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Migration, violence, and the “other”: A biogeochemical approach to identity-based violence in the Epiclassic Basin of Mexico

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ABSTRACT

Bioarchaeological studies are highly successful in accessing multivalent past social identities. This study applies social identity theory to contexts of violence, developing a theoretical framework to investigate identity-based violence at the Epiclassic (600–900 CE) central Mexican shrine site of Non-Grid 4, where at least 180 individuals were ritually sacrificed and interred. Ethnohistoric and archaeological data indicate that geographic origin was a culturally significant indicator of social difference in pre-Hispanic Mesoamerica. This study therefore reconstructs the residential histories of sacrificed individuals ($n = 73$), analyzing radiogenic strontium ($^{87}Sr/^{86}Sr$) and stable oxygen ($\delta^{18}O$) isotopes to consider how the perception of social difference, inferred from geographic origins, contributed to the selection of victims of ritual violence. Biogeochemical results demonstrate that 70% of sampled sacrificed individuals were born and lived their early lives outside of the Basin of Mexico, migrating into the region later in life. In contrast, only 22% of individuals were born and lived in the Basin their entire lives. Observed paleomobility patterns among sacrificial victims thus suggest that they were targeted for identity-based violence based on their divergent geographic origins in the volatile socio-political landscape of the Epiclassic Basin of Mexico.

1. Introduction

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

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

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understanding identity-based violence in Epiclassic central Mexico.

2. Social boundaries and identities

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

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

2.1. Theorizing the link between social identity and violence

Despite this consistent bias against outgroup members, ingroup/outgroup social boundary formation often takes place non-violently through the course of intergroup interactions. In Barth's (1969) seminal essay on ethnic groups and social boundaries, he argues that intergroup interactions are essential in the reification of social boundaries, as there can be no "self" without an "other" against which to identify. Cultural evolutionary modeling studies further support this precept, finding social group differences to be strongest at cultural boundaries (e.g., McElreath et al., 2003).

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

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

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

A bioarchaeological approach is particularly well suited to empirically reconstruct past individuals' multivalent social identities. Many facets of identity such as age, sex, or phenotypic expressions of biological relatedness are grounded in the physical body, while others leave traces on the body through behavior, such as dietary preferences or cultural modification (Buikstra and Scott, 2009; Knudson and Stojanowski, 2009, 2008). For example, a bioarchaeological case study from the pre-Hispanic central Andes provides convincing evidence of identity-based violence in the past. The ethnohistorically-documented Chanka ethnic group, marked by a visibly distinct form of cranial modification, experienced increased rates of both non-lethal and lethal trauma during the period of political decentralization following the decline of the Wari Empire, indicating that these individuals were targeted for violence at least in part based on their highly visible ethnic identity (Kurin, 2016, 2014). Thus, historical and limited archaeological evidence indicates that during periods of socio-political disruption, groups with visibly distinct social identities may perceive each other as potentially threatening, culminating in intergroup violence.

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

2.2. Geographic origins and social difference in ancient Mesoamerica

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

Ample ethnohistoric evidence indicates that geographic origin was a salient indicator of social difference in pre-Hispanic Mesoamerica. Contact period Nahua codices such as the Codex Boturini, the Codex Chimalpopoca, the Codex Azcatitlan, and others all emphasize migration stories and the importance of sacred places of origin (Akademische Druck, 1979; *Codex* Azcatitlan, 1949; *Codex Boturini: tira de la peregrinación mexica*, 1944; *Códice Aubin: manuscrito azteca de la Biblioteca Real de Berlín*, 1963; Durán, 1867; Feliciano Velázquez, 1975; Kirchhoff et al., 1976). Similarly, the Florentine Codex, which describes daily life within the Aztec Empire, consistently associates non-Nahua peoples with the geographic locations of their city-states of origin. Indeed, many ethnic descriptors in the Florentine Codex come from the name of the lands these peoples inhabited. For example, in a passage describing the Toloque peoples, Sahagún writes: "By [the city of Tolocan] lies their mountain…It is said its name is Tolotzin [or] Tolotepetl. Some say – furthermore the Toloque also say – that because many reeds grow there the city is Tolocan, and the people Toloque" (de Sahagún, 1961, p. 182).

In addition to cataloguing the importance of distinct ethnic groups' places of origin, the Florentine Codex also describes specific customs tied to their places of origin, including characteristic forms of dress, hairstyles, cuisines, languages, forms of worship, and skilled labor. Moreover, in some cases the Codex—which was written by ethnic Nahuas—disparages ethnically distinct groups, not only detailing modes of dress, hairstyles, occupations, and foods, but also associating these peoples with negative stereotypes. For example, the Otomí are described as "untrained [and] stupid" (de Sahagún, 1961, p. 178) as well as "lazy [and] shiftless" (de Sahagún, 1961, p. 179). According to the Codex, within Nahua society being described as an Otomí was a grave insult: "Not only art thou like an Otomí, thou art a real Otomí, a miserable Otomí, a green-head, a thick-head, a big tuft of hair over the back of the head, an Otomí blockhead, an Otomí…" (de Sahagún, 1961, p. 178). These customs, as well as their associated stereotypes, would likely have persisted and marked these peoples as different even after leaving their places of origin.

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

For example, several neighborhoods within Teotihuacan exhibit a persistent identification with and invocation of distant places of origin. The Tlailotlacan and N1W5:19 neighborhoods near the western edge of the city are respectively associated with the Oaxaca Valley approximately 360 km south, and the Zacapu Basin in Michoacán, some 300 km to the west. Archaeologists identified these ethnic enclaves through the presence of high volumes of non-local material culture, including foreign-style ceramics made out of local clays and produced using non-local technologies (Abascal et al., 1974). Furthermore, non-local mortuary patterns (Begun, 2013; Gómez Chavez, 2002; Spence and Gamboa Cabezas, 1999) and the incorporation of foreign architectonic elements into Teotihuacan-style facades and apartment compounds (Cabrera Castro, 1998; Gómez Chavez, 1998; Spence, 2005) indicate a deliberate maintenance of a distinct social identity tied to residents' place of origin even after having relocated to central Mexico.

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

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

3. Epiclassic central Mexico and the Non-Grid 4 shrine site

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

3.1. Migration in Epiclassic central Mexico

The Epiclassic period is also associated with large-scale migrations into the Basin of Mexico. Archaeologists have sought to reconstruct evidence for Epiclassic migrations into the Basin using material correlates. The appearance of the Coyotlatelco ceramic complex throughout central Mexico has been interpreted as evidence of immigration into the region (Beekman and Christensen, 2003; Cowgill, 2013; Crider, 2013; Healan and Cobean, 2019; Rattray, 1966; Sánchez, 2013; Solar Valverde, 2006; Tozzer, 1921). Although these ceramics bear little resemblance to antecedent ceramic industries in central Mexico, some maintain that the complex represents either a local or autonomous development (Fournier and Bolaños, 2007; Sanders, 2006, 1986; Sugiura Yamamoto, 2006). Most scholars, however, find Coyotlatelco ceramics strongly resemble older ceramic industries from outside central Mexico. Suggested possible origins for the complex include the Bajío region (Beekman and Christensen, 2011, 2003; Brambila Paz and Crespo, 2005; Healan, 2012; Hernández, 2016; Hernández and Healan,

2019) and Malpaso Valley-La Quemada settlement system (Mastache et al., 2002; Nelson and Crider, 2005), both in northwestern Mexico.

Other changes in central Mexican material culture coincide with the appearance of Coyotlatelco ceramics during the Epiclassic. New forms of food preparation equipment and ritual paraphernalia became common throughout the Basin (Clayton, 2020; Hicks, 2013; Morehart et al., 2012; Morehart and Crider, 2016). The Epiclassic period also saw the advent of new forms of lithic production throughout central Mexico (Carballo, 2011; Nelson, 2009; Rattray, 1987). These techniques produced projectile points that were distinct from previous Classic period artifacts (Cowgill, 2015b, p. 111). Additionally, central Mexican Epiclassic sites with large numbers of Coyotlatelco ceramics also appeared to be exploiting obsidian sources distinct from those preferred during the Classic period (Charlton and Spence, 1983; Healan, 1997; Pastrana, 1998). Interestingly, Ucareo-Zinapécuaro, the obsidian source dominating many of these assemblages, is located in the Bajío region, coinciding with one of the proposed origins of Coyotlatelco ceramics (Hernández and Healan, 2019). Scholars have thus hypothesized that these combined shifts in material culture patterns make up an intrusive material culture complex suggestive of migration into Epiclassic central Mexico (Cowgill, 2015b, 2013; Hernández and Healan, 2019).

Public art and architectural styles during the Epiclassic period also represent a clear break with Classic period traditions and are characterized by their hybridity. In particular, murals and public monuments at the site of Cacaxtla in central Mexico have been described as stylistically foreign or international. While this eclecticism has been attributed to emulation of foreign art styles (Nagao, 2014, 1989), it has also been held up as an additional line of evidence supporting Epiclassic migration hypotheses within central Mexico (Turner, 2019). Similarly, structures at the site of Chicoloapan in the southern Basin of Mexico exhibit a great deal of variation in architectural styles and construction techniques, suggesting the presence a multiethnic community at the settlement (Clayton, 2016).

Cognizant of critiques of cultural-historical archaeology and its oversimplified approach to migration, however (Cabana, 2011), many researchers have been hesitant to equate changes in material culture with the incursion of new peoples into central Mexico (Clayton, 2016; Cowgill, 2013; Crider, 2013). Such changes could also be explained by the local emulation of foreign material forms, as well as by an intentional social, political, or moral distancing from previous material forms that may have fallen out of vogue with Teotihuacan's declining regional political and economic influence during the Epiclassic period (Cowgill, 2013). Distinguishing the subtle difference between the introduction of a foreign style by migrants and local emulation of a foreign style, however, is difficult to discern archaeologically and little work has been done on the topic.

Additional lines of evidence further support Epiclassic migration hypotheses. Extensive regional survey data reveal stark discontinuities between Classic and Epiclassic settlement patterns in the Basin of Mexico. While the majority of Classic period settlements were located in clusters on the alluvial plain, most Epiclassic settlements are found on dispersed hilltops (Healan, 2012; Healan and Cobean, 2019; Mastache et al., 2002; Parsons et al., 2008; Sanders et al., 1979). Many Classic period settlements were abandoned during the Epiclassic, including sectors of Teotihuacan itself (Cabrera Castro and Gómez Chavez, 2008; Healan and Cobean, 2019; Rattray, 2006). Of the Classic settlements that persisted, few show evidence of interaction with new Epiclassic sites, as inferred through the lack of appreciable amounts of Coyotlatelco ceramics (Healan and Cobean, 2019; but see Clayton, 2016 for an important exception). The association of new settlement patterns with the introduction of novel forms of material culture thus also suggest the arrival of a migrant population.

While these archaeological data strongly support Epiclassic migration hypotheses, Cowgill notes that "the most decisive evidence about migrations will probably eventually come through bioarchaeological methods" (2013, p. 143). Limited biogeochemical analyses of Epiclassic human remains have demonstrated the presence of migrant individuals (three of five individuals analyzed) buried in the Cueva de las Varillas at Teotihuacan (Price et al., 2000). Furthermore, ancient DNA (Fournier and Vargas Sanders, 2002; Manzanilla, 2005; Morales-Arce et al., 2019) and biodistance analyses (Beekman and Christensen, 2003; Christensen, 1997; García Velasco, 2019; González-José et al., 2007; Meza-Peñaloza et al., 2019; Ragsdale and Edgar, 2018) suggest substantial gene flow from greater Mesoamerica into the Basin of Mexico took place during the Epiclassic period. Thus, as a period characterized by dramatic social change including political reorganization, competition for access to resources, increased conflict, immigration, and demographic change, the Epiclassic provides an optimal setting within which to examine identity-based violence.

3.2. *Ritual violence at Non-Grid 4*

Identified through the course of regional survey, the site of Non-Grid 4 is located on an anthropogenic rise in the now-extinct Lake Xaltocan in the northern Basin of Mexico (Fig. 1). The site has been interpreted as a shrine as it was the locus of ritual activities and lacks a residential component (Morehart, 2017, 2010; Morehart et al., 2012). It is comprised of an elevated, fairly amorphous platform built via the accumulation of clay and limestone fill and is associated with multiple deposits of human remains and interspersed with ritual paraphernalia (Meza-Peñaloza et al., 2019; Morehart et al., 2012). The site's lacustrine setting and the recovery of water deity figurines and incense burners suggest that it was established to petition and repay deities associated with rain, water, and the earth.

Stratigraphy at Non-Grid 4 indicates that offerings of crania and associated ritual paraphernalia were made in multiple distinct events over the course of the site's use during the Epiclassic period. Offerings were recovered from the base of the platform's fill approximately 80–100 cm below the surface on a prepared limestone surface, in a large concentration of stratigraphically associated crania and cranial fragments between 15 and 40 cm below the surface, as well as in isolated intrusive pits (Morehart, 2015; Morehart et al., 2012). Offerings appear to have been deposited and buried in different episodes, contributing to the feature's amorphous condition. The repeated use of the space for ritual offering and burial created a complex stratigraphy that was also affected by several other formation processes, such as changes in lake hydrology, mechanical plowing, animal burrowing, and looting.

AMS radiocarbon dates of charcoal recovered directly beneath crania from different burial contexts range from 651 to 987 CE (Table 1), indicating that the shrine was the site of repeated depositional events over the course of its use. These dates coincide with previously published AMS radiocarbon dates of botanical remains from Non-Grid 4 that placed its construction and principal use from 550 to 890 CE, with dates associated with crania between 640 and 890 CE (Morehart et al., 2012: 437). Moreover, a range of artifacts recovered from the site, including Coyotlatelco Red on Natural, Garita Black-Brown *ollitas*, and Mazapan Red on Natural ceramics also suggest the site remained in use throughout the Epiclassic period (Morehart, 2010; Morehart et al., 2012), as these ceramics are widely accepted as Epiclassic (600–900 CE) and transitional Epiclassic to Early Postclassic (800–1000 CE) chronological markers (Cowgill, 1996; Crider, 2011).

The human remains interred at Non-Grid 4 postdate Teotihuacan's decline and have been interpreted as sacrificial deposits (Morehart et al., 2012). Although bioarchaeological evidence of violence in central Mexico during the Epiclassic period is rare, the human remains at Non-Grid 4 represent a major exception. Many of the deposited crania exhibit sharp force peri-mortem trauma consistent with throat slitting, exsanguination, and subsequent decapitation (Meza-Peñaloza et al., 2019; Pacheco-Forés, 2017). The presence of articulated mandibles and cervical vertebrae in association with the crania, along with the lack of evidence of sharp force trauma consistent with defleshing or trophy head preparation, and the lack of weathering all suggest that individuals

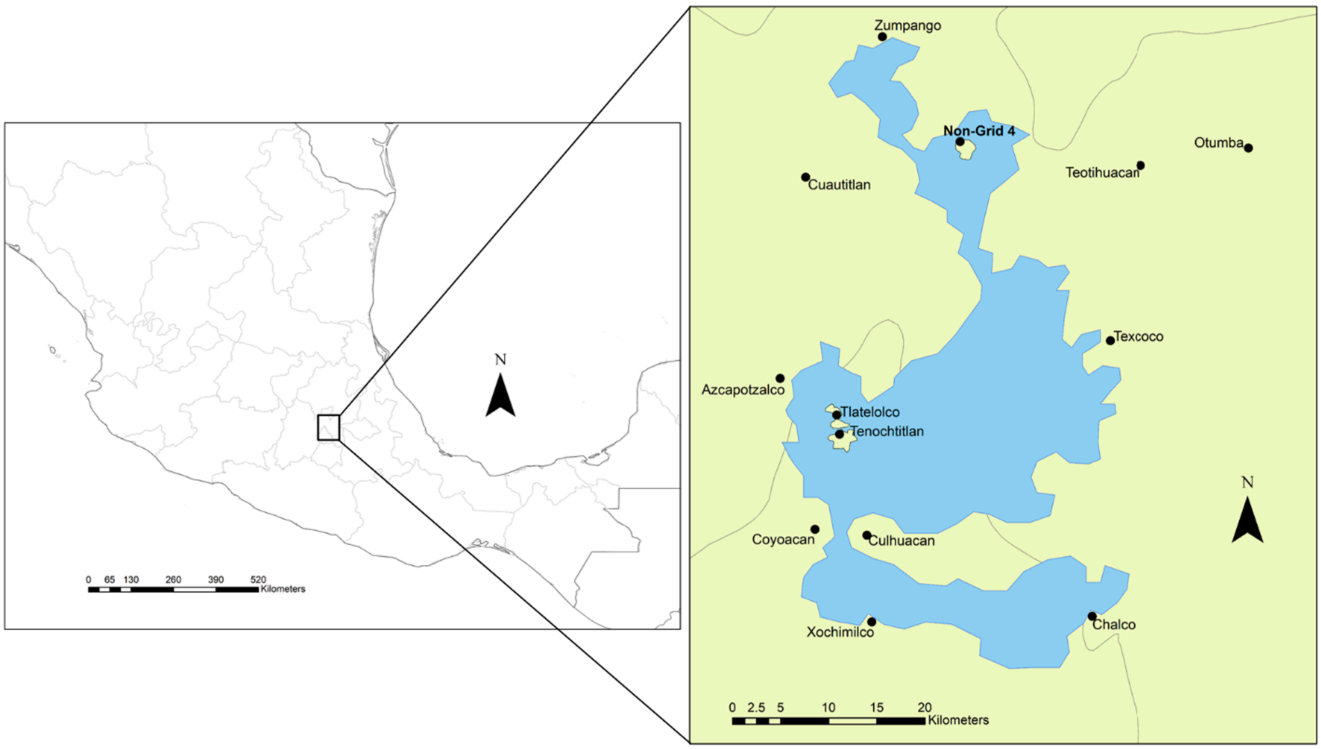

Fig. 1. The Non-Grid 4 shrine site and pre-Hispanic highland lake system within the Basin of Mexico.

Table 1
AMS dates from charcoal associated with burial contexts at Non-Grid 4.

Lab Code[a]	Sample Provenience (Unit, Lot, Level)	Conventional Radiocarbon Age	2 sigma calibration
UCIAMS-158162	E14N8-L76-L4	1140 ± 20 BP	774–987 CE
UCIAMS-158163	E12N4-L61-L3	1160 ± 20 BP	772–974 CE
UCIAMS-158164	E12N6-L63-L3	1265 ± 20 BP	672–820 CE
UCIAMS-158165	E10N6-L122-L6	1220 ± 20 BP	706–883 CE
UCIAMS-158166	E22N4-L216-L8	1335 ± 20 BP	651–774 CE
UCIAMS-158167	E10/12 N8/8-L96/91-L5/5	1225 ± 20 BP	706–881 CE
UCIAMS-158168	E14N10-L201-L4	1165 ± 20 BP	771–973 CE

[a] Dates were processed at the Keck Carbon Cycle AMS Facility at the University of California, Irvine and calibrated using the IntCal20 northern hemisphere radiocarbon age calibration curve on OxCal 4.4 (Ramsey, 2009; Reimer et al., 2020).

were decapitated *in situ* and their heads were interred shortly after decapitation (Meza-Peñaloza et al., 2019; Morehart et al., 2012) as a part of repeated ritual offering events at the site (Morehart, 2017). The remains' presence at the shrine site has thus been interpreted as evidence of competition and conflict over political influence in the wake of Teotihuacan's collapse and access to resources in a possible period of climatic change (Morehart et al., 2012).

The human remains within the sacrificial deposits were extensive. A minimum of 180 human crania associated with mandibles and cervical vertebrae were unearthed in east-facing rows beneath the shrine platform, as well as in pits across the platform (Morehart, 2017, 2015; Morehart et al., 2012). Limited additional postcranial material was recovered from the site, with the exception of distal manual and pedal phalanges, which were found in the eye orbits of sacrificed individuals (Morehart et al., 2012). Most individuals were adult males, although some females and adolescents of both sexes were also present (Table 2), and many of the deposited crania exhibit cranial and dental modification (García Velasco, 2014; Pacheco-Forés, 2016; Sholts et al., 2014). Reported sex estimates are based on anthroposcopic assessment of sexually dimorphic features of the cranium and associated mandible (if available), while age-at-death estimates are based on patterns of dental eruption and dental wear, following published osteological standards (Buikstra and Ubelaker, 1994). Cranial suture closure was not used in age-at-death assessments, as cranial modification has documented effects on cranial suture complexity and closure (Anton et al., 1992; El-Najjar and Dawson, 1977; White, 1996).

3.3. Human sacrifice and identity-based violence

Ethnohistoric and archaeological evidence indicate that human sacrifice was a culturally sanctioned form of violence practiced ubiquitously throughout ancient Mesoamerica (Galtung, 2013; Graulich, 2006; López Luján and Olivier, 2010; de Sahagún, 1951; Tiesler and Olivier, 2020). Most bioarchaeological analyses of victims of ritual violence are framed in the context of state or elite power consolidation. For example, studies investigating the age-at-death and sex of sacrificed individuals argue that victims represented deity impersonators who were sacrificed

Table 2
Demography of Non-Grid 4 sacrificial victims.

	Adolescents[a]		Adults[b]		Unobservable		Total	
Sex	*n*	%	*n*	%	*n*	%	*n*	%
Male	12	7%	114	63%	7	4%	133	74%
Female	5	3%	6	3%	0	0%	11	6%
Indeterminate	5	3%	17	9%	14	8%	36	20%
Total	22	12%	137	76%	21	12%	180	100%

[a] Individuals designated as "Adolescents" were 15–21 years old based on dental eruption.
[b] Individuals designated as "Adults" were over 21 years old, based on dental eruption.

at times of great adversity to curry favor with the gods and gain political prestige for ruling elites (De La Cruz et al., 2008; López Luján et al., 2010; Román Berrelleza, 2010; Verdugo et al., in press). Similarly, researchers investigating the geographic origins of sacrificial victims at Teotihuacan argue the diverse residential histories of sacrificial victims interred at the Pyramid of the Feathered Serpent and the Pyramid of the Moon reflect the city's far-reaching influence and militaristic presence within Mesoamerica (Spence et al., 2004; White et al., 2007, 2002), while isotopic studies finding locals and non-locals among Aztec sacrificial victims at the Templo Mayor in the Postclassic imperial capital of Tenochtitlan have been used to argue for the effectiveness of the Mexica imperial system (Moreiras Reynaga, 2019). Likewise, in the Maya region, analyses of residential mobility have been used to characterize victims in terms of their relationships to powerful elites as either retainer burials or captive warriors put to death to commemorate a military victory or a ruler's passing (Hoffmeister and Wright, 2016; Lorenz et al., 2016; Price et al., 2007). The absence of an affiliated state or centralized power, or indeed even of a residential component of the site at the Non-Grid 4 shrine sets it apart from these previous studies. The site cannot be understood through a lens of state or elite power consolidation.

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

In the volatile socio-political landscape of the central Mexican Epiclassic, aspects of victims' social identities, including their sex and age, as well as their geographic origins and residential histories, could have acted as powerful indicators of social difference that culminated in violence. Particularly striking in the demographic makeup of individuals interred at Non-Grid 4 is the prevalence of adult males, who make up 63% of the sacrificial victims (Table 2). This suggests the possibility of gendered identity-based violence at Non-Grid 4, where adult males rather than females or juveniles were specifically targeted for violence. This has important implications for gendered participation in violence, ritual sacrifice, and possibly warfare during the central Mexican Epiclassic (Morehart et al., 2014). While we recognize the importance of intersectionality in shaping past peoples' lived experiences, this manuscript focuses specifically on how individuals' migratory status may or may not have predisposed them to suffer ritual violence.

4. Reconstructing paleomobility through biogeochemistry

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

4.1. Strontium isotope baseline variability in central Mexico

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

Studies of bioavailable radiogenic strontium sources, including plants, water, and alluvial soils within the Basin of Mexico itself confirm that the Basin can be distinguished from neighboring parts of central Mexico using radiogenic strontium isotopes. For example, Pacheco-Forés et al. (2020) reported a local range of $^{87}Sr/^{86}Sr = 0.7046–0.7048$ ($n = 60$) for the Basin of Mexico, while Price et al. (2008) reported a consistent but slightly broader local range of $^{87}Sr/^{86}Sr = 0.7046–0.7051$ ($n = 86$) for the region.. The Basin of Mexico's local range thus stands in contrast to other central Mexican subregions with higher reported local ranges of $^{87}Sr/^{86}Sr = 0.7053–0.7058$ ($n = 8$; Pacheco-Forés et al., 2020) in the Puebla-Tlaxcala Valley to the east, and $^{87}Sr/^{86}Sr = 0.7053–0.7061$ ($n = 4$; Pacheco-Forés et al., 2020) in the Xochicalco Formation in Morelos immediately to the south of the Basin. Furthermore, significant variability in strontium isotopes exists within the Basin of Mexico itself, allowing many sites within the Basin to be distinguished isotopically using strontium isotopes (Pacheco-Forés et al., 2020).

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

The expected local range for the Non-Grid 4 shrine site is $^{87}Sr/^{86}Sr = 0.70478–0.70484$ ($n = 22$; Pacheco-Forés et al., 2020). However, because the Non-Grid 4 shrine site did not contain a residential component, using the Non-Grid 4 site-specific “local” range may artificially inflate the number of non-local individuals identified, as there is no archaeological evidence that individuals interred at the site lived in and consumed strontium and oxygen sources from the immediate shrine environment. Therefore, for the purposes of this study, we use the combined Basin of Mexico local range of $^{87}Sr/^{86}Sr = 0.7046–0.7051$ ($n = 86$; Price et al., 2008) to represent “local” Non-Grid 4 values. This broader “local” range provides a more conservative and robust means of identifying individuals who were non-local not only to the immediate vicinity of the shrine site, but to the whole Basin. Unless otherwise indicated, all expected local $^{87}Sr/^{86}Sr$ ranges represent interquartile ranges of sampled $^{87}Sr/^{86}Sr$ values, as these are often non-normally distributed (Price et al., 2008).

4.2. Oxygen isotope baseline variability in central Mexico

In addition to geologic variability, there is also great diversity in rainfall, temperature, humidity, and elevation across central Mexico and Greater Mesoamerica, indicating that stable oxygen isotopes are suitable for examining paleomobility in the region (Wallén, 1955; Wassenaar et al., 2009; White et al., 1998). General models of oxygen isotope behavior indicate that low elevation, hot, humid, or rainy regions typically exhibit higher $\delta^{18}O$ values, while those at higher elevations, or are cooler and dried have lower $\delta^{18}O$ values (e.g., Bowen et al., 2005; Craig, 1961a; Dansgaard, 1964; Gat, 1996). Thus, the Basin of Mexico, which is at a high elevation and receives relatively little rain annually (~750 mm; Wallén, 1955) has a reported meteoric water range of $\delta^{18}O_{mw(VSMOW)} = -10.8‰$ to $-8.8‰$ (Issar et al., 1984; Ortega-Guerrero et al., 1997). This local range includes data on shallow groundwater as well as surface precipitation, as several studies have found negligible differences in $\delta^{18}O_{VSMOW}$ values between these two water sources throughout Mexico (IAEA, 1992; Issar et al., 1984; Wassenaar et al., 2009).

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

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

4.3. Strontium and oxygen isotope sources in the Basin of Mexico

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

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

Marine resources are also a significant source of strontium and reflect seawater values of $^{87}Sr/^{86}Sr = 0.7092$ (Veizer, 1989). Diet in the Basin of Mexico, however, largely excluded marine resources (Moreiras Reynaga et al., 2020; Nado et al., 2016; Parsons, 2008; Widmer and Storey, 2017). While there is evidence of importation of marine fish to one elite residential compound at Teotihuacan (Manzanilla, 2007; Rodríguez Galicia and Valadez Azúa, 2013), wider paleodietary reconstructions indicate that consumption of marine resources was atypical (Moreiras Reynaga et al., 2020; Nado, 2017). Similarly, the consumption of marine salt, which was widely traded throughout the Maya region, could also be a non-local source of strontium that would reflect seawater rather than local values (Andrews, 1983; Fenner and Wright, 2014; Wright, 2005). There is extensive evidence, however, of local salt production within the Basin of Mexico along the shores of the three saline highland lakes (Parsons, 2001; Sanders et al., 1979, pp. 57–58). Therefore, individuals living in the Basin would most likely have consumed these local sources of salt.

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

5. Materials and methods

5.1. Sampling strategy

Approximately 40% (n = 73) of the total number of individuals excavated from the Non-Grid 4 site were selected for biogeochemical analysis. Sampled individuals replicate the demographic structure (see Table 2) of the sacrificial deposit and were included in the sample based on a secure association of the cranium with dentition. We compared intra-individual $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ values across several dental and skeletal elements (N = 194) representing discrete developmental periods to reconstruct sacrificial victims' patterns of mobility between distinct geologic or environmental zones over the life course (Ericson, 1985; Knudson et al., 2016; Luz and Kolodny, 1989; Price et al., 1994; Sealy et al., 1995). Tooth enamel does not remodel, preserving isotopic signatures from the time of its initial mineralization, while bone remodels continuously throughout life (Hillson, 1996; Katzenberg, 2008). We sampled first molars (n = 73), which mineralize *in utero* until three years of age, and third molars (n = 73), which mineralize from 7 to 12 years of age, from all sampled individuals (Hillson, 1996). Additionally, we sampled cranial bone fragments (n = 48) from a subset of sampled individuals with fragmented crania to limit destruction of osteological material. Cranial bones remodel at a rate of 1.8% per year in adults and reflect an average of the last 40–50 years of life (Pate, 1994; Torres-Lagares et al., 2010).

5.2. Biogeochemical methods

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

5.3. Radiogenic strontium isotope analysis

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

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

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

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

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

5.4. Stable oxygen isotope analysis

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

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

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

5.5. Reconstruction of residential history through inferred migratory status

Generated enamel and bone $^{87}Sr/^{86}Sr$ and converted $\delta^{18}O_{drinking\ water(VSMOW)}$ values were compared to expected local baseline ranges to reconstruct individuals' residential histories. Individuals were given an inferred migratory status of "local" if observed isotopic values in sampled tissues fell within expected local ranges. In contrast, individuals were designated as "foreigners" if values in all sampled tissues fell outside of expected local ranges. Individuals with a first molar falling outside the Basin's isotopic baseline but with subsequent tissues (either third molar or bone) falling inside the Basin's baseline were designated as "immigrants", while individuals with a first molar falling inside the local baseline, but with all subsequent tissues falling outside the baseline were designated as "emigrants". Finally, individuals with a first molar and bone sample falling within the local baseline, but a third molar falling outside the local baseline were designated as "circular migrants."

It is important to note that these inferred migratory status designations reflect biogeochemical distinctions that may not always coincide with meaningful social distinctions. For example, an individual who relocated to the northern Basin of Mexico from the south of the Basin may still have been considered a social outsider by northern Basin "locals" but would not appear as such isotopically. Similarly, given the proximity of the Non-Grid 4 shrine to the northern edge of the Basin—a region notably lacking the mountainous barriers enclosing the Basin to the east, west, and south (Mooser, 1975)—it is possible that individuals from just north of the Basin who appear isotopically non-local may have been socially perceived as "locals." Inferred migratory statuses of sampled individuals are thus constrained by the limitations of biogeochemically distinct regions and represent a conservative approximation rather than a direct reflection of culturally meaningful social distinctions.

6. Results

In 194 enamel and bone samples collected from 73 individuals, Ca/P values varied from 1.94 to 2.33, with a mean of Ca/P = 2.03 ± 0.12 (1σ, $n = 194$), U/Ca values varied from 3.21E−08 to 6.97E−05, with a mean of U/Ca = 6.82E−06 ± 1.30E−05 (1σ, $n = 194$), and Nd/Ca values varied from 2.24E−07 to 2.17E−06, with a mean of Nd/Ca = 2.98E−07 ± 3.15E−07 (1σ, $n = 193$; Table 3). Observed $^{87}Sr/^{86}Sr$ values ranged from 0.70387 to 0.70738, with a mean of $^{87}Sr/^{86}Sr$ = 0.70500 ± 0.00061 (1σ, $n = 194$), and $\delta^{18}O_{c(VPDB)}$ ranged from −11.26 to −0.38‰, with a mean of $\delta^{18}O_{c(VPDB)}$ = −6.33 ± 1.11‰ (1σ, $n = 194$; Table 3).

7. Discussion

7.1. Examining diagenetic contamination at Non-Grid 4

Results from major, minor, and trace elemental concentration analyses suggest some diagenetic contamination affected archaeological enamel and bone tissues recovered from the Non-Grid 4 shrine site. While all enamel samples fall beneath the expected biogenic apatite ratio of Ca/P = 2.15 (Price et al., 1992), most bone samples exhibited slightly higher Ca/P values, which may indicate at least some diagenetic contamination in these samples (Table 3). Enamel and bone observed U/Ca and Nd/Ca ratios (with the exception of two bone U/Ca ratios) fall below reported biogenic U/Ca values of 4.9E−05 ± 1.8E−04 (1σ, $n = 52$; Knudson et al., 2014) and Nd/Ca values of 2.31E−06 ± 3.52E−06 (2σ, $n = 14$; Knudson et al., 2012).

Comparison of analyzed enamel and bone samples' rare earth element (REE), Th, and U concentrations (ppm) relative to Kamenov et al. (2018) experimentally established Maximum Threshold Concentrations (MTC) for each of these elements indicates that the majority of samples exhibit some diagenetic contamination. Select REE (Nd and Dy) and U concentrations in over half of enamel samples fall above the MTC of 1 (Fig. 2), indicating some diagenetic alteration has affected these samples' biogenic Sr values. Similarly, REE and U concentrations in nearly all bone samples exhibit concentrations above the MTC (Fig. 3), suggesting advanced diagenetic alteration of biogenic Sr values has taken place in analyzed bone samples.

Multiple lines of evidence thus offer conflicting indications of diagenesis among sampled tissues from Non-Grid 4. Although concentrations of select REE and U in many enamel samples exceed Kamenov et al.'s (2018) MTC, all enamel samples fall within expected biogenic ranges for Ca/P, U/Ca, and Nd/Ca ratios. Likewise, MTC and Ca/P ratios indicate diagenesis in bone values, while U/Ca and Nd/Ca ratios in these samples are consistent with published biogenic values.

If biogenic $^{87}Sr/^{86}Sr$ values in sampled tissues were diagenetically altered, then we would expect observed $^{87}Sr/^{86}Sr$ values to fall within or be pulled toward the $^{87}Sr/^{86}Sr$ range of the depositional environment. Non-Grid 4's site-specific local baseline is $^{87}Sr/^{86}Sr$ = 0.70478–0.70484. However, we instead see nearly all observed enamel $^{87}Sr/^{86}Sr$ values falling outside the Non-Grid 4 local baseline (Fig. 4). Indeed, the vast majority of observed enamel $^{87}Sr/^{86}Sr$ values fall well outside the broader Basin of Mexico $^{87}Sr/^{86}Sr$ baseline used in this study to infer migratory status. This indicates that while some enamel samples may have suffered diagenesis, the biogenic $^{87}Sr/^{86}Sr$ signals in these tissues have not been wholly overwhelmed by the depositional environment's $^{87}Sr/^{86}Sr$ signal. Similarly, nearly all observed bone $^{87}Sr/^{86}Sr$ values fall outside the Non-Grid 4 shrine site's local range, although all fall within the broader Basin of Mexico local range (Fig. 5). Observed bone $^{87}Sr/^{86}Sr$ values could thus represent non-local $^{87}Sr/^{86}Sr$ values that were diagenetically masked to appear local or biogenic local $^{87}Sr/^{86}Sr$ values.

As this study is primarily interested in individuals' "non-locality"—whether their tissues exhibit Sr values outside the expected local range of the Basin of Mexico—the preservation of a non-local $^{87}Sr/^{86}Sr$ signature in enamel is sufficient to distinguish non-local "migrants" from "locals". Although diagenetic skewing of enamel $^{87}Sr/^{86}Sr$ values toward the Non-Grid 4 baseline may result in the undercounting of non-local "migrant" individuals (individuals with an inferred migratory status of "immigrant" or "foreigner"), biogenic $^{87}Sr/^{86}Sr$ signals in enamel were robust enough to allow for the identification of a substantial number of migrants present among sacrificial victims at Non-Grid 4 (Table 3). Among these Non-Grid 4 migrants, however, distinguishing between immigrants and foreigners is less secure, as diagenetic skewing of bone $^{87}Sr/^{86}Sr$ values toward the Non-Grid 4 baseline may result in the overcounting of immigrants relative to foreigners. While these data and the individuals' associated inferred migratory statuses are still presented in Table 3, we note that individuals identified

Table 3
Biogeochemical data generated from Non-Grid 4 enamel and skeletal samples.

Laboratory Number	Specimen Number	Sex	Age	Element	Ca/P[a]	U/Ca[b]	Nd/Ca[c]	$\delta^{18}O_{c(VPDB)}$	$\delta^{18}O_{dw(VSMOW)}$[d]	$^{87}Sr/^{86}Sr$[e]	Inferred Status[f]
ACL-7969	XAL-C1-1	M	Adult	M1	1.99	2.39E−07	5.05E−07	−6.6	−11.4	*0.70564*	Immigrant
ACL-7970	XAL-C1-1	M	Adult	M3	1.97	1.71E−07	5.49E−07	−6.1	−9.7	*0.70558*	
ACL-7971	XAL-C1-1	M	Adult	Bone	*2.23*	9.04E−06	7.54E−07	−5.3	−8.4	*0.70478*	
ACL-7972	XAL-C1-2	M	Adult	M1	1.96	1.21E−07	3.67E−07	−5.9	−10.4	*0.70608*	Immigrant
ACL-7973	XAL-C1-2	M	Adult	M3	1.98	3.68E−07	2.15E−07	−6.3	−9.9	*0.70555*	
ACL-7974	XAL-C1-2	M	Adult	Bone	*2.29*	3.31E−05	3.78E−07	−7.4	−11.6	*0.70483*	
ACL-7975	XAL-C1-4	M	Adult	M1	1.98	2.73E−07	3.46E−07	−6.1	−10.8	*0.70466*	Circular migrant
ACL-7976	XAL-C1-4	M	Adult	M3	1.96	1.46E−07	1.49E−07	−7.2	−11.3	*0.70596*	
ACL-7977	XAL-C1-4	M	Adult	Bone	*2.30*	3.13E−05	2.27E−07	−8.0	−12.6	*0.70471*	
ACL-7978	XAL-C2-1	M	Adult	M1	1.96	2.12E−07	2.19E−07	−6.2	−10.8	*0.70555*	Foreigner
ACL-7979	XAL-C2-1	M	Adult	M3	1.99	3.34E−07	1.71E−07	−7.1	−11.1	*0.70541*	
ACL-7980	XAL-C2-2	M	Adult	M1	1.95	1.42E−07	1.38E−07	−6.1	−10.7	*0.70451*	Immigrant
ACL-7981	XAL-C2-2	M	Adult	M3	2.00	1.07E−07	1.30E−07	−7.1	−11.3	0.70525	
ACL-7982	XAL-C2-2	M	Adult	Bone	*2.27*	8.80E−06	3.43E−07	−7.0	−11.0	*0.70477*	
ACL-7983	XAL-C2-3	M	Adult	M1	1.98	2.37E−07	1.24E−07	−5.9	−10.5	*0.70530*	Foreigner
ACL-7984	XAL-C2-3	M	Adult	M3	1.98	7.33E−08	1.41E−07	−7.3	−11.4	*0.70530*	
ACL-7985	XAL-C3-3	M	Adult	M1	1.96	3.22E−08	1.79E−07	−6.2	−10.9	*0.70387*	Foreigner
ACL-7986	XAL-C3-3	M	Adult	M3	1.95	3.43E−07	6.18E−07	−6.5	−10.3	*0.70448*	
ACL-7987	XAL-C4-1	M	Adol.	M1	1.96	1.48E−07	2.10E−07	−7.5	−12.9	*0.70602*	Immigrant
ACL-7988	XAL-C4-1	M	Adol.	M3	1.97	7.53E−08	2.11E−07	−7.0	−11.1	*0.70584*	
ACL-7989	XAL-C4-1	M	Adol.	Bone	*2.29*	3.41E−05	2.17E−06	−7.4	−11.7	*0.70481*	
ACL-7990	XAL-C4-2	M	Adult	M1	1.98	3.40E−07	4.48E−07	−6.1	−10.8	*0.70525*	Immigrant
ACL-7991	XAL-C4-2	M	Adult	M3	1.99	1.97E−07	9.25E−08	−8.6	−13.5	*0.70530*	
ACL-7992	XAL-C4-2	M	Adult	Bone	*2.26*	2.57E−05	6.92E−07	−8.4	−13.2	*0.70479*	
ACL-7993	XAL-C4-4	M	Adult	M1	1.97	1.89E−07	5.95E−07	−5.5	−9.8	*0.70719*	Immigrant
ACL-7994	XAL-C4-4	M	Adult	M3	1.97	1.63E−07	6.37E−07	−6.4	−10.1	*0.70703*	
ACL-7995	XAL-C4-4	M	Adult	Bone	*2.29*	*6.97E−05*	2.81E−07	−11.3	−17.7	*0.70499*	
ACL-7996	XAL-C5-2	M	Adult	M1	1.98	6.74E−08	1.36E−07	−5.3	−9.5	0.70598	Immigrant
ACL-7997	XAL-C5-2	M	Adult	M3	1.97	1.36E−07	1.25E−07	−5.2	−8.3	*0.70540*	
ACL-7998	XAL-C5-2	M	Adult	Bone	*2.23*	8.82E−06	1.91E−07	−6.3	−9.9	*0.70485*	
ACL-7999	XAL-C5-3	M	Adult	M1	1.96	9.20E−08	1.01E−07	−5.8	−10.3	*0.70472*	Local
ACL-8000	XAL-C5-3	M	Adult	M3	1.97	1.14E−07	1.28E−07	−5.8	−9.2	*0.70477*	
ACL-8001	XAL-C8-2	M	Adult	M1	1.96	1.76E−07	4.50E−07	−6.1	−10.7	*0.70475*	Local
ACL-8002	XAL-C8-2	M	Adult	M3	1.99	1.92E−07	4.29E−07	−6.3	−9.9	*0.70464*	
ACL-8003	XAL-C8-2	M	Adult	Bone	*2.26*	2.69E−05	5.86E−07	−4.5	−7.2	*0.70468*	
ACL-8004	XAL-C8-3	M	Adult	M1	1.97	6.61E−08	1.11E−07	−6.7	−11.6	0.70602	Foreigner
ACL-8005	XAL-C8-3	M	Adult	M3	1.95	4.22E−08	1.22E−07	−6.5	−10.2	0.70603	
ACL-8006	XAL-C9-1	F	Adult	M1	1.96	7.02E−08	1.18E−07	−6.6	−11.5	0.70416	Immigrant
ACL-8007	XAL-C9-1	F	Adult	M3	1.97	6.98E−08	1.69E−07	−7.3	−11.5	*0.70408*	
ACL-8008	XAL-C9-1	F	Adult	Bone	*2.23*	1.30E−05	6.66E−07	−6.5	−10.2	*0.70472*	
ACL-8009	XAL-C9-3	Ind.	Adol.	M1	1.98	2.68E−07	6.46E−07	−6.0	−10.6	*0.70471*	Local
ACL-8010	XAL-C9-3	Ind.	Adol.	M3	1.97	1.23E−07	1.69E−07	−5.5	−8.7	*0.70484*	
ACL-8011	XAL-C9-3	Ind.	Adol.	Bone	*2.25*	2.37E−05	3.07E−07	−4.9	−7.7	*0.70477*	
ACL-8012	XAL-C9-4	M	Adult	M1	1.95	1.11E−07	3.30E−07	−5.7	−10.1	*0.70469*	Local
ACL-8013	XAL-C9-4	M	Adult	M3	1.95	7.69E−08	3.94E−07	−8.0	−12.6	*0.70464*	
ACL-8014	XAL-C9-4	M	Adult	Bone	*2.25*	2.00E−05	4.94E−07	−7.5	−11.8	*0.70473*	
ACL-8015	XAL-C10-4	M	Adult	M1	1.99	5.20E−07	7.37E−07	−5.5	−9.7	*0.70451*	Foreigner
ACL-8016	XAL-C10-4	M	Adult	M3	1.98	5.74E−07	9.42E−07	−6.5	−10.2	*0.70428*	
ACL-8017	XAL-C12-2	M	Adult	M1	2.04	1.73E−07	4.22E−07	−5.0	−9.0	*0.70443*	Immigrant
ACL-8018	XAL-C12-2	M	Adult	M3	2.04	1.56E−07	4.30E−07	−5.9	−9.3	*0.70423*	
ACL-8019	XAL-C12-2	M	Adult	Bone	*2.33*	2.62E−05	1.10E−07	−5.7	−9.1	*0.70472*	
ACL-8020	XAL-C13-1	M	Adult	M1	1.98	1.16E−07	4.76E−08	−4.4	−8.0	*0.70507*	Local
ACL-8021	XAL-C13-1	M	Adult	M3	1.98	7.47E−08	4.04E−08	−5.4	−8.6	0.70493	
ACL-8022	XAL-C13-1	M	Adult	Bone	*2.20*	2.92E−05	2.75E−07	−3.9	−6.2	*0.70477*	
ACL-8023	XAL-C13-3	M	Adult	M1	1.96	1.44E−07	4.23E−08	−5.8	−10.3	0.70465	Local
ACL-8024	XAL-C13-3	M	Adult	M3	1.96	1.45E−07	4.84E−08	−7.0	−11.0	0.70476	
ACL-8025	XAL-C13-4	M	Adult	M1	1.96	2.78E−07	9.85E−08	−6.2	−10.8	*0.70537*	Immigrant
ACL-8026	XAL-C13-4	M	Adult	M3	1.97	6.78E−08	5.58E−08	−7.0	−11.0	0.70499	
ACL-8027	XAL-C13-4	M	Adult	Bone	*2.24*	1.60E−05	4.15E−07	−7.0	−11.1	*0.70475*	
ACL-8028	XAL-C14-1	Ind.	Adult	M1	1.95	4.16E−07	7.58E−08	−5.9	−10.4	*0.70451*	Foreigner
ACL-8029	XAL-C14-1	Ind.	Adult	M3	1.96	2.15E−07	9.64E−08	−6.6	−10.4	*0.70561*	
ACL-8030	XAL-C14-5	M	Adult	M1	1.96	3.38E−07	2.64E−07	−6.9	−12.0	*0.70432*	Foreigner
ACL-8031	XAL-C14-5	M	Adult	M3	1.96	2.73E−07	1.45E−07	−8.4	−13.2	*0.70434*	
ACL-8032	XAL-C15-3	M	Adult	M1	1.97	1.65E−07	6.33E−08	−5.3	−9.4	*0.70448*	Immigrant
ACL-8033	XAL-C15-3	M	Adult	M3	1.94	1.58E−07	7.43E−08	−5.4	−8.5	*0.70471*	
ACL-8034	XAL-C15-3	M	Adult	Bone	*2.23*	1.35E−05	5.06E−07	−7.0	−11.0	*0.70476*	
ACL-8035	XAL-C15-4	M	Adol.	M1	1.97	4.93E−07	1.21E−07	−6.3	−11.1	*0.70454*	Immigrant
ACL-8036	XAL-C15-4	M	Adol.	M3	1.97	1.45E−07	5.03E−08	−5.3	−8.5	*0.70466*	
ACL-8037	XAL-C15-6	M	Adult	M1	1.99	1.69E−07	5.00E−08	−5.7	−10.1	*0.70463*	Local
ACL-8038	XAL-C15-6	M	Adult	M3	1.96	8.69E−08	4.24E−08	−6.7	−10.6	0.70503	
ACL-8039	XAL-C16-1	M	Adult	M1	1.98	1.09E−07	1.95E−07	−6.8	−11.8	*0.70463*	Emigrant
ACL-8040	XAL-C16-1	M	Adult	M3	1.98	2.03E−07	4.95E−07	−7.5	−11.8	*0.70453*	
ACL-8041	XAL-C16-2	M	Adult	M1	1.97	2.33E−07	1.60E−07	−6.0	−10.6	*0.70552*	Foreigner
ACL-8042	XAL-C16-2	M	Adult	M3	1.97	8.60E−08	5.17E−08	−6.2	−9.8	0.70591	

(*continued on next page*)

Table 3 (*continued*)

Laboratory Number	Specimen Number	Sex	Age	Element	Ca/P[a]	U/Ca[b]	Nd/Ca[c]	$\delta^{18}O_{c(VPDB)}$	$\delta^{18}O_{dw(VSMOW)}$[d]	$^{87}Sr/^{86}Sr$[e]	Inferred Status[f]
ACL-8043	XAL-C16-3	M	Adult	M1	1.98	2.25E−07	1.65E−07	−6.1	−10.7	*0.70473*	Local
ACL-8044	XAL-C16-3	M	Adult	M3	1.96	1.94E−07	2.89E−07	−6.9	−10.8	*0.70473*	
ACL-8045	XAL-C16-4	F	Adult	M1	1.99	1.33E−07	4.05E−08	−6.7	−11.6	*0.70550*	Foreigner
ACL-8046	XAL-C16-4	F	Adult	M3	2.06	1.55E−07	4.50E−08	−7.7	−12.1	*0.70552*	
ACL-8047	XAL-C16-5	M	Adol.	M1	2.05	8.26E−08	3.60E−08	−6.2	−10.9	0.70550	Immigrant
ACL-8048	XAL-C16-5	M	Adol.	M3	2.03	7.54E−08	4.30E−08	−7.4	−11.7	0.70559	
ACL-8049	XAL-C16-5	M	Adol.	Bone	*2.21*	1.25E−05	1.70E−07	−6.0	−9.4	*0.70480*	
ACL-8050	XAL-C17-1	Ind.	Adol.	M1	1.96	6.07E−08	4.30E−08	−6.5	−11.3	0.70591	Immigrant
ACL-8051	XAL-C17-1	Ind.	Adol.	M3	1.98	1.17E−07	4.30E−08	−6.6	−10.4	*0.70575*	
ACL-8052	XAL-C17-1	Ind.	Adol.	Bone	*2.21*	3.01E−05	3.95E−07	−0.4	−0.8	*0.70483*	
ACL-8053	XAL-C17-4	M	Adult	M1	1.97	1.74E−07	2.31E−08	−5.2	−9.3	*0.70472*	Emigrant
ACL-8054	XAL-C17-4	M	Adult	M3	1.95	1.44E−07	2.24E−08	−5.1	−8.1	*0.70459*	
ACL-8055	XAL-C17-5	F	Adol.	M1	1.96	1.95E−07	5.13E−08	−3.2	−6.2	*0.70595*	Immigrant
ACL-8056	XAL-C17-5	F	Adol.	M3	1.96	1.37E−07	3.72E−08	−3.6	−5.7	*0.70698*	
ACL-8057	XAL-C17-5	F	Adol.	Bone	*2.26*	3.42E−05	1.14E−06	−5.0	−7.9	*0.70478*	
ACL-8058	XAL-C17-6	M	Adol.	M1	1.95	9.84E−08	3.82E−08	−5.9	−10.5	0.70463	Circular migrant
ACL-8059	XAL-C17-6	M	Adol.	M3	1.96	7.49E−08	3.16E−08	−6.7	−10.6	0.70452	
ACL-8060	XAL-C17-6	M	Adol.	Bone	*2.25*	4.03E−05	1.61E−07	−5.8	−9.1	*0.70468*	
ACL-8061	XAL-C18-1	M	Adol.	M1	1.99	2.11E−07	1.02E−07	−6.7	−11.7	*0.70402*	Immigrant
ACL-8062	XAL-C18-1	M	Adol.	M3	1.98	9.50E−08	6.22E−08	−7.8	−12.3	0.70419	
ACL-8063	XAL-C18-1	M	Adol.	Bone	2.15	2.07E−05	1.78E−07	−6.8	−10.7	*0.70465*	
ACL-8064	XAL-C18-3	M	Adult	M1	1.96	1.61E−07	7.38E−08	−5.9	−10.4	*0.70579*	Immigrant
ACL-8065	XAL-C18-3	M	Adult	M3	1.95	5.91E−08	3.67E−08	−5.8	−9.2	0.70525	
ACL-8066	XAL-C18-3	M	Adult	Bone	*2.19*	1.54E−05	7.13E−07	−4.0	−6.3	*0.70476*	
ACL-8067	XAL-C19-1	M	Adult	M1	1.94	1.24E−07	6.79E−08	−5.0	−9.1	0.70478	Circular migrant
ACL-8068	XAL-C19-1	M	Adult	M3	1.96	2.09E−07	5.85E−07	−7.0	−11.1	*0.70457*	
ACL-8069	XAL-C19-1	M	Adult	Bone	*2.17*	4.32E−05	2.99E−07	−5.8	−9.2	*0.70476*	
ACL-8070	XAL-C19-6	M	Adult	M1	1.97	1.13E−07	1.27E−07	−5.8	−10.3	0.70539	Foreigner
ACL-8071	XAL-C19-6	M	Adult	M3	1.96	1.42E−07	4.06E−07	−7.1	−11.2	*0.70564*	
ACL-8072	XAL-C21-3	M	Adult	M1	1.97	3.26E−07	2.03E−07	−4.9	−8.8	*0.70448*	Immigrant
ACL-8073	XAL-C21-3	M	Adult	M3	1.95	9.36E−08	1.56E−07	−6.9	−10.9	*0.70475*	
ACL-8074	XAL-C22-1	M	Adult	M1	1.96	2.97E−07	4.96E−07	−6.4	−11.2	*0.70605*	Foreigner
ACL-8075	XAL-C22-1	M	Adult	M3	1.96	9.90E−08	9.52E−08	−6.8	−10.8	0.70636	
ACL-8076	XAL-C22-3	M	Adult	M1	1.97	1.06E−06	3.41E−07	−5.5	−9.8	*0.70459*	Foreigner
ACL-8077	XAL-C22-3	M	Adult	M3	1.96	8.25E−08	1.38E−07	−5.3	−8.4	*0.70445*	
ACL-8078	XAL-C22-4	M	Adult	M1	1.97	4.92E−07	1.01E−07	−6.6	−11.5	*0.70519*	Immigrant
ACL-8079	XAL-C22-4	M	Adult	M3	1.97	1.18E−07	1.07E−07	−7.9	−12.4	0.70529	
ACL-8080	XAL-C22-4	M	Adult	Bone	*2.27*	4.01E−05	1.53E−07	−5.5	−8.8	*0.70477*	
ACL-8081	XAL-C23-2	M	Adult	M1	1.96	2.03E−07	1.83E−07	−5.6	−10.0	*0.70539*	Immigrant
ACL-8082	XAL-C23-2	M	Adult	M3	1.97	3.49E−07	1.01E−07	−6.9	−10.8	*0.70525*	
ACL-8083	XAL-C23-2	M	Adult	Bone	*2.26*	3.39E−05	6.59E−08	−6.3	−10.0	*0.70476*	
ACL-8084	XAL-C23-5	M	Adult	M1	1.96	1.70E−07	5.15E−07	−5.6	−9.9	*0.70450*	Foreigner
ACL-8085	XAL-C23-5	M	Adult	M3	1.96	4.99E−08	4.85E−08	−6.9	−11.0	*0.70448*	
ACL-8086	XAL-C24-2	M	Adult	M1	1.97	1.21E−06	2.28E−07	−5.0	−9.0	*0.70546*	Foreigner
ACL-8087	XAL-C24-2	M	Adult	M3	1.96	7.97E−08	2.09E−07	−6.7	−10.5	*0.70573*	
ACL-8088	XAL-C24-4	F	Adol.	M1	1.97	6.35E−07	2.91E−07	−7.2	−12.4	*0.70546*	Immigrant
ACL-8089	XAL-C24-4	F	Adol.	M3	2.05	6.88E−06	3.02E−07	−7.0	−11.1	*0.70486*	
ACL-8090	XAL-C24-4	F	Adol.	Bone	*2.18*	4.04E−05	1.59E−07	−5.1	−8.1	*0.70476*	
ACL-8091	XAL-C24-5	M	Adol.	M1	1.95	5.32E−08	5.19E−08	−6.0	−10.5	0.70531	Immigrant
ACL-8092	XAL-C24-5	M	Adol.	M3	1.97	6.20E−08	5.48E−08	−6.1	−9.6	0.70523	
ACL-8093	XAL-C24-5	M	Adol.	Bone	*2.25*	2.24E−05	7.56E−07	−3.7	−6.0	*0.70481*	
ACL-8094	XAL-C24-6	M	Adult	M1	1.97	6.01E−07	5.46E−07	−7.2	−12.4	*0.70632*	Foreigner
ACL-8095	XAL-C24-6	M	Adult	M3	1.96	1.55E−07	1.05E−07	−6.9	−10.8	*0.70738*	
ACL-8096	XAL-C25-2	M	Adult	M1	1.96	1.98E−07	1.29E−07	−4.5	−8.3	*0.70464*	Local
ACL-8097	XAL-C25-2	M	Adult	M3	1.96	1.83E−07	1.93E−07	−5.7	−9.0	*0.70472*	
ACL-8098	XAL-C25-3	Ind.	Adol.	M1	1.96	3.29E−07	2.33E−07	−6.2	−10.9	*0.70482*	Local
ACL-8099	XAL-C25-3	Ind.	Adol.	M3	1.95	9.33E−08	4.01E−08	−6.3	−9.9	0.70493	
ACL-8100	XAL-C25-3	Ind.	Adol.	Bone	*2.21*	2.02E−05	4.22E−07	−6.0	−9.5	*0.70477*	
ACL-8101	XAL-C25-4	M	Adult	M1	1.96	2.71E−07	2.80E−07	−5.9	−10.4	*0.70473*	Local
ACL-8102	XAL-C25-4	M	Adult	M3	1.96	2.42E−07	1.15E−07	−6.5	−10.3	*0.70462*	
ACL-8103	XAL-C25-4	M	Adult	Bone	2.07	2.57E−05	3.03E−07	−5.9	−9.3	*0.70473*	
ACL-8104	XAL-C25-5	M	Adult	M1	1.96	1.46E−06	4.26E−07	−4.0	−7.4	*0.70483*	Local
ACL-8105	XAL-C25-5	M	Adult	M3	1.97	6.99E−07	1.28E−07	−4.2	−6.7	*0.70491*	
ACL-8106	XAL-C25-5	M	Adult	Bone	*2.24*	4.00E−05	1.58E−07	−5.3	−8.4	*0.70477*	
ACL-8107	XAL-C26-1	M	Adult	M1	1.96	2.92E−07	1.48E−07	−6.9	−12.0	*0.70438*	Foreigner
ACL-8108	XAL-C26-1	M	Adult	M3	1.97	1.32E−07	2.08E−07	−5.8	−9.2	*0.70446*	
ACL-8109	XAL-C26-3	M	Adult	M1	1.97	2.84E−07	7.63E−07	−6.1	−10.8	*0.70438*	Immigrant
ACL-8110	XAL-C26-3	M	Adult	M3	1.97	6.51E−08	7.92E−08	−5.7	−9.0	0.70432	
ACL-8111	XAL-C26-3	M	Adult	Bone	1.97	9.78E−06	NA	−6.4	−10.1	*0.70468*	
ACL-8112	XAL-C26-4	M	Adult	M1	1.96	2.00E−07	1.99E−07	−7.1	−12.3	*0.70447*	Immigrant
ACL-8113	XAL-C26-4	M	Adult	M3	1.96	2.41E−07	2.65E−07	−6.8	−10.8	*0.70439*	
ACL-8114	XAL-C26-4	M	Adult	Bone	*2.29*	*6.20E−05*	6.31E−07	−5.6	−8.9	*0.70472*	
ACL-8115	XAL-C27-2	M	Adol.	M1	1.97	1.04E−07	8.30E−08	−6.0	−10.6	0.70494	Local
ACL-8116	XAL-C27-2	M	Adol.	M3	1.97	1.44E−07	5.80E−08	−6.8	−10.7	*0.70460*	
ACL-8117	XAL-C27-2	M	Adol.	Bone	*2.19*	3.62E−05	2.09E−07	−6.6	−10.4	*0.70472*	
ACL-8118	XAL-C27-4	M	Adult	M1	1.96	1.32E−07	4.82E−07	−6.3	−11.1	*0.70443*	Immigrant

(*continued on next page*)

Table 3 (*continued*)

Laboratory Number	Specimen Number	Sex	Age	Element	Ca/P[a]	U/Ca[b]	Nd/Ca[c]	$\delta^{18}O_{c(VPDB)}$	$\delta^{18}O_{dw(VSMOW)}$[d]	$^{87}Sr/^{86}Sr$[e]	Inferred Status[f]
ACL-8119	XAL-C27-4	M	Adult	M3	1.99	4.79E−07	4.64E−07	−6.8	−10.7	*0.70451*	
ACL-8120	XAL-C27-4	M	Adult	Bone	*2.25*	2.37E−05	1.17E−07	−5.7	−9.1	*0.70472*	
ACL-8121	XAL-C27-5	M	Adult	M1	1.95	1.91E−07	4.10E−07	−4.9	−8.9	*0.70481*	Local
ACL-8122	XAL-C27-5	M	Adult	M3	1.97	1.74E−07	5.49E−07	−7.8	−12.3	*0.70464*	
ACL-8123	XAL-C27-5	M	Adult	Bone	*2.19*	3.30E−05	7.92E−08	−5.8	−9.2	*0.70474*	
ACL-8124	XAL-C28-2	M	Adol.	M1	1.98	1.71E−07	1.16E−07	−4.9	−8.9	*0.70595*	Immigrant
ACL-8125	XAL-C28-2	M	Adol.	M3	2.07	7.00E−06	1.76E−06	−4.8	−7.6	*0.70510*	
ACL-8126	XAL-C28-2	M	Adol.	Bone	*2.20*	3.35E−05	2.09E−07	−5.2	−8.2	*0.70489*	
ACL-8127	XAL-C28-3	M	Adult	M1	1.97	1.10E−07	1.21E−07	−4.1	−7.6	*0.70599*	Immigrant
ACL-8128	XAL-C28-3	M	Adult	M3	1.99	4.95E−07	1.59E−06	−6.3	−9.9	*0.70627*	
ACL-8129	XAL-C28-3	M	Adult	Bone	*2.22*	3.68E−05	2.80E−07	−4.8	−7.6	*0.70482*	
ACL-8130	XAL-C28-4	M	Adult	M1	1.97	2.24E−07	5.84E−07	−5.7	−10.1	*0.70459*	Immigrant
ACL-8131	XAL-C28-4	M	Adult	M3	1.96	4.76E−07	5.97E−07	−6.4	−10.1	*0.70459*	
ACL-8132	XAL-C28-4	M	Adult	Bone	*2.21*	2.37E−05	8.39E−07	−5.3	−8.5	*0.70475*	
ACL-8133	XAL-C29-1	F	Adol.	M1	1.95	6.53E−08	3.87E−08	−5.2	−9.3	0.70632	Immigrant
ACL-8134	XAL-C29-1	F	Adol.	M3	1.97	2.05E−07	8.24E−08	−6.6	−10.4	*0.70522*	
ACL-8135	XAL-C29-1	F	Adol.	Bone	*2.22*	1.25E−05	2.51E−07	−5.7	−9.1	*0.70485*	
ACL-8136	XAL-C29-3	M	Adult	M1	1.96	5.85E−07	2.74E−07	−4.9	−8.9	*0.70462*	Local
ACL-8137	XAL-C29-3	M	Adult	M3	1.97	1.42E−06	1.65E−06	−7.2	−11.3	*0.70464*	
ACL-8138	XAL-C29-3	M	Adult	Bone	*2.21*	1.85E−05	1.02E−06	−6.6	−10.4	*0.70474*	
ACL-8139	XAL-C30-2	M	Adult	M1	1.96	6.58E−08	7.19E−08	−6.2	−10.9	0.70620	Immigrant
ACL-8140	XAL-C30-2	M	Adult	M3	1.96	3.28E−07	6.66E−07	−7.1	−11.2	*0.70454*	
ACL-8141	XAL-C30-2	M	Adult	Bone	*2.29*	5.29E−06	2.22E−07	−3.8	−6.1	*0.70482*	
ACL-8142	XAL-C30-5	M	Adult	M1	1.96	3.65E−07	7.16E−07	−4.9	−8.9	*0.70494*	Local
ACL-8143	XAL-C30-5	M	Adult	M3	1.98	7.19E−07	2.49E−07	−5.0	−7.9	*0.70484*	
ACL-8144	XAL-C30-5	M	Adult	Bone	*2.26*	1.24E−05	1.49E−07	−5.5	−8.8	*0.70476*	
ACL-8145	XAL-C31-1	F	Adol.	M1	1.97	2.46E−07	5.50E−07	−4.8	−8.7	*0.70526*	Immigrant
ACL-8146	XAL-C31-1	F	Adol.	M3	1.95	1.82E−07	7.08E−07	−5.4	−8.6	*0.70556*	
ACL-8147	XAL-C31-1	F	Adol.	Bone	*2.23*	2.11E−05	1.29E−07	−4.5	−7.1	*0.70479*	
ACL-8148	XAL-C32-4	M	Adult	M1	1.97	1.49E−07	5.31E−08	−6.1	−10.7	*0.70452*	Immigrant
ACL-8149	XAL-C32-4	M	Adult	M3	1.94	5.54E−08	6.04E−08	−6.1	−9.6	0.70432	
ACL-8150	XAL-C32-4	M	Adult	Bone	*2.23*	3.17E−05	6.86E−07	−5.8	−9.2	*0.70471*	
ACL-8151	XAL-C32-5	M	Adult	M1	1.94	1.93E−07	5.63E−07	−4.9	−8.8	*0.70622*	Immigrant
ACL-8152	XAL-C32-5	M	Adult	M3	1.95	3.56E−07	4.34E−07	−6.7	−10.5	*0.70617*	
ACL-8153	XAL-C32-5	M	Adult	Bone	*2.16*	2.73E−05	1.93E−07	−7.2	−11.3	*0.70485*	
ACL-8154	XAL-C34-1	M	Adult	M1	1.98	1.19E−06	5.25E−07	−5.0	−9.0	*0.70465*	Circular migrant
ACL-8155	XAL-C34-1	M	Adult	M3	1.98	3.57E−07	2.58E−07	−6.2	−9.8	*0.70453*	
ACL-8156	XAL-C34-1	M	Adult	Bone	*2.20*	2.01E−05	2.62E−07	−6.4	−10.1	*0.70472*	
ACL-8157	XAL-C34-2	M	Adult	M1	1.94	2.09E−07	8.24E−08	−6.4	−11.2	*0.70455*	Immigrant
ACL-8158	XAL-C34-2	M	Adult	M3	2.04	6.73E−06	1.38E−07	−4.2	−6.7	*0.70474*	
ACL-8159	XAL-C34-2	M	Adult	Bone	*2.19*	2.46E−05	9.23E−08	−5.7	−9.1	*0.70476*	
ACL-8160	XAL-C34-3	M	Adult	M1	1.96	5.26E−07	3.26E−07	−5.6	−9.9	*0.70450*	Immigrant
ACL-8161	XAL-C34-3	M	Adult	M3	1.95	3.14E−07	1.22E−07	−6.6	−10.4	*0.70448*	
ACL-8162	XAL-C34-3	M	Adult	Bone	*2.23*	2.79E−05	1.53E−07	−6.2	−9.8	*0.70472*	

[a] Italicized values fall above the expected biogenic apatite ratio of Ca/P = 2.15 (Price et al., 1992).
[b] Italicized values fall above published biogenic values of U/Ca = 4.9E−05 (Knudson et al., 2014).
[c] Italicized values fall above published biogenic values of Nd/Ca = 2.31E−06 (Knudson et al., 2012).
[d] Observed $\delta^{18}O_{c(VPDB)}$ values were converted to $\delta^{18}O_{drinking\ water(VSMOW)}$ values using equations cited in Section 5.4 for direct comparison with $\delta^{18}O_{drinking\ water\ (VSMOW)}$ baseline generated by Moreiras Reynaga (2019).
[e] Italicized values had at least one REE, Th, or U C/MTC value falling above the expected maximum threshold concentration of 1 (Kamenov et al., 2018).
[f] Inferred Status was assigned using the definitions discussed in Section 5.5 in reference to $^{87}Sr/^{86}Sr$ data. Limitations in interpretation of $\delta^{18}O_{c(VPDB)}$ data are discussed in Section 7.2.

as "immigrants" solely on the basis of a local $^{87}Sr/^{86}Sr$ value in a bone sample may be artifacts of diagenetic alteration. This difficulty discerning immigrants from foreigners, however, does not alter the fundamental finding of non-local migrant individuals at the Non-Grid 4 shrine site who would have been considered socially distinct or "other" by Basin locals.

7.2. Residential histories of sacrificial victims at Non-Grid 4

As previously discussed, individuals interred at Non-Grid 4 consuming primarily local sources of strontium were expected to exhibit $^{87}Sr/^{86}Sr$ values falling within the combined Basin of Mexico local range of $^{87}Sr/^{86}Sr$ = 0.7046–0.7051 (n = 86; Price et al., 2008). Similarly, individuals consuming local drinking water sources—the largest contributor to $\delta^{18}O$ values in human hard tissues—were expected to fall within a local range of $\delta^{18}O_{mw(VSMOW))}$ = −12.6 to −6.4‰. Individuals with enamel or bone $^{87}Sr/^{86}Sr$ or $\delta^{18}O_{mw(VSMOW)}$ values falling outside of this conservative local range thus likely represent migrants.

A summary plot of $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ results in all sampled tissues reveals that many of the individuals interred at the Epiclassic Non-Grid 4 shrine were migrants (Fig. 6). A majority of first and third molar enamel samples fall outside the expected local Basin of Mexico $^{87}Sr/^{86}Sr$ range. Non-local $^{87}Sr/^{86}Sr$ values in these tissues, which form during infancy and early childhood (first molars), and early adolescence (third molars), indicate that these individuals originated from regions that were geologically distinct from the Basin of Mexico. This provides further supporting evidence of the long-debated presence of Epiclassic migrants within the Basin of Mexico.

Nearly all of these enamel samples, however, fall within the $\delta^{18}O$ range for the Basin of Mexico, suggesting that these individuals hailed from locales environmentally indistinguishable from the Basin of Mexico. Conversely, the relative paucity of non-local $\delta^{18}O$ values could also indicate that the established Non-Grid 4 $\delta^{18}O$ local range, necessarily expanded by the MMD of 3.1‰ to account for interlaboratory variability in sample treatment, is too broad to capture meaningful variation in distinct environments within ancient Mesoamerica, which

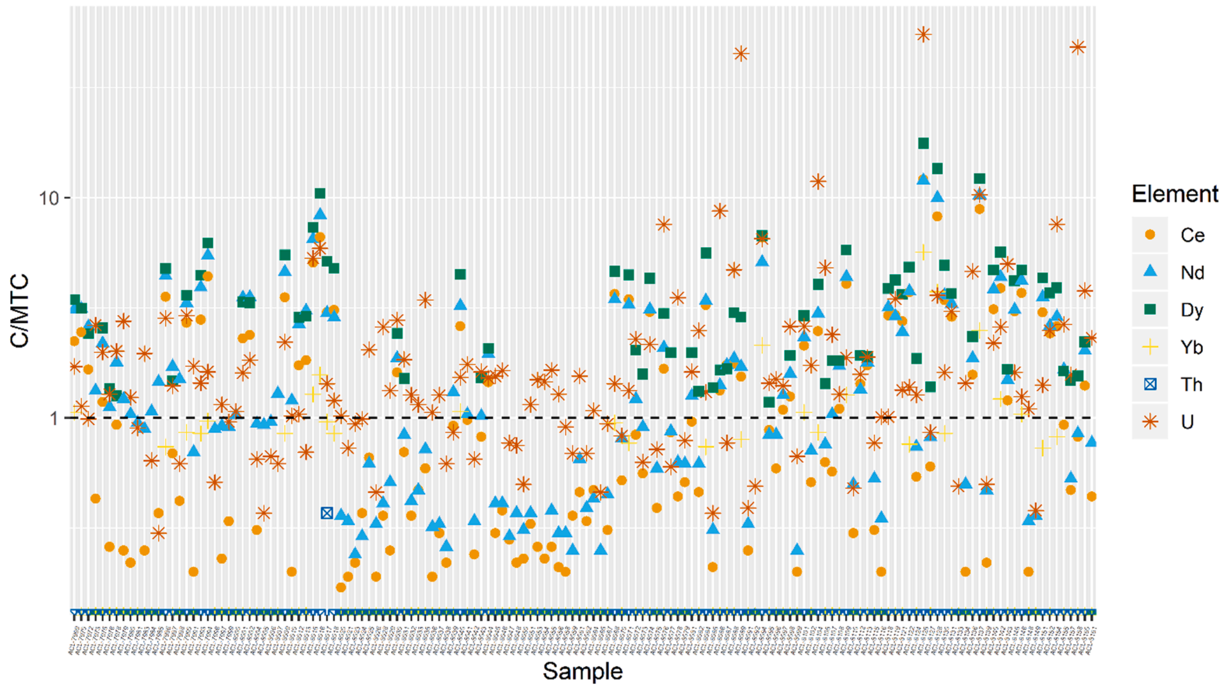

Fig. 2. REE, Th, and U concentrations (ppm)/MTC for all enamel samples. The dashed line demarcates the C/MTC threshold for biogenic values of 1, following Kamenov et al. (2018).

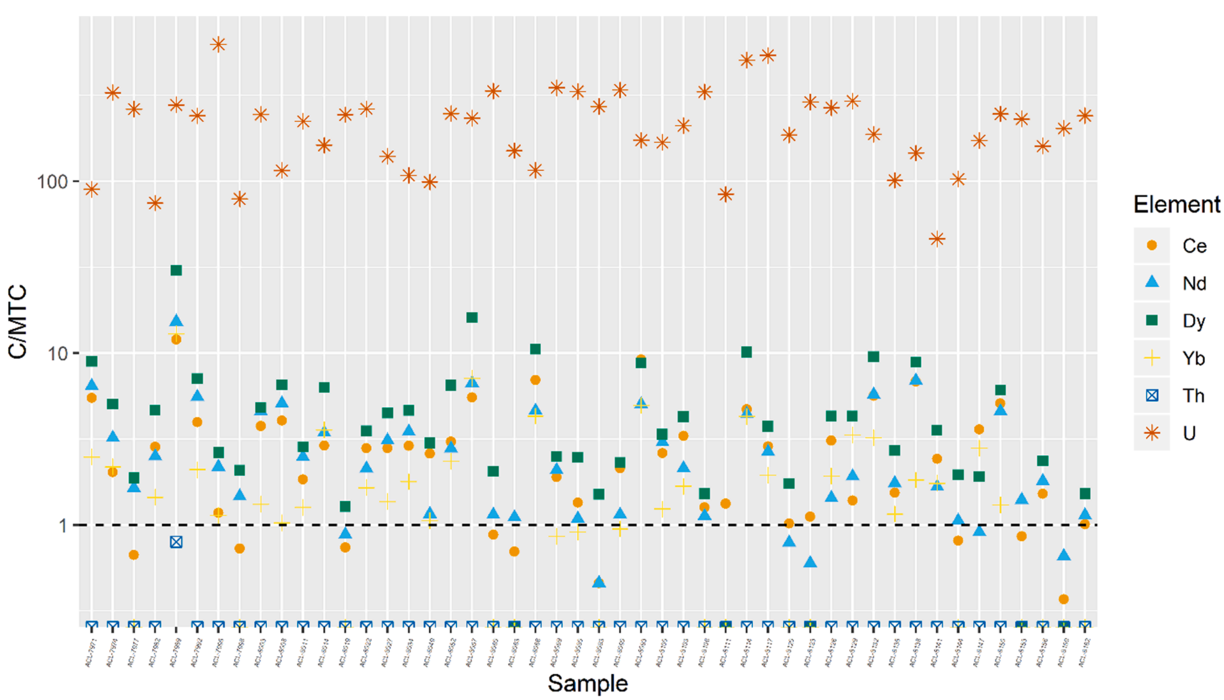

Fig. 3. REE, Th, and U concentrations (ppm)/MTC for all bone samples. The dashed line demarcates the C/MTC threshold for biogenic values of 1, following Kamenov et al. (2018).

tend to range clinally in increments of 1‰ (Wassenaar et al., 2009; White et al., 1998; Moreiras Reynaga, 2019). In stark contrast to enamel tissues, all bone samples fall within the combined local Basin of Mexico $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ ranges. While this may be an artifact of diagenetic contamination of bone samples, it could also suggest that migrant sacrificed individuals may have lived locally within the Basin for at least some period of time prior to their deaths.

Interestingly, there is great diversity in non-local $^{87}Sr/^{86}Sr$ values among migrant individuals (individuals with inferred migratory status designations of “immigrant” or “foreigner” in Table 3), who together make up 70% of sampled sacrificial victims. This suggests that sacrificial victims originated from multiple geologically distinct regions. Observed non-local $^{87}Sr/^{86}Sr$ values range from $^{87}Sr/^{86}Sr$ = 0.70387–0.70738, falling significantly outside the expected Basin local range of $^{87}Sr/^{86}Sr$ = 0.7046–0.7051. Because $^{87}Sr/^{86}Sr$ values are not unique, but rather reflect the age and composition of local bedrock, it is not possible to

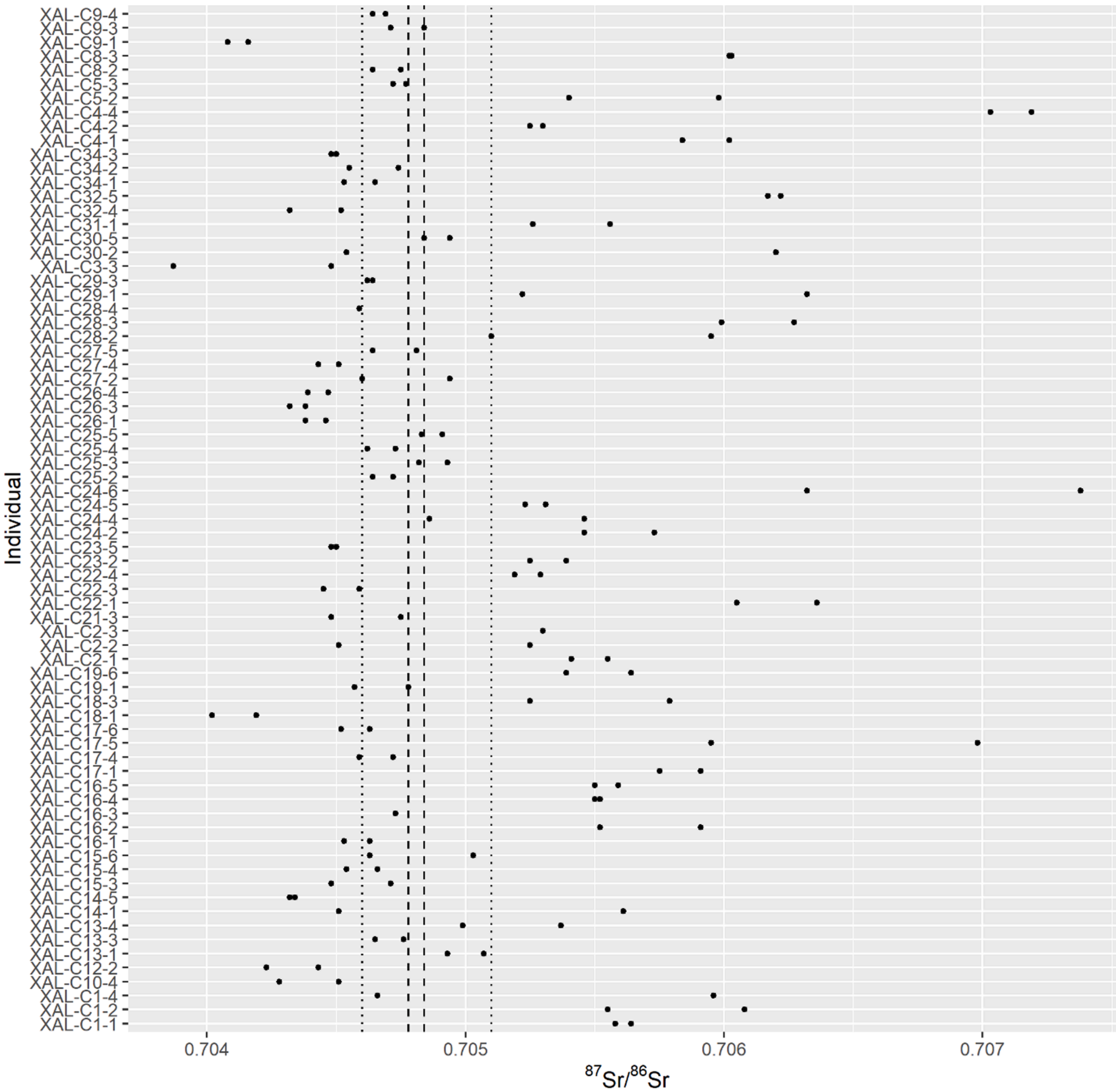

Fig. 4. Radiogenic strontium values in enamel samples. Dashed lines indicate the local $^{87}Sr/^{86}Sr$ range for the Non-Grid 4 shrine site, while dotted lines indicate the local $^{87}Sr/^{86}Sr$ range for the Basin of Mexico.

geolocate from where individuals with non-local $^{87}Sr/^{86}Sr$ values originated. However, comparison of observed $^{87}Sr/^{86}Sr$ values in sacrificial victims with reported local $^{87}Sr/^{86}Sr$ ranges throughout Mesoamerica discussed above offer some suggestions as to potential source locations for Non-Grid 4 migrants.

Sacrificial victims with non-local $^{87}Sr/^{86}Sr$ values falling below the expected local Basin of Mexico range overlap with local ranges from the Maya volcanic highlands, western Mexico, and the Montagua Valley within the Maya metamorphic province (Hodell et al., 2004; Price et al., 2008). Similarly, sacrificed individuals with $^{87}Sr/^{86}Sr$ values falling above the expected Basin of Mexico range coincide with local $^{87}Sr/^{86}Sr$ ranges from the Puebla-Tlaxcala Valley and the Xochicalco Formation within central Mexico, as well as with further regions, including northern Mexico, the southern Maya lowlands, and the Oaxaca Valley (Hodell et al., 2004; Offenbecker, 2018; Pacheco-Forés et al., 2020). Countless other regions throughout Mesoamerica have yet to be characterized biogeochemically. Therefore, further investigations using biogeochemistry as well as other bioarchaeological methods are needed to better discern the source of the Non-Grid 4 Epiclassic migrants in the Basin of Mexico. Furthermore, as some enamel samples exhibit evidence of diagenetic alteration, observed $^{87}Sr/^{86}Sr$ values may not exactly reflect their geological region of origin.

Examining intra-individual patterns in $^{87}Sr/^{86}Sr$ values among sacrificial victims at the Non-Grid 4 shrine allows us to reconstruct their residential histories across the life course to gain a more nuanced understanding of mobility patterns at the site (Fig. 7, Table 3). A majority of sampled individuals (48%, $n = 35$) exhibited non-local first molar $^{87}Sr/^{86}Sr$ values and local third molar and/or bone $^{87}Sr/^{86}Sr$ values, suggesting they were immigrants who were born in a geologically distinct region but moved to the Basin of Mexico sometime after the first few years of life. Similarly, 22% ($n = 16$) of sampled individuals exhibited non-local $^{87}Sr/^{86}Sr$ values among all sampled tissues, suggesting they were foreigners who lived outside the Basin of Mexico for most of their lives, relocating to the Basin only shortly before their deaths, before their bone tissues incorporated a significant Basin $^{87}Sr/^{86}Sr$ signature. However, due to sampling limitations, none of these foreigners have data from bone samples. Designated "foreign" individuals therefore may or may not have exhibited local bone $^{87}Sr/^{86}Sr$ values.

Furthermore, 5% ($n = 4$) of sampled individuals exhibited local

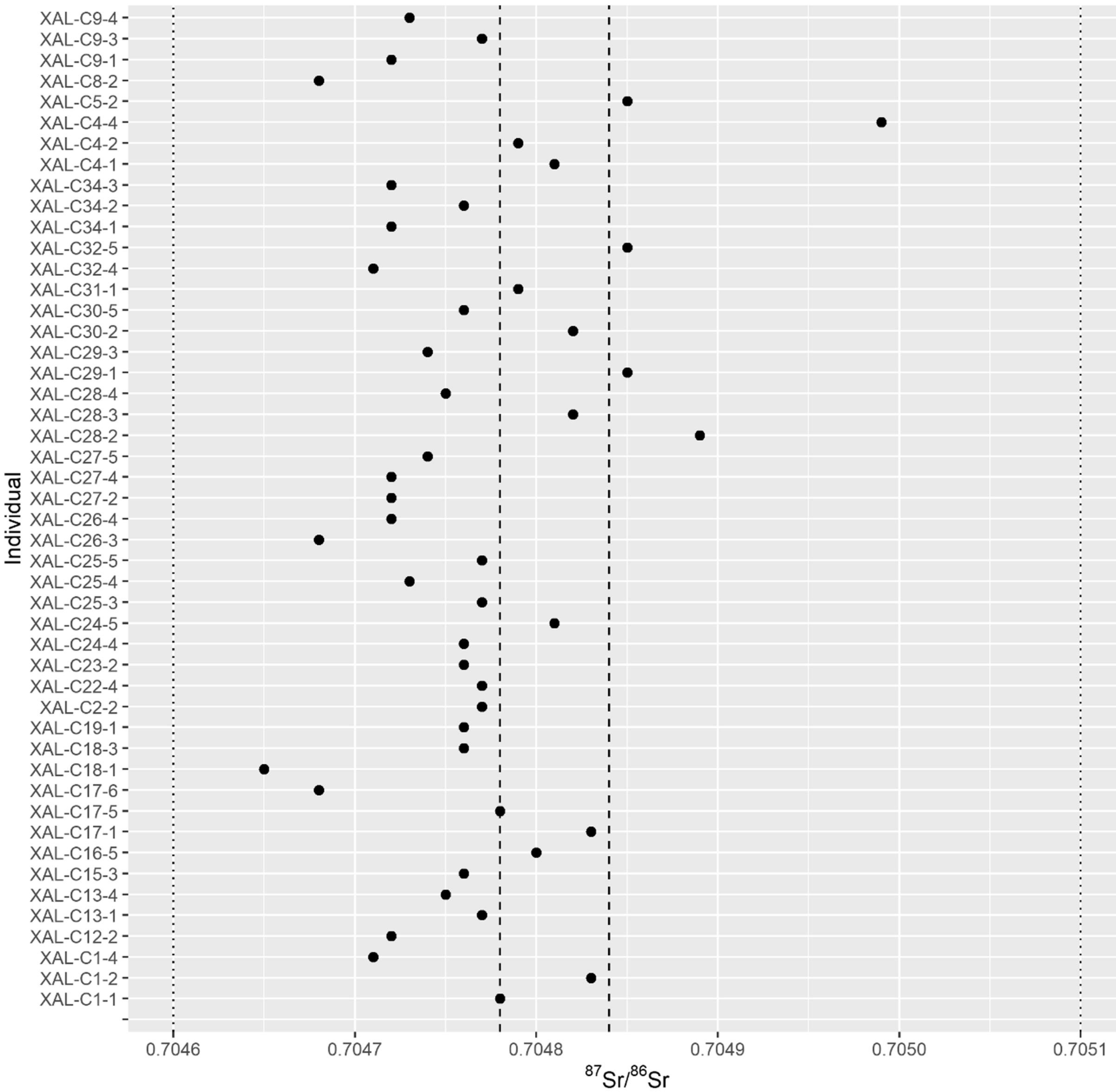

Fig. 5. Radiogenic strontium values in bone samples. Dashed lines indicate the local $^{87}Sr/^{86}Sr$ range for the Non-Grid 4 shrine site, while dotted lines indicate the local $^{87}Sr/^{86}Sr$ range for the Basin of Mexico.

$^{87}Sr/^{86}Sr$ values in first molar and bone samples, and non-local $^{87}Sr/^{86}Sr$ values in third molars. These individuals were likely circular migrants who were born in the Basin but would leave and return periodically. Although the $^{87}Sr/^{86}Sr$ values in two individuals (XAL-C16-1 and XAL-C17-4) suggest they were emigrants (3% of the total sample) who were born in the Basin of Mexico (first molar) and left later in life (third molar), this interpretation is based solely on enamel samples reflecting their early life and adolescence. They thus may or may not have also been circular migrants. Finally, only 22% (n = 16) of sampled individuals exhibited local Basin $^{87}Sr/^{86}Sr$ values among all sampled tissues, suggesting they were locals who lived in the region their entire lives. Thus, while some locals were present among the Non-Grid 4 shrine sacrificial victims, the vast majority of sampled sacrificed individuals were migrants (i.e., either immigrants or foreigners) to the Basin of Mexico.

7.3. Identity-based violence at Non-Grid 4

Although this study primarily focuses on how individuals' migratory status may or may not have predisposed them to suffer ritual violence, we briefly consider sex and age-at-death patterns among the sampled sacrificial victims (Table 4). The sample was dominated by adult males, replicating the demographic breakdown of the overall sacrificial assemblage (Table 2). Migratory status among males (n = 63), as well as among all adults (n = 58) and adolescents (n = 15) roughly mimic patterns seen more broadly in the sample as a whole, with migrants being significantly overrepresented relative to locals in each of these demographic groups. Interestingly, females represent a radical example of this pattern, as all sampled females (n = 6) were migrants. This could suggest that local females were not perceived as culturally acceptable targets of human sacrifice during the central Mexican Epiclassic, while migrant females were not afforded the same protected status. Given the low numbers of females recovered from the Non-Grid 4 shrine site (n = 11), however, this finding could be an artifact of sampling error.

Sacrificial victims' residential histories clarify the relationship between geographic origin, migration, and violence in central Mexico during the Epiclassic period. The high proportion of migrant individuals (70%) and the low proportion of locals (22%) among the sampled sacrificial victims at Non-Grid 4 suggests that individuals with divergent geographic origins were more likely to suffer ritual violence during this

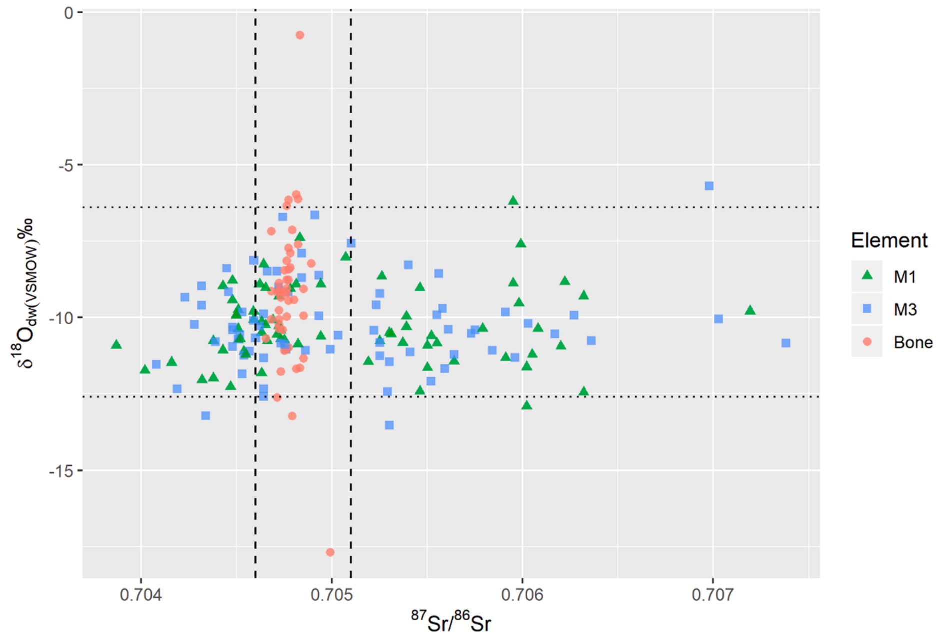

Fig. 6. $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ results across all sampled elements ($N = 194$), including first molars ($n = 73$), third molars ($n = 73$), and bone ($n = 48$). The expected Basin of Mexico $^{87}Sr/^{86}Sr$ local range is indicated by the dashed lines, while the expected Basin of Mexico $\delta^{18}O$ local range is indicated by the dotted lines.

period of socio-political reorganization. Furthermore, the fact that the sacrificial offerings at Non-Grid 4 represent multiple repeated events at the site indicates that the identity-based violence evident at Non-Grid 4 did not represent an aberrant single instance, but was instead a sustained phenomenon throughout the Epiclassic period in the northern Basin of Mexico.

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

In the absence of normative Epiclassic central Mexican burial contexts, we compare Non-Grid 4 paleomobility patterns with those from Classic period Teotihuacan. Teotihuacan was known to have maintained its population through immigration (Nichols, 2016; White et al., 2004). We thus use the prevalence of migrants at Teotihuacan as a rough approximation for expectations for a normative Epiclassic community dynamic. Previous biogeochemical studies examining migration at Classic Teotihuacan residential compounds found that migrants made up approximately one-third of sampled individuals, ranging from 27% to 37% depending on the compound (Nado, 2017; Schaaf et al., 2012; Solís Pichardo et al., 2017; White et al., 2004). In contrast, at Non-Grid 4, 70% of individuals are migrants. Migrant individuals are thus present in sacrificial contexts in far greater numbers than would be expected, even in a community experiencing sustained immigration.

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

8. Conclusion

The biogeochemical data presented here provide compelling evidence that the individuals ritually sacrificed and interred at the Epiclassic Non-Grid 4 shrine site in the northern Basin of Mexico were victims of identity-based violence. A large majority of sampled individuals (70%) were born and lived their early lives outside of the Basin of Mexico, though most of these individuals relocated to the Basin prior to their deaths (see Fig. 7). We therefore provide direct evidence of first-generation migrants in the Epiclassic Basin of Mexico.

Furthermore, the relative paucity of sacrificial victims who were born and lived their entire lives in the Basin (22%) suggests that migrant individuals were disproportionately more likely to suffer ritual violence during the Epiclassic period. As geographic origin was an ethnohistorically and archaeologically demonstrated salient indicator of social difference in pre-Hispanic Mesoamerica, these migrant individuals were most likely targeted for violence based on their divergent residential histories and geographic origins. This work further develops a theoretical framework within which to examine identity-based violence archaeologically, connecting broader research on identity and violence within the social sciences to bioarchaeologically observable aspects of identity in the past in contexts of large-scale violence. It thus contributes to anthropological knowledge of the social context of violence, examining the interaction between specific social identities; complex social processes like political fragmentation, migration, and demographic change; and instances of mass violence.

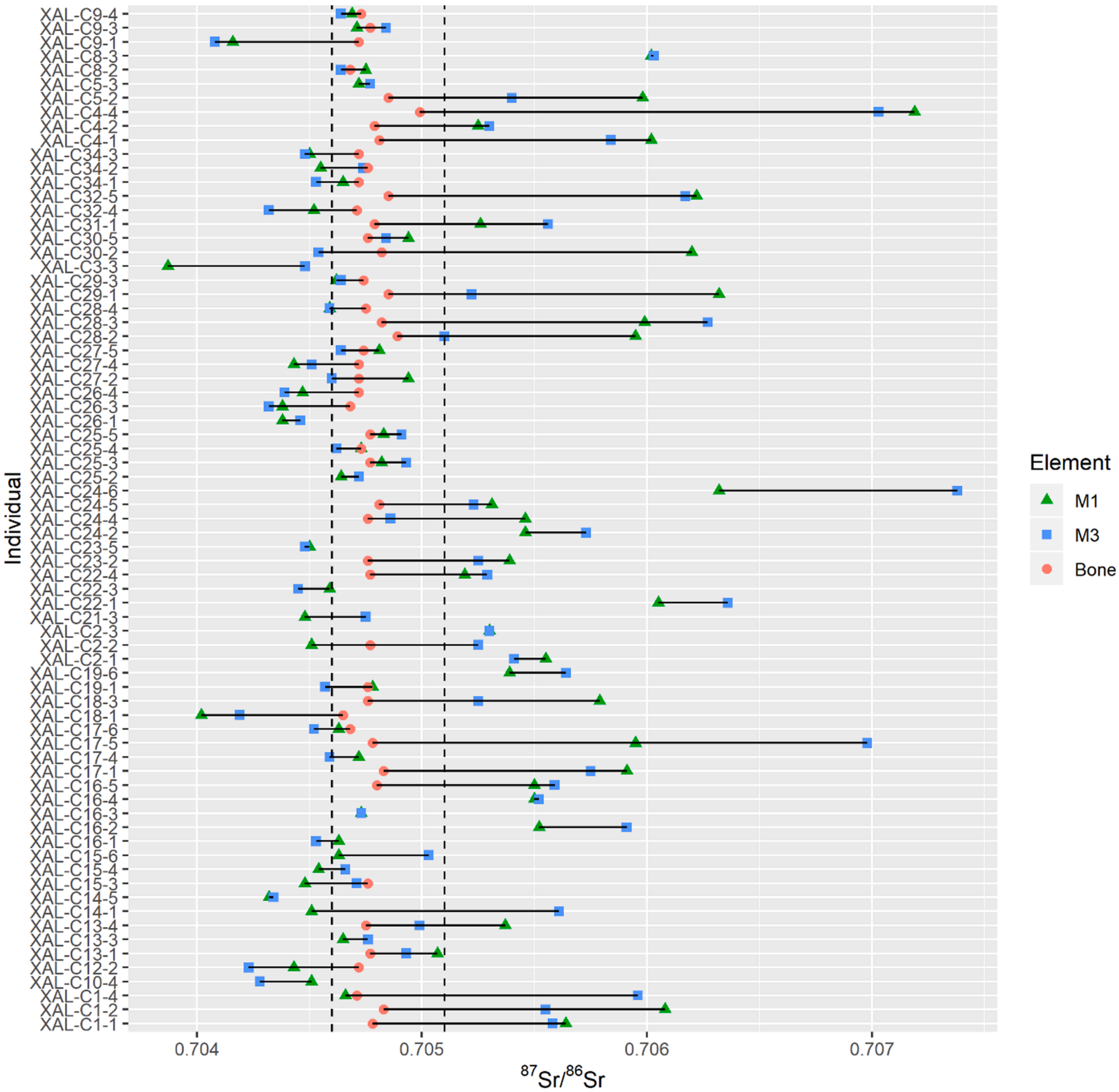

Fig. 7. Intra-individual mobility among sacrificial victims interred at Non-Grid 4 as indicated by ^{87}Sr/^{86}Sr values for each sampled skeletal element. Solid horizontal lines connect sampled skeletal elements taken from a single individual. Vertical dashed lines indicate the expected local ^{87}Sr/^{86}Sr range for the Basin of Mexico.

Table 4
Demography and inferred migratory status among sampled individuals at Non-Grid 4.

	Inferred Migratory Status[a]				
Demographic Category	Local	Circular Migrant	Emigrant	Immigrant	Foreigner
Adult Male	13	3	2	23	14
Adolescent Male	1	1	0	6	0
Adult Female	0	0	0	1	1
Adolescent Female	0	0	0	4	0
Ind. Adult[b]	0	0	0	0	1
Ind. Adolescent[b]	2	0	0	1	0
Total	16	4	2	35	16

[a] Due to advanced diagenetic alteration in bone samples, inferred migratory status designations of "immigrant" and "foreigner" are discussed in the text as migrants of non-local origin.
[b] "Ind." refers to Individuals of indeterminate sex.

CRediT authorship contribution statement

Sofía I. Pacheco-Forés: Conceptualization, Formal analysis, Investigation, Resources, Data curation, Writing - original draft, Visualization, Funding acquisition. **Christopher T. Morehart:** Resources, Writing - review & editing, Funding acquisition. **Jane E. Buikstra:** Writing - review & editing. **Gwyneth W. Gordon:** Methodology, Validation, Resources, Data curation. **Kelly J. Knudson:** Methodology, Validation, Resources, Writing - review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jaa.2020.101263.

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