consumption (Chapter 6) after European colonization are both linked to continuity of the political and economic structures that survived and transformed with Spanish colonization in Mesoamerica. These economic and political structures specifically include communally operated agricultural infrastructure and tribute paying relationships between settlements and individuals. Economic participation in the markets and payment of tribute through goods after entanglement with colonial demands served as motivations for the continuity of landesque capital in the marshlands of the Basin of Mexico. These continuities in economic production identified in historical research contextualized the interpretations of findings of the constituent studies. I conclude with a summary of findings in the constituent studies (Chapters 3–6) and how these relate to political and economic continuities in Mesoamerica despite colonization.

Chapter three discussed iterative Bayesian models of calibrated radiocarbon dates to estimate the span of use of the cemetery and infer occupation of the rural El Japón settlement. The model also timed the use of the rural cemetery in relation to the presumed completion of Indigenous population aggregation near 1610 CE (Jalpa Flores 2008). The favored and accepted model estimates use of the cemetery between 1565–1640 CE. Contextual information from the historical record of central Mesoamerica and the archaeology of El Japón site facilitated a justified focus on two of three intercepts for each calibrated radiocarbon determination via a *Calendar date* (Chapter 3, p. 83). Contextual information in this research permitted a more specific radiocarbon estimation than may otherwise be expected for the middle of the second millennium CE.

Radiocarbon dating of El Japón cemetery supports an understanding that the hamlet site was populated well after the initiation and presumed peak of settlement aggregation activity in central Mesoamerica. Settlement in the chinampas surrounding El Japón between 1565–1640 CE problematizes the timing and measure of success of the historical narrative that early Spanish authorities relocated Indigenous people. El Japón residents likely persisted in place for decades despite historically documented changes in economics, tribute demands, pressures to relocate, and regular epidemics.

Colonial authorities aimed for geographic centralization of native populations (Ricard 1966; de la Torre Villar 1995; Zamudio Espinosa 2001; MacLachlan 2015) but the amalgam of Indigenous household choices, communal investment in and productivity in chinampa agriculture may have permitted occupation of the remote settlement for at least 2 or 3 decades past the presumed completion of reducciones. Indigenous towns by composite choice of individuals and sometimes by influence of civil and religious authorities were limited to settlements where people of native descent resided in majority or almost in absolute numbers (Conway 2014). This historically substantiated generalization of homogeneity within settlements however has not been previously tested in peer-reviewed literature for the early colonial period via biological indicators of relatedness.

Biodistance analysis of El Japón individuals (Chapter 4) hypothesized and identified phenotypic dental similarity to other Indigenous communities of the Basin of Mexico, as well as North and South America more widely. Based in theory of dental traits, phenotypic similarity or distance from other population samples is reflective of known distances. The interpretation of biological population continuity with little European gene flow in the first decades of Spanish contact in the chinampa area is consistent with previous biodistance analysis (Ragsdale et al. 2019) and with prevalent historical interpretation of an Indigenous majority in the Xochimilco area (Conway 2012).

The dental biodistance analysis (Chapter 4) demonstrates no diachronic decrease in variation within the cemetery. This result is seemingly at odds with the expectation of diachronically decreasing genetic variation (Stojanowski 2005; Ragsdale et al. 2019) linked with the demonstrated deleterious effects of Spanish colonialism in the Americas which included contagious disease, depressed autonomy, and shortened life expectancies (Larsen 1994; Klaus and Tam 2009; Warinner et al. 2012). More widely in Mesoamerica, decades of epidemic pressure following European contact (Storey 2012) decreased genetic variation in Indigenous populations (Ragsdale et al. 2019). In contexts of colonial transitions, biological anthropologists (Stojanowski

2005; Stojanowski and Schialli 2006; McIlvaine 2014) stress the importance of careful selection of dental traits that capture biological variation to adequately address proposed research questions.

Chapter 4 kept a focused view of the question of diachronically increasing or decreasing variation within the El Japón recognizing the qualifications of a dataset with wide chronological ranges in comparative samples (e.g., Cuicuilco, Scott and Irish 2017) and little availability of published individual-level datasets for Europeans. Available open-source data is notably lacking from Iberian population samples which are the most appropriate comparison for questions of gene flow between continental populations following Spanish colonization and settlement in the Americas. Even with recognition of the methodological limitations, Chapter 4's biodistance results contextualize further bioarchaeological analysis of colonial El Japón by demonstrating any departure from expected Mesoamerican patterns of diet and labor (Chapters 5 and 6) are not due to differing ethnic identities. Ethnic identities and "caste", or racial identities, often determined tribute responsibilities, economic opportunities, religious and political offices, and even permissible locations for settlement in colonial Mesoamerica (Porras Munoz 1982; McLachlan 2015). A non-elite Indigenous status (macehual) is inferred for the majority of El Japón inhabitants due to the biological link to prehispanic populations, the status as a hamlet and its subordinate status to San Gregorio Atlapulco. These reconstructions and inference of who the inhabitants of El Japón were in turn inform questions of physical labor and dietary patterns in Chapters 5 and 6.

Chapter 5 demonstrated that cross-sectional properties (CSPs) of the upper limbs differed appreciably between El Japón individuals and comparative individuals from roughly contemporaneous European agricultural and non-agricultural settlements. These differences are attributed to distinct life-long methods of agricultural labor and transportation. Only minor changes in these CSPs are observed diachronically within El Japón indicating continuity in agricultural techniques rather than adoption of European ones.

Chapter 5's principal statistical tool, Linear Discriminant Analysis (LDA), separates El Japón from roughly contemporaneous eastern and western European agricultural communities where plow agriculture and draft animal use was the norm. The LDA, however also demonstrates ample variation within all populations: an unsurprising result considering class distinctions, economic specializations, and gendered divisions of tasks in late Medieval and early modern cultures (Ruff, ed. 2018). Class distinctions, economic specializations (Brumfiel and Robin 2012), and intra-familial gendered division of labor (Anderson and Dibble 1975; Durán 1994) were common in postclassic Mesoamerica and likely continued into the colonial period. Spanish colonialism in central Mesoamerica primarily sought to extract material resources and labor from the Indigenous population and as such altered existing labor patterns.

New legal structures, including the encomienda system, placed demands on traditional ways of labor organization and settlement (Gibson 1964). Agricultural production occurred through continued investment in local landesque capital, regional markets, and regional trade networks. Intensive agriculture in the marshland environments of the Lake Texcoco system may have required fidelity to local methods and technologies as alternative European methods of draft animals and plows are more adapted to dry land. Based on the differing CSPS from Europeans, it is interpreted that El Japón residents maintained the chinampa system with precontact techniques and hand tools rather than introduced draft animals and plows.

Modification of hand tools with new materials that included iron may have taken place at El Japón, as is observed in other Mesoamerican areas (Rojas Rabiela 1984). CSP consistency within the El Japón sample support an interpretation that agricultural production did not change at in the first 150 years after Spanish colonization and both males and females were involved in either the production or transportation of agricultural products, or both. Modified forms of communal labor and persistence in the crafted landscape and methods of chinampa agriculture may have been sufficient to both maintain autonomy, rights to continue inhabiting a geographically remote settlement, meeting the taxes levied by the incipient colonial system.

The interpreted continuities in landesque capital investment and food production, however, are not interpreted as untouched or unaltered subsistence following European contact. The encomienda system was pervasive, demanding tributed goods and labor with eventual replacement with taxed money (Gibson 1964). El Japón was likely subject to the *encomenderos* (encomienda-holders) of Xochimilco. Labor-intensive agriculture may have been carried out with at least partial destination toward encomienda tribute payment. A seemingly traditional or unchanged method in the context of new political and taxation structures make the agricultural means of production *entangled* with these new structures. Even if the methods of production or physical place of production were unchanged, the context of the magnitude of production and destination of the benefits of these goods or capital produced were linked to a transformed political context.

While Chapter 5 examined hypothesized continuities in agricultural production, Chapter 6 examined postulated continuity in dietary consumption at El Japón. Carbon and nitrogen stable isotopes in bone collagen and bioapatite from El Japón individuals are consistent with those of multiple Mesoamerican populations both predating and postdating European contact (Chapter 6: *Mayan Comparative Set* 1, Mayan *Comparative Set 2*, and *Central Mesoamerican Comparative Set*). The consistency in isotopic data indicate heavy reliance on C_4 foods at El Japón with potentially more limited variation in whole diet than prior to European contact.

El Japón residents continued in the foodways of prehispanic antecessors (Chapter 6). Carbon stable isotopic indicators of plant foods demonstrate only minor shifts and are influenced by theorized introduction of nonlocal plant sources (e.g., wheat, barley, and Eurasian legumes), or an increase in existing C_3 plant sources (e.g., endemic legumes and *Chenopodium spp.*) and CAM plant sources (e.g., *Opuntia ficus-indica*). Plant foods likely provided the bulk of diet with minimal share of animal protein and fats (Alarcón Tinajero et al. 2022). The size of the stable isotope dataset and chronological modeling of the radiocarbon results (Chapter 3) permits inference of diachronic dietary change within El Japón.

Only modest diachronic changes in isotopic indicators of carbohydrate and lipid sources occurred, e.g., higher $\delta^{13}C_{bioapatite}$ in more recent males at El Japón when compared to earlier ones. This one specific finding is an exception to a general pattern of consistency in dietary patterns at the site. Consistency in the bulk of diet does not imply a lack of change or a lack of European influence on subsistence practices. Indigenous political and economic elites often farmed European crops and owned, traded, and consumed European livestock in the areas bordering Xochimilco (Jalpa Flores 2008). In the same document-based datasets, commoner households owned and likely consumed less of this livestock than their Indigenous peers of higher status (Jalpa Flores 2008). Continuity of class-based distinctions of economic resources and environmental experiences (e.g., Blaikie and Brookfield 1987) likely persisted circumscribing the opportunities to incorporate new food sources. Though difficult to define access through purchase — markets may have made European foods available to an audience beyond elite individuals and families.

Evidence for production or sale of European foods in the Valley of Mexico may not equate to generalized accessibility, preference, or adoption. The isotopically substantiated reliance on plant foods over livestock at El Japón may be linked to a disconnect between market availability and generalized adoption. In addition to potentially limited availability, Indigenous households may have chosen to persist in local foodways: chinampa agricultural production and exploit of wild lacustrine and foothill sources. Continuity in these foodways can be interpreted as multigenerational persistence in local food production and local sources in the context of colonially transformed modes of production, exchange, and taxation.

El Japón in the Colonial Context

Following European contact, Indigenous chinampa agriculturalists of El Japón may have continued in lifeways that included labor, subsistence, and marriage patterns without direct manipulation by outsiders. Although the political and economic hierarchies changed with the transition from the Mexica to Spanish empires, land as the most important agricultural resource and class-based distinctions did not – these features of the political economy may have been unchallenged or challenged only unsuccessfully. Blaikie and Brookfield (1987) conclude that existing inequalities in access to resources are often reproduced or reified when institutional or governmental shifts occur. Reproduced or even exacerbated inequalities between elites and commoners occurred in colonial New Spain (Gibson 1964). Details of El Japón's subsistence and diet are likely linked to continuities of class-based distinctions in labor and land tenure that survived the onset of colonization and regional political change.

Phenetic variation changed only marginally within El Japón (Chapter 4) — likely not influenced by intercontinental gene flow in the first decades of Spanish contact. Mestizaje as the blending of populations may have not taken hold in the Xochimilco area until after use and abandonment of El Japón (ca. 1640 CE). If so, this pattern of low gene flow may be in line with the general Mesoamerican pattern of infrequent multi-ethnic household unions and marriages until later in the colonial period (Pescador 1992). Based in the same intrapopulation analysis of phenetic traits (Chapter 4), it can be deduced that few outsiders were interred at El Japón, and few outsiders likely inhabited, built, and used its agricultural landscape. This implies an ethnically and possibly regionally endogamous pattern which in turn would have been linked to postcontact continuity of long-term practices that include land inheritance (Kellog 1995), land tenure and legal designations of individual and communal landholdings (Cline 1984).

As Indigenous subjects assigned to encomiendas, the inhabitants of El Japón were tied to the land by hegemonic relationships of tribute and monarchical subjectivity (MacLachlan 2015), potentially similar to what was experienced by tribute paying commoners in the Postclassic period. A pattern of reified inequalities is observed in colonial Mesoamerica (Gibson 1964) as an elite/non-elite dichotomy was preserved, including the Basin of Mexico area, e.g., Chalco (Jalpa Flores 2008), Xochimilco (Conway 2012), and Texcoco (García Loaeza 2014). As in the Postclassic period, colonial period chinampas provided a means for households to not only meet tribute demands but also to provide sustenance for their households through labor-intensive methods. Physical labor at El Japón was widely different from roughly contemporaneous Europeans known to have employed plows and draft animals (Chapter 5). Four adult males differ from the rest of El Japón which may indicate involvement of individual adult males with labor outside of a chinampa context and more directly entangled with colonial-period encomienda labor.

Local production of foods and similar social and economic standing of chinampa hamlet inhabitants likely had a homogenizing effect on types of foods consumed and therefore the foods that contributed to the isotopic indicators in skeletal remains (Chapter 6). Low intrapopulation variation in dietary patterns may be rooted in fidelity to local foodways as willful expression of local customs as well as the sum of quotidian choices made by individuals within the economic means of Indigenous commoners in the early colonial Valley of Mexico.

When interpreting cross-sectional and stable isotopic data together, it is evident that the Indigenous community of El Japón likely persisted in local (i.e., Basin of Mexico) food production methods and regional food consumption patterns (i.e., pan-Mesoamerican) after European contact. The CSG and stable isotopic datasets provide case-specific insight into broad-stroke understanding of Spanish colonizing practices which included forced population movement and incorporation into tribute-paying structures. Apparent absence of Spanish material influence at El Japón is informative in comparison to other Basin of Mexico subregions where novel Indigenous use of introduced material goods and livestock and crop adoption are apparent. El Japón cemetery use ceased by 1640 CE with the surrounding settlement likely depopulated or relocated at that time, potentially pressured by tributary demands and the difficulty of subsisting with limited numbers of households able to pool labor.

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Dissertation Appendix

Appendix Table 1. Table of Data available per Individual.

Burial Number [1]	Biodistance [2]	Stable Isotopes	Cross-Sectional Geometry	Radiocarbon
1	Y	Y	-	-
2	-	Y	Y	Y
3	Y	Y	-	Y
4	-	Y	-	-
5	-	Y	-	-
6	Y	Y	-	-
7	Y	Y	-	Y
8	-	Y	-	-
9	-	Y	-	-
13	Y	Y	Y	-
15	Y	Y	-	-
19	Y	Y	Y	-
22	Y	-	-	-
23	-	Y	-	-
25	Y	-	-	-
26A	-	Y	-	-
27	Y	Y	-	-
29	Y	Y	-	Y
31	Y	Y	-	-
33	Y	Y	-	-
33A	Y	-	-	-
35	Y	Y	-	-
37	-	Y	-	-
39	Y	Y	-	-
46	Y	-	-	-
48	Y	-	-	-
49	Y	-	-	-
50	Y	Y	-	Y
51	Y	-	-	-
52	Y	-	-	-
53	Y	Y	-	Y
55	Y	Y	Y	-
58	Y	Y	-	-
59	Y	-	-	-
60	Y	-	-	-
61	Y	-	-	-
62	Y	Y	-	-

69	Y	-	-	-
73	-	Y	-	-
76	Y	-	-	-
78	Y	-	-	-
79	Y	-	Y	-
80	Y	-	-	-
83	Y	-	-	-
86	Y	Y	-	-
87	Y	Y	-	Y
88	Y	Y	Y	-
90	Y	Y	-	Y
91	Y	Y	Y	-
96	Y	Y	-	-
97	Y	Y	-	-
102	Y	Y	-	-
103	Y	-	-	-
108	Y	Y	-	-
109	Y	-	-	-
110	Y	Y	Y	-
112	Y	Y	-	-
113	Y	Y	-	-
113A	Y	-	-	-
116	Y	-	-	-
117	Y	-	-	-
119	Y	Y	-	-
120	Y	-	-	-
124	Y	-	Y	-
125	Y	Y	Y	-
126	Y	Y	-	-
127	Y	-	-	-
129	Y	-	-	-
136	Y	-	-	-
138	Y	-	-	-
139	Y	-	-	-
142	Y	-	-	-
143	Y	Y	-	-
145	Y	Y	Y	Y
153	Y	-	-	-
156	Y	Y	-	-
162	Y	Y	Y	-
170	Y	-	-	-

171	Y	-	-	-
174	-	Y	-	-
180	Y	Y	-	Y
181	Y	-	Y	-
184	Y	-	-	-
185	Y	-	Y	-
192	Y	-	-	-
194	Y	-	-	-
197	Y	-	-	-
202	Y	Y	Y	-
208	Y	-	-	-
212A	Y	-	-	-
218	Y	-	-	-
219	Y	Y	-	-
220	Y	-	-	-
221A	Y	-	-	-
221B	Y	-	-	-
222	Y	Y	-	-
223	Y	-	-	-
227	Y	Y	-	-
228	Y	Y	-	-
230	Y	-	-	-
232	Y	-	-	-
235	Y	-	-	-
236A	Y	-	-	-
237	Y	Y	-	-
238	Y	Y	Y	-
243	Y	-	-	-
244	Y	Y	Y	-
251	Y	-	-	-
255	Y	Y	Y	-
256	Y	Y	Y	-
257	Y	-	-	-
258	Y	-	Y	-
260	Y	-	-	-
260A	Y	-	-	-
262	Y	Y	Y	-
264	Y	-	-	-
265	Y	Y	Y	-
267	Y	-	-	-
272	Y	-	-	-

273	Y	-	-	-
275	Y	Y	Y	-
276	Y	-	-	-
279	Y	-	-	-
280	Y	-	-	-
290	Y	Y	-	-
293	Y	Y	-	-
301	-	Y	-	-
306	Y	-	-	-
309C	Y	-	-	-
310	Y	-	-	-
311	Y	-	-	-
315.1	Y	-	-	-
316	Y	-	-	-
320	Y	-	Y	-
325	Y	Y	Y	-
330	-	Y	-	-
333	Y	Y	Y	-
341	Y	-	-	-
345	Y	-	-	-
346	Y	-	Y	-
347	Y	-	-	-
348	Y	Y	-	-
350	Y	-	-	-
353	Y	-	Y	-
356	Y	-	Y	-
357	Y	Y	Y	Y
358	Y	Y	Y	-
359	Y	-	Y	-
360	Y	Y	Y	-
362	Y	-	Y	-
363	Y	-	Y	-
376	Y	Y	-	-
379	Y	Y	-	-
380	Y	-	Y	-
381	Y	Y	Y	-
384	Y	Y	Y	-

"Y" stands for "yes" and "-" denotes data absence.
1 Assigned during excavation, detailed in Chapter 3.
2 At least 12 traits examined, detailed in Chapter 4.