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Title: Pastoralism and Emergent Complex Settlement in the Middle Bronze Age, Azerbaijan: isotopic analyses of mobility strategies in transformation.

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Burial ID*	Skeleton ID	Area	Group	Sex	Age	Sampled Elements	Burial Description
CR2	CR2.Sk1	Highland	I	U	Adult	M1 M3 (n=5) Rib	Flexed, facing CR2.Sk2. Hands placed on the face. Surrounded by bowls and large jars
CR2	CR2.Sk2	Highland	I	U	Adult	M1 M3 (n=5) Rib	Flexed, facing CR2.Sk1. Holding a neonate caprid. Surrounded by bowls and large jars
CR3	CR3.Sk1	Highland	I	U	Adult	M1 M3 (n=5) Rib	Primary interment. Individual flexed, wears a necklace and bracelet made of assorted beads, and associated with a small cache of obsidian arrows. Accompanied by caprid remains, two cattle crania, and several bowls and jars.
CR3	CR3.Sk2	Highland	I	U	Adult	M1 M3 (n=5) Rib	Secondary interment. Individual flexed and held a neonate caprid and a neonate canid. Accompanied by caprid remains, two cattle crania, and several bowls and jars.
CR3	CR3.Sk3	Highland	I	U	16-17	M1 M3 (n=5) Rib	Secondary interment. Individual flexed and wore a burnished shell possible necklace. Accompanied by caprid remains, two cattle crania, and several bowls and jars.
CR4	No Human Remains	Highland	I	-	-	-	Disturbed burial
CR6	CR6	Lowland	II	U	Adult	Femur	Individual accompanied by small collection of bowls and jars, quiver of obsidian arrows, obsidian scraper, whetstone, and bronze pin
CR7	CR7	Lowland	II	F	30-40	M1 M3 (n=5) Rib	Individual held a small jar and bowl in each hand. Accompanied by additional bowls, a quiver with multi-colored obsidian arrows, bronze pin, and spearhead
CR8	CR8	Lowland	II	M	30-40	M1 M3 (n=5) Rib	Individual wore a bib-like beaded necklace and was surrounded by a circle of stacked bowls and jars, arrows, spearhead, many bronze pins. Burial also contains a nearly complete cattle.

CR9	No Human Remains	Highland	III	-	-	-	Disturbed burial
CR11	No Human Remains	Highland	III	-	-	-	Disturbed burial
CR12	CR12	Lowland	II	U	Adult	M1 M3 (n =5) Rib	Individual was surrounded by small bowls, a jar, a cup, a groundstone, and wore a carnelian bracelet
CR13	No Human Remains	Lowland	II	-	-	-	Likely burial, but no preserved human remains
CC4	CC4	Lowland	Isolated	M	50+	I1 I2 C Rib Femur	Simple pit with no architecture and no objects. Individual's hands and feet were bound and contained charred twigs

TABLE 1 Qızqala MBA burials excavated for this study, individuals sampled for isotopic analysis, and contextual archaeological information.

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ABSTRACT

Objectives: This article explores the scale and seasonal patterns of mobility at the complex settlement site of Qızqala during the Middle Bronze Age (2400-1500 BCE). By integrating human bone, teeth, and environmental samples this research tests the hypothesis of the persistent importance of community-wide seasonal pastoral transhumance during the early formation of complex settlement systems of the South Caucasus.

Methods: This research applies stable oxygen and radiogenic strontium isotope analyses on incremental samples of human tooth enamel, bulk tooth enamel, and bone to resolve mobility patterns. Sequential and bulk sampling techniques elucidate seasonal and residential mobility behaviors. Extensive environmental isotope samples of plant and water were collected through regional survey and establish local and regional isotopic baselines, which are compared to human isotope analysis results.

Results: Qızqala individuals exhibit low isotopic variability compared to regional contemporaries. $^{87}Sr/^{86}Sr$ ratios from human remains indicate seasonal and residential isotopic variability within the baseline ranges of local landscapes. $\delta^{18}O$ values display erratic patterns, but correspond to seasonal variability with fluctuations between highland and lowland altitudinal zone baseline values.

Conclusions: Results suggest that isotopic analysis of multiple elements and sequential enamel samples offers finer resolution on the complexities of human mobility strategies and elucidate the daily lives of often overlooked mobile populations. Higher resolution of individual mobility reveals shared routine behaviors that underscore the importance of diverse social collaborations in forming complex polities in the South Caucasus.

INTRODUCTION

This study explores biogeochemical evidence for the scale and temporality of mobility at one of the earliest recorded complex polity sites in the South Caucasus. During the Late Bronze Age (LBA, *c.* 1500-1150 BCE) and Iron Age (IA, *c.* 1150-300 CE), fortified urban centers and polities dominated the highland landscapes of the South Caucasus (Ristvet, 2011; Smith, 2005, 2012). The scale and organization of walled settlements contrasted to the preceding Middle Bronze Age (MBA *c.* 2400-1500 BCE), during which a decline in the number of settlements and increased representation of *kurgan* (or mounded) burials was associated with politically fragmentary and decentralized mobile pastoralist societies (Belli & Bahşaliyev, 2001; Belli & Sevin, 1999; Hammer, 2014; Kushnareva, 1997; Özfırat, 2001).

However, emerging evidence from the few recorded MBA settlements of Qızqala, Kültepe II, and Metsamor in the Aras River Basin (**Fig.1)**, at the southern extent of the South Caucasus, has recently led archaeologists to propose that the politically complex, fortified settlements that characterized the LBA/IA originated during the MBA (Gopnik, 2016; Hammer, 2014). The development of politically complex polities during a period archaeologically characterized by widespread mobile pastoralism raises important questions about the relationship between mobility and political complexity in this region.

A long history of anthropological and archaeological scholarship has viewed mobility as socially divisive and antithetical to development of social complexity (Lattimore, 1940; Barth, 1961; Khazanov, 1984; Bates & Lees, 1977; Cribb, 1991). However, increasing research in the Eurasian steppe (Frachetti, 2009, 2012; Honeychurch, Wright, & Amartuyshin, 2009; Honeychurch, 2015; Sneath, 2007) and the Near East (McCorriston, 2013; Porter, 2012) finds that the organizational differences resulting from the mobile economies and politics of pastoral peoples gave rise to complex political relationships built on spatially distributed authority and networks extending beyond core settlement areas. Honeychurch (2014) describes these complex sociopolitical organizations among pastoral groups as "alternative complexities" that diverge from the classical Near Eastern models of complexity based on hierarchy, centralization, and sedentism. Despite recent interest in the issue, the inherent difficulty in observing mobility in the archaeological record remains an issue in detailing pastoralist practices through material culture. This research expands on these works by considering the detailed mobility practices underlying social connections evident in human skeletal remains and what implications these practices had for community identity and organization. The discovery of human skeletal remains at the early fortified complex settlement site of Qızqala presented the ideal opportunity to examine seasonal pastoral mobility practices with greater granularity and how patterns of movement influenced social organization in the Aras River Basin.

The site of Qızqala is located in the Şərur Valley of the Naxçıvan Autonomous Republic of Azerbaijan and consists of a settlement and cemetery complex. Excavations and survey identified large fortification architecture, a settlement complex, dense ceramic distributions, and an extensive cemetery dating to the MBA (Baxşəliyev, Ristvet, Gopnik, Swerida, & Nugent, 2016; Gopnik, 2016; Hammer, 2014; Proctor & Lau, 2016). The archaeologically attested dominance of mobile pastoralism in the South Caucasus during the MBA raises questions as to whether it remained a dominant practice and, if so, how it was practiced in the presence of complex settlement contexts. Based on the wider regional importance of transhumance and pastoral economy established in the archaeological scholarship of the South Caucasus, I hypothesized that individuals from Qızqala were highly mobile. This hypothesis was tested by integrating multi-element sampling of bone and teeth as well as sequential sampling of dental enamel for isotopic analyses to examine the scale and seasonal patterns of transhumance over individual lifespans at Qızqala. This analysis offers the first direct evidence for mobility strategies during the MBA South Caucasus, which reveals how movement and communal subsistence practices structured social organization in the context of emergent complexity.

Radiogenic strontium and stable oxygen isotope analyses on archaeological remains are increasingly powerful tools for illuminating the variation of human movement in the past. Radiogenic strontium and stable oxygen isotopes are incorporated in tissues through food and water consumed during tissue development. Radiogenic strontium isotope ratios ($^{87}Sr/^{86}Sr$) differ geographically according to the age and composition of bedrock geology, which reflects ratios in local soil and water through bedrock erosion (Gosz, Brookins, & Moore, 1983; Ericson, 1985; Price, Burton, & Bentley, 2002). Stable oxygen isotope values ($\delta^{18}O$) vary geographically in different water sources due to the compounded climatic factors of latitude, altitude, temperature, and precipitation patterns (Epstein & Mayeda, 1953; Dansgaard, 1964; Longinelli, 1984; Luz, Kolodny, & Horowitz, 1984; Koch, 1998; Bowen & Wilkinson, 2002). Together, strontium isotope ratios and oxygen isotope values represent independent lines of evidence for assessing palæomobility across a geologic and climatic landscape.

Isotopic analysis of multiple skeletal and dental elements for each individual (i.e. Barberena et al., 2017; Knudson, Pestle, Torres-Rouff, & Pimentel, 2012; Knudson, Stanish, Cerna, Faull, Tantaleán, 2016; Reitsema and Vercellotti, 2012; Salesse et al., 2013) makes it possible to assess the spatial scale of movement, the temporal shifts in mobility, and changes in dietary choices over individual lifetimes. This approach is based on the premise that different tissues develop at different periods in an individual's life and thus, reflect dietary isotope values over these various periods (Knudson et al., 2016). Intra-individual sampling is particularly useful for populations that may engage in more complex movement than residential mobility (also referred to as local vs nonlocal status) alone. However, the study of nomadic people, whose movement occurs over the course of weeks and months rather than years or a lifetime, requires more detailed examination of isotopic variation in mineralized tissues.

In this article, I aim to a) establish isotopic baselines for regional soils and water by integrating results from plant and water samples; b) compare isotopic baselines to human isotopic results to examine degree of seasonal and residential mobility at Qızqala and Plovdağ (a comparative cemetery population); c) explore the relationship between isotopic profiles and the organization and elaboration of funerary contexts to understand how mobility patterns correspond to social differentiation and shared elements of community identity at Qızqala.

In the discussion, I situate isotopic and archaeological data at Qızqala within the broader context of subsistence and social organization in the South Caucasus. I examine how the persistence of diminished, yet collective and regularized seasonal mobility in the context of a fortified settlement may have supported a growing community in the construction of community identity. Coordinated group movements may have stimulated shared memory and place in wider sphere beyond the “core” settlement space. I conclude with an assessment of the benefits and shortcomings of using isotopic analysis to track human mobility and behaviors using a sequential and multi-element sampling strategies.

2 BACKGROUND

2.1 Archaeology of the Aras River Basin

The South Caucasus underwent major social and economic changes at the end of the third millennium BCE. The network of Early Bronze Age (EBA) Kura-Araxes farming communities that characterized much of the region for the preceding millennium were interrupted in the MBA by the near disappearance of sustained occupation sites from the archaeological record (Kushnareva, 1997; Sagona, 2014; Kohl, 2009). The processes leading to the decline and disappearance of Kura-Araxes settlements are debated in archaeological scholarship. The predominant theories for explaining these changes are 1) the migration and arrival of new populations to the region who brought nomadic pastoralist subsistence practices as well as new traditions in burial practice and material culture (Kohl, 1992; Rothman, 2005; Kohl & Lyonnet, 2008), and 2) climate instability and aridification, which led to the abandonment of settlements relying on farming (Palumbi & Chataigner, 2014). The scarce evidence for settlement during the MBA as well as increased representation of burial sites, emergence of elaborately constructed, high-status tumuli (*kurgan*) burials, changes in ceramic traditions, and increase in metalwork has been interpreted as a wide-scale adoption of broadly defined nomadic pastoralist subsistence, but little is known about the social dynamics and domestic practices of these communities (Alizadeh, Maziar, & Mohammadi, 2018; Smith &

Rubinson, 2003; Kohl, 2009).

The most visible and well-studied features of the MBA are *kurgans*, which are large, elaborately furnished pit burials with distinctive surface mounding. *Kurgans* in the South Caucasus may be as large as 100m in diameter and contain an abundance of offerings, including ceramic vessels, bronze and lithic weaponry, jewelry, wagons, and assorted fauna. Ceramic technologies were predominantly painted red wares with a great deal of regional heterogeneity in decorative styles (Kushnareva, 1997; Özfırat, 2001). The inclusion of transportation technologies (i.e. wagons and carts) as well as herd animals in burial signifies the increased importance of mobility in daily life and funerary ritual (Smith, 2015). The close connection between these *kurgans* and pastoral subsistence is further echoed in their frequent placement in highlands that may have concurrently served as grazing pastures. The Qızqala cemetery was also situated in the hills surrounding the Şərur Valley, which likely functioned as culturally charged landscape on which residents could pass through with their herds, commune with the dead, and build a shared community identity through social memory. The increased prevalence of weaponry in burial suggests that the iconography of warfare also becomes a prominent feature of this period. However, burials are not equally ostentatious, even within communities, suggesting that individuals had differential access to wealth. This material inequality diverges from the more communal and egalitarian funerary traditions of preceding Kura-Araxes cultures (Palumbi & Chataigner, 2014).

With advancements in archaeological techniques and survey technologies, increasing evidence suggests that the region's southern zones along the Aras River supported large, organizationally complex settlements not previously evident in the wider South Caucasus region. Excavations during the 2014-2016 seasons of the Naxçıvan Archaeological Project at Qızqala have revealed houses, part of a cyclopean stone wall, and ritual spaces with figurines and burning events, all radiocarbon dated to the MBA (Baxşəliyev et al., 2016; Gopnik, 2016). Due to the heavy erosional deposits around Qızqala over the MBA levels, the exact extent of the settlement cannot presently be determined. However, survey identified dense MBA pottery scatters that span an area of approximately 8-10 hectares (Hammer, 2014). The associated cemetery space (**Fig. 2**) occupies roughly 100 hectares on the hilltops and in the valleys north of the settlement and contains at least 131 identifiable *kurgans* (Nugent, 2017). Heavy slope erosion in the Dərələyəz foothills obscures visibility of these burial structures, but the application of new ground penetrating survey approaches will likely increase this estimate significantly (Herrmann & Hammer, 2019).

In order to best represent diversity within the expansive Qızqala cemetery, three *kurgan* burial groups were excavated from each of the densely constructed sectors (**Fig. 3**). Burial Group I consisted of larger *kurgans* located along a ridge on the western hill of the cemetery. Burial Group II was an interconnected cluster of *kurgans* located in the eastern valley. Burial Group III consisted of smaller *kurgans* located at the southernmost hills of the cemetery. However, this group did not contain any preserved human skeletal remains and is not represented in this isotopic analysis. An isolated burial feature was also located outside of the cemetery and adjacent to the settlement wall. The Naxçıvan Archaeological Project excavated 11 *kurgan* features in total, described in (**Table 1)**. Seven features contained preserved human remains while the remainder were either disturbed by later human activity or damaging soil chemistry.

Qızqala is also accompanied by two likely contemporary walled settlements of Kültepe II and Metsamor in the Aras River Basin. These sites have not been conclusively radiocarbon dated, but ceramic styles appear contemporary to those found at Qızqala. Kültepe II is a tell site located approximately 50km southeast of Qızqala and occupation spans from the EBA through the MBA. The MBA settlement occupies an area of ten hectares and features domestic structures surrounded by a large stone enclosure wall (Abibullayev, 1963; Ristvet, Baxşəliyev, & Aşurov, 2011). Metsamor is located approximately 80km to the northwest of Qızqala in Armenia and emerged as a large settlement invested in the production of bronze. The settlement is surrounded by a large stone enclosure wall attributed to the later phases of the MBA and occupies an area of approximately 10.5 hectares (Khanzadian, Mkrtchian, & Parsamian, 1973). These sites do not fit the traditional characterization of politically fragmented, highly mobile pastoralist societies that have come to characterize the region during this period. On the one hand, the material culture of these settlements and associated *kurgans* closely resemble the regional repertoires of ceramics, bronzes, lithics, and beads that characterize the MBA South Caucasus (Belli & Sevin, 1999; Belli & Bahşaliyev, 2001; Kushnareva, 1997; Ristvet et al., 2011). However, these walled settlements also echo the organization and scale of complex polities that emerged in the proceeding LBA, suggesting the process of sedentarization and social cohesion may have been rooted in the social dynamics of the MBA (Hammer, 2014; Nugent, 2017).

In order to evaluate whether isotopic variance from individuals at Qızqala was meaningfully distinct from hypothesized regional patterns of seasonally recurrent transhumance, samples were also collected from the only regionally accessible MBA skeletal collection at Plovdağ, located 80 km southeast from Qızqala. Plovdağ is a multi-period site with occupation spanning from the EBA through the LBA/EIA (Halilov & Yavan, 2014; İbrahimli, 2007, 2017; İbrahimli, Qədirzadə, & Xəlilov, 2011, 2012; İbrahimov, 2005). Excavations started in 1987 and are ongoing under the direction of Bəhlul İbrahimli and Toğrul Halilov. The cemetery consists of *kurgan* burials composed of earthen pits and stone cists typically containing single individuals accompanied by burial assemblages (similar to that of Qızqala), including ceramics, beaded, jewelry, sheep/goat remains, and occasionally weaponry. Burials are demarcated by stone cromlechs between 3-5m in diameter. The cemetery is not associated with evidence for a contemporary settlement, which mirrors commonly attested ephemeral occupation practices across the South Caucasus during this period (İbrahimov, 2005). Because examining mobility at Qızqala is the primary goal of this article, and because the Plovdağ cemetery is largely unpublished, mortuary data for this site have not been presented in depth in this paper.

2.2 Geology and ecology of the Aras River Basin

The Greater Caucasus Mountains and the Aras River, flanked by the Caspian Sea to the east and Black Sea to the west, encompass the region known as the South Caucasus. The study area is located on the southwestern slopes of the Dərələyəz mountain pass in the Şərur Valley along the Arpa River in the Naxçıvan Autonomous Republic. Naxçıvan is an exclave of Azerbaijan and occupies the southernmost extent of the South Caucasus, from the southern slopes of the Lesser Caucasus Range to the banks of the Aras River.

Geology. The Aras River Basin encompasses an area of great geological diversity (**Fig. 4**). The northern highlands and southern plains of the basin form a distinct division in the geological landscape of this region, while high volcanic ridges form its eastern extent. Correspondingly, this region divides into three major morphostructural regions: (1) Middle Aras Syncline Kettle; (2) Dərələyəz-Zangezur Anticline; and (3) Ordubad Volcanic Transversal Segment. The geological diversity and distinctive regional patterning in deposits within these regions make the Aras River Basin, and Naxçıvan an ideal location for testing mobility through radiogenic strontium analyses. While each region contains complex and diverse geologies, these morphostructural zones served as a basic framework for designing a regional survey to collect environmental baseline samples, which allowed this study to further refine local strontium isotope bioavailability, which more closely reflects dietary strontium, in the local areas surrounding Qızqala.

The lowland Middle Aras Kettle reaches an average elevation of 890 meters above sea level (masl) and is formed at the convergence of the valleys and interconnected floodplains of numerous highland streams with the Aras River. This region is primarily composed of Holocene and Pleistocene alluvial-proluvial soils interspersed with Neogene hills (Bairamov et al., 2008).

The high mountains of the Dərələyəz-Zangezur Anticline form the northern edge of the basin have average elevations of 2400masl. The geology of these ranges varies across their extent from west to east. The western Sədərək-Şərur region—where Qızqala is located—consists of Devonian, Carboniferous, and Triassic sedimentary bedrock. The central Sahbuz-Babek region consists of Mesozoic, Neogene and Paleogene sedimentary bedrock. The eastern Culfa extent has Miocene and Pleistocene sedimentary deposits interspersed with igneous Eocene extrusive domes. Abutting the eastern edge of the Zangezur, the Ordubad Transversal Segment features intrusive Eocene and Oligocene volcanic ridges (Alizadeh, Güliyev, Kadirov, & Eppelbaum, 2016; Bairamov et al., 2008).

Climate and ecology. The Aras River Basin has a cold, semi-arid, steppe climate characterized by warm summers and cool winters. The mountainous northern border acts as a rain shadow diminishing precipitation in the region. Dry, warm air masses originating from semi-desert zones in the Iranian steppe also contribute to the region's aridity. The nearest major body of water to Naxçıvan is Lake Sevan, located approximately 50km to the north. It is also located approximately 400km away from the Black Sea to the west, and the Caspian Sea to the east. Precipitation is <200mm annually and occurs with the intrusion of cold air masses from the north and reaches an annual maximum during the late spring and early summer (Hüseynov & Malikov, 2009).

The Şərur Valley contains the largest agriculturally productive area in the region. Despite the abundance of highland streams, the arid climate supports otherwise scant vegetation consisting mostly of sparse shrubland punctuated by highland pastures and narrow areas of pine forest in the central highlands (Nirova, Museibova, Neremova, Nerimova, & Sulejmanova, 1975). During the summer seasons when aridity diminishes the availability of lowland vegetation, the cooler highland pastures support herds of grazing sheep, goats, and occasionally cattle. The narrow geographic focus of this study means that precipitation patterns vary negligibly across the study area. However, notable hydrological distinctions in highland versus lowland water sources arise from an altitudinal perspective, which benefit the application of stable oxygen analyses for mobility in the local landscape.

2.3 Isotope Biogeochemistry

Strontium Strontium has four naturally occurring isotopes: ^{88}Sr, ^{87}Sr, ^{86}Sr, and ^{84}Sr (Faure and Powell 1972). Analysis for geographic origins, mobility, and migration utilizes measurements of ^{87}Sr and ^{86}Sr. These isotopes in the human skeleton originally derive from soil and rocks. Variation in $^{87}Sr/^{86}Sr$ ratios in these geological sources is based on differences in mineral type and mineral age. ^{87}Sr is a radiogenic isotope created by the radioactive β-decay of rubidium (Faure, 1986). Consequently, older rocks have higher ^{87}Sr while younger rocks have lower ^{87}Sr (Bentley, 2006; Ericson, 1985; Faure, 1986). Different geographic regions are characterized by distinct strontium isotopic ratios due to geological variations in the types and ages of minerals present in the local environment (Bentley, 2006; Price et al., 2002).

However, the integration of strontium in the human skeleton does not take a direct path from earth to bone. Instead, it is a complex system under the influence of biocultural factors related to diet and skeletal biology. Strontium ($^{87}Sr/^{86}Sr$) isotopes are incorporated from rocks and soil into local water through the weathering of bedrock and are reflected in the local trophic system when consumed by plants and animals (Bentley, 2006; Ericson, 1985; Faure, 1986). Since strontium has a large atomic mass, it does not fractionate and maintains the same ratio as it passes from bedrock through the ecosystem (Clauer & Chaudhuri, 1992; Copeland et al., 2011). However, a geological zone, and even a given rock may be composed of many types of minerals with various $^{87}Sr/^{86}Sr$ ratios. Weathering of bedrock may distribute minerals through the local environment in unpredictable patterns, causing an averaging effect in the soil, which is reflected in the local plant and faunal life (Price et al., 2002). Therefore, local bedrock alone is not an accurate predictor of ratios for the local food chain. For this reason, local $^{87}Sr/^{86}Sr$ ratios and how they are represented in the human skeleton are best represented through an assessment of biologically, rather than geologically available strontium.

Bioavailable strontium is used to assess whether humans are local or non-local by comparison to the strontium ratios of local plants and fauna. Plant metabolism averages strontium ratios of the soil, groundwater, and precipitation in which it grows (Bentley, 2006).

A single plant may not represent the average ratio of a geographic area, but a series of plants reflect extent of local strontium isotopic variation. Fauna reflect ratios of a broader geographic scope than plants (Sealy, van der Merwe, Sillen, Kruger, & Krueger, 1991; Sillen, Hall, Richardson, & Armstrong, 1998). Sampling fauna thus offers the opportunity to collect fewer environmental samples in a given environment. However, the ranging behaviors of fauna may also mask local-scale isotopic variation across pasturing lands. Fauna that consume resources over a wider local environment, may consume food and water over potentially different geological zones, make local bioavailable strontium baselines appear more homogenous. Similarly, a geographically wide pasturing area may not necessarily correspond to the cultural boundaries in the landscape, because herds may consume plants outside of the designated "local" area. Due to the interest in scales of mobility, local and regional isotopic variations are critical considerations and were preferable for the purposes of this study.

Oxygen Oxygen has three naturally occurring isotopes:^{18}O, ^{17}O, and ^{16}O. Isotopic assessment of mobility investigates the relationship of ^{18}O to ^{16}O in the following notation: $^{18}O/^{16}O$, or $\delta^{18}O$ (Luz et al., 1984). While strontium reflects mobility in relation to the geographic location of certain geologies, oxygen reflects mobility in relation to geographic location of consumed water sources (Luz et al., 1984; Luz & Kolodny, 1985; Knudson & Price, 2007). These water sources may include precipitation, groundwater, rivers, and lakes (Dansgaard, 1964).

The value of $\delta^{18}O$ in water sources varies by the process of fractionation. Fractionation in oxygen is influenced by altitude, temperature, and distance from large bodies of water (Epstein & Mayeda, 1953; Dansgaard, 1964; Longinelli, 1984; Luz et al., 1984; Koch, 1998; Bowen & Wilkinson, 2002). In higher temperatures, water undergoes the process of evaporation in which ^{16}O preferentially evaporates due to its lighter mass. This results in enriched ^{18}O, and thus a more positive $\delta^{18}O$ value. Similarly, in cooling, and the process of condensation, which leads to precipitation, the heavier mass of ^{18}O causes it to be preferentially removed compared to lighter ^{16}O, resulting in a lower $\delta^{18}O$ value. With each precipitation event, the vapor cloud travels further away from the body of water from which it was formed and has lower $\delta^{18}O$ values, accounting for differences due to distance from coastlines. Finally, higher altitude conditions, also referred to the orographic effect, also produces lower $\delta^{18}O$ values of precipitation due to cooler temperatures as elevation increases (Dansgaard, 1964).

However, cultural factors of how humans treat and consume water create potential complications in oxygen isotopic analyses that alter the values of natural water sources. That is, water stored in vessels and cisterns may mimic the fractionation processes resulting from evaporation in standing water, resulting in lower values (Cappa, Hendricks, DePaolo, & Cohen, 2003; Luz, Barkan, Yam, & Shemesh 2009). Hydrological infrastructure such as damming, irrigation channeling, and aqueducts manipulate natural water sources such that they arrive from longer distances and similarly undergo evaporation processes that may appear isotopically different than natural bodies of water. Consumption of prepared beverages, such as alcohol, or cooked liquids and foods, also results in lower oxygen values (Brettell, Montgomery, & Evans, 2012; Daux et al., 2008; Royer, Daux, Fourel, & Lecuver, 2017). For this reason, it is critical to consider oxygen in relation to strontium values to gauge the influence of natural and anthropogenic water and thus attempt to distinguish mobility from cultural influences on local water consumption practices.

Multi-element and Sequential Isotope Analysis Bone hydroxyapatite remodels continuously throughout life. Trabecular bone and skeletal elements with abundant trabecular tissue, such as ribs, remodel rapidly while dense cortical bone, such as the diaphysis of a femur, remodels slowly (Mulhern & Van Gerven, 1997; Teitelbaum, 2000). Depending on the skeletal element, bone undergoes complete replacement roughly every 7 to 20 years (Lowenstam & Weiner, 1989; Hill, 1998). Sampling bone for isotopic analysis therefore allows evaluation of residence and diet in the final decades before death.

Dental enamel develops in a multi-stage process during a defined period in life and does not remodel thereafter (Kohn, Schoeninger, & Valley, 1998). Samples for this study were taken from first, second, and third left, mandibular molars. Because teeth are highly mineralized, they are minimally affected diagenetically by environment or diet compared to other tissues (Al Qahtani, Hector,, & Liversidge, 2014). Dental enamel also forms at known developmental stages in an individual’s life. The precise timing of enamel variation formation may be somewhat affected by population variation, but this study does not operate at this level of precision. In humans, the enamel of the first molar initiates development around the time of birth and the crown is completed around 3 years of age. The enamel of the second molar initiates development at approximately 3 years of age and the crown is complete by approximately 6 years of age. Finally, the third molar enamel commences development at approximately 8 years of age and crown completes by approximately 11 years of age (Reid & Dean, 2006).

Dental enamel formation, or amelogenesis, occurs incrementally in appositional and imbricational arrangement. Mineralization of the enamel commences at the tooth apex where hydroxyapatite crystals are deposited in approximately 24-hour increments in enamel prisms (or rods) oriented perpendicular to the enamo-dentine junction (EDJ) (Boyde, 1967). Each layer is completely mineralized within a week on average. After maturation, each successive layer is deposited appositionally from apex to cervix, forming layered structures called striae of Retzius (Ramirez Rozzi, 1994). Extensive isotopic research (see Balasse, 2002; Zazzo, Bendrey, Vella, Moloney, Monahan, & Schmidt, 2012; Blumenthal et al., 2014; Towers, Gledhill, Bond, & Montgomery, 2014; Chase, Meiggs, Ajithprasad, & Slater, 2014; Krzemińska, Sołtysiak, & Czupyt, 2017; Makarewicz, Arbuckle, & Öztan, 2017; Makarewicz, Pederzani, & Hermes, 2017; Makarewicz and Pederzani, 2017; Meiggs, 2007; Price, Meiggs, Weber & Pike-Tay, 2017) indicates that the isotopic composition of mammalian dental enamel reflects diet over the course of amelogenesis, but there is some time-averaging effect. While evidence suggests a chronological sequence is respected along the growth axis of the enamel, delay in maturation, mixing of water sources, and body water reservoir may introduce bias that has been shown to attenuate, or dampen values (Balasse, 2003). For this reason, this study does not treat individual sequential samples as discrete chronological periods.

3 MATERIALS AND METHODS

3.1 Sample selection

Regional isotopic baselines were established from 37 plant and 36 water samples collected from the distinct geological and altitudinal zones in Naxçıvan. Results from the analysis of these samples were the basis for evaluating mobility on 299 human bone and teeth samples from 22 individuals to assess their isotopic patterns over different developmental periods in individual lifetimes.

Environmental Samples Plant and water samples were collected during geological survey of Naxçıvan using a selective sampling strategy. Based on the geological map produced by Bairamov et al. (2008), I selected sampling areas within each distinct bedrock geology and at each altitudinal zone. In order to maintain consistency across vegetation zones, plant samples consisted primarily of common, small varieties of sage-brush with shallow-moderate rooting depth similar to the rooting systems of crops consumed by humans.

Water samples were collected from rivers, springs, and wells following methods established by Grimstead, Nugent, & Whipple (2017). Caution was taken to sample from sources that had minimal to no visible anthropogenic contamination from agricultural, industrial, or human waste pollutants. Sources where potential contamination was suspected due to visual assessment of the water and surrounding contexts were noted. Results were compared to estimated modern annual $\delta^{18}O_{mw}$ values using the Waterisotopes Database to account for seasonal variations not captured by the timing of sample collection (Bowen 2018). The nearest station from which the modeled data was estimated was the Dalbahçe GNIP, located roughly 100km west in Turkey.

Human Remains Samples Human skeletal remains were sampled from the Qızqala cemetery excavation collection (n=10) as well as a comparison collection from the nearby, contemporary cemetery at Plovdağ (n=12).

For each individual, three elements produced during different developmental periods were collected: (1) first mandibular molar (M1), (2) third mandibular molar (M3), and (3) Rib (or femur). An exception was CC4, a mostly edentulous individual. For this case, I bulk-sampled a rib, femur, first mandibular incisor (I1), second mandibular incisor (I2), and mandibular canine (C). The dentition sampled from this individual represents in-utero enamel mineralization, and serve as a proxy for movement of the mother and child (Hillson, 1996).

Following analysis, all samples were returned and reaccessioned into the Naxçıvan Archaeological Project excavation storeroom in Naxçıvan, Azerbaijan. These samples, as well as all excavated skeletal remains, will be permanently stored in the archives of the National Academy of Sciences branch in Naxçıvan City with access permission provided by Veli Bakhshaliyev, directors of the Naxçıvan Archaeological Project, and myself.

3.2 Methods

Environmental Samples Plant samples were processed at the Archaeological Isotope Laboratory at The Ohio State University and the Archaeological Chemistry Laboratory at Arizona State University. Leaves were air-dried and brushed of any adhering soil and removed from the stem for preparation. Approximately 10g of leaves were trimmed from the stems ashed at 800˚C for 12 hours in ceramic crucibles and 4-6mg of resulting ash were transferred to 1.5mL centrifuge tubes. Ashed samples were dissolved in 0.5mL twice distilled 5M nitric acid (HNO_3) until the powder completely dissolved.

Sample preparation for radiogenic strontium analysis took place at the W.M. Keck Foundation Laboratory for Environmental Biogeochemistry Clean Laboratory, Arizona State University. Strontium was chemically separated from the sample following protocol established by Knudson & Price (2007) and analyzed using a Thermo Electron Neptune Multi-Collector Inductively Coupled Plasma Mass Spectrometer (MC-ICP-MS). Instrumental error was tested with carbonate standard SRM-987. Analyses of strontium carbonate standard SRM-987 yielded a value of $^{87}Sr/^{86}Sr = 0.710255 \pm 0.000001$ (2σ, n = 72), which agrees with analyses of SRM-987 using a thermal ionization mass spectrometer, where $^{87}Sr/^{86}Sr = 0.710263 \pm 0.000016$ (2σ), as well as analyses using an identical MC-ICP-MS, where $^{87}Sr/^{86}Sr = 0.710251 \pm 0.000006$ (2σ) (Stein et al., 1997).

Water samples were collected in 50ml vials sealed with Teflon and electrical tape following protocol by Grimstead et al. (2017). Vials were centrifuged to separate suspended particulates and supernatant water was pipetted into to 5ml vials. These were then analyzed in a Picarro L1102-i liquid water isotope analyzer at the Environmental Geochemistry Laboratory, The Ohio State University. Calibration was performed using internal laboratory standards consisting of deionized water aliquots from Florida ($\delta^{18}O$ = -2.3‰), Ohio ($\delta^{18}O$ = -9.3‰), Nevada ($\delta^{18}O$ = -14.2‰) and Colorado ($\delta^{18}O$ = -17.0‰). Standards were standardized relative to Standard Light Antarctic Precipitation (SLAP) and Vienna Standard Mean Ocean Water (VSMOW) using standard gas-source mass spectrometry techniques. Correction of the potential influence of the memory effect was applied using memory coefficients derived from reference waters used to normalize to VSMOW/SLAP. Isotopic values are presented as per mil (‰) values. Accuracy was ≤2.5% for $\delta^{18}O$, calculated by relative standard error comparing the Picarro measurement of an internal laboratory standard and the Ice Core Paleoclimatology Laboratory isotopic measurement of this standard. Precision was calculated as ≤0.02% for $\delta^{18}O$ using relative standard deviation.

Human Remains Samples Human bone and enamel samples were processed at the Archaeological Isotope Laboratory at The Ohio State University and the Archaeological Chemistry Laboratory at Arizona State University. The outermost layer of teeth was abraded to remove possible diagenetic layers from contact with soil. Cortical bone was isolated by removing trabecular bone and the outermost layer of bone was abraded as well. Bone and enamel for bulk-sampled teeth was sampled using a 0.5mm tungsten-carbide cylinder burr. Sequentially sampled enamel was drilled using a 0.4mm diamond-tipped burr on a micromill with microscope attachment at 30x magnification. A low rotation speed was preferred to increase precision and limit overheating. Each molar was drilled on the buccal face, which has thicker enamel (Smith, Olejniczak, Reid, Ferrell, & Hublin, 2006). Drilling commenced at the cervix and a small horizontal line was abraded on an oblique angle to the enamel-dentine junction until approximately 2mg was collected. Subsequent samples were collected by proceeding to the apex at successively wider angles, following the incremental pattern of the lines of Retzius. Depending on the height of the molar, between five and seven samples were collected along the growth axis, each corresponding to roughly three to four months of enamel mineralization (Reid & Dean, 2006), the period of roughly a season.

For radiogenic strontium analysis, bone and enamel samples were processed following standard procedures for isotope analysis of dental enamel samples (Knudson & Price, 2007). Samples were analyzed with the Thermo Electron Neptune MC-ICP-MS. Instrumental error was tested using the same carbonate standard SRM-987 as previously discussed environment samples, which was measured to be 0.710255 ± 0.000019 (2σ, n=72).

Sample elemental concentrations to assess diagenesis were analyzed with a Thermo Scientific iCAP Quadrupole ICPMS. Four standard solutions with known elemental concentrations including cow bone ash, llama bone ash, calibration solution, and blanks were also analyzed as controls. In ash from modern bone, the Ca/P ratio is approximately 2.0–2.3 (Knudson & Price 2007; Price, 1989; Sillen, 1989; Truman & Tuross, 2002). Bone and enamel samples had a range of Ca/P= 1.9-2.8 with mean Ca/P=2.2 ± 0.2. Most bone samples had elevated values suggesting diagenesis. These samples were not included in analysis, but are detailed in Supplementary Data. Overall, dental enamel samples for Qızqala and Plovdağ were consistent with minimal diagenetic contamination.

For stable oxygen analysis of bone and enamel carbonate, samples were prepared following published methods in Koch, Tuross, & Fogel (1997). Bone and enamel carbonate sample preparation for stable oxygen analysis took place at the Environmental Isotope Laboratory at the University of Arizona. Samples were measured on an automated carbonate preparation device (KIEL-III) coupled to a gas-ratio mass spectrometer (Finnigan MAT 252). Oxygen isotope values ($\delta^{18}O$) were first expressed in delta notation (δ) and per mil (‰) units relative to the international carbonate reference standard VPDB (Vienna Pee Dee Belemnite). Reproducibility for $\delta^{18}O$ was ±0.1‰.

Standard conversion equations (Coplen, Kendall, & Hopper, 1983; Iacumin, Bocherens, Mariotti, & Longinelli, 1996; Luz et al., 1984) were used to convert enamel $\delta^{18}O_{c(VPDB)}$ values to $\delta^{18}O_{dw(VSMOW)}$ values in order to compare results to local water values. While recent investigations (Chenery, Pashley, Lamb, Sloane, & Evans, 2012; Pollard, Pellegrini, & Lee-Thorp, 2011) have revealed considerable error (±1.0‰, 2σ and ±1%, 95%CI, respectively) in calibration while performing conversion, there are not sufficient local $\delta^{18}O_{c(VPDB)}$ comparison datasets to generate accurate local oxygen isotope baselines based on archaeological enamel. Therefore, converted $\delta^{18}O_{dw(VSMOW)}$ values were presented as a guide that allowed for cautious comparison to locally bioavailable water sources. Both $\delta^{18}O_{c(VPDB)}$ and $\delta^{18}O_{dw(VSMOW)}$ results are included in Supplementary Data.

Statistical Analysis Statistical Package for Social Sciences (SPSS) version 25 was used to perform statistical computations. Nonparametric Mann-Whitney U and Kruskall-Wallis tests were applied to compare the distribution of values between individuals at Qızqala and Plovdağ as well as between burial groups at Qızqala. These tests determine whether two (Mann-Whitney U) or more (Kruskall-Wallis) independent sample groups have similar distributions. Bootstrapping analyses with a simulation of 10,000 at a 0.05 significance level were also applied to randomly rearrange data to test whether samples differed when assigned to different sites/burial groups.

4 RESULTS

4.1 Bioavailable strontium and oxygen isotopes

Strontium The Şərur region, which encompasses the Qızqala site exhibited two distinct areas of strontium bioavailability. The lowlands to the south of the Qızqala settlement area had high radiogenic strontium isotope ratios, with mean $^{87}Sr/^{86}Sr = 0.70782 \pm 0.00020$ (1σ, n=5). By contrast, the Şərur Highlands had lower ratios with mean $^{87}Sr/^{86}Sr = 0.70714 \pm 0.00053$ (1σ, n=3) (**Fig. 5**).

Analysis of plants for radiogenic strontium isotope ratios beyond the Şərur region reflected the wide geological diversity of the Aras River Basin. As evident in published geological references, each of the morphostructural zones in Naxçıvan contained a variety of bedrock geologies, which was reflected in the wide dispersion of ratios within each zone. The Dərələyəz-Zangezur Anticline exhibited a wide range of ratios across its extent. The Dərələyəz range was characterized by higher radiogenic strontium isotope ratios with mean $^{87}Sr/^{86}Sr$ = 0.70747 ± 0.00085 (1σ, n=6). This corresponds to the older formation times of the Devonian and Carboniferous bedrock with younger Triassic geology at its eastern extent. The Zangezur range overlapped with these higher ranges in western Mesozoic extent, but exhibited lower Paleogene and Neogene formations to the east with mean $^{87}Sr/^{86}Sr$ = 0.70711 ± 0.00060 (1σ, n=10). The most recent geological formations in the volcanic features of the Ordubad Transect corresponded to the lowest radiogenic strontium isotope ratios with mean $^{87}Sr/^{86}Sr$ = 0.70582 ± 0.00040 (1σ, n=5). As a basin that accumulates erosional soils from the surrounding mountains and the tilling force of the Aras River, the Middle Aras Kettle had intermediary ratios between the other morphostructural zones with mean $^{87}Sr/^{86}Sr$ = 0.70752 ± 0.00034 (1σ, n=8).

Oxygen Analysis of water samples produced a negative correlation (R^2= 0.9, p= 0.05 ; n=23) between the altitude of water sources and $\delta^{18}O_{w(VSMOW)}$ (**Fig. 6**). This pattern was consistent across all types of sources. Stable oxygen isotope values ranged from -12.1‰ at highest altitude zone to -8.1‰ in the lowland plains. The Şərur region had mean $\delta^{18}O_{w(VSMOW)}$ values of -8.8 ± 0.5‰ (1σ) to in the valley and -10.6 ± 0.8‰ (1σ) in the highlands. Water samples suspected of anthropogenic contamination by agricultural/industrial runoff or human waste prior to collection tended to skew more negative and weakened the correlation.

To supplement results from water samples with modern seasonal precipitation fluctuations, modern stable water isotope prediction models estimate this region has $\delta^{18}O_{mw}$ values have annual fluctuations between -15‰ (winter) and -2‰ (summer) at the minimum elevation (600m) and between -18‰ (winter) and -4‰ (summer) at the maximum elevation (2300m) (Bowen, 2018; Bowen, Wassenaar, & Hobson, 2005; IAEA/WMO 2015).

4.2 Strontium isotope ratios and oxygen isotope values from human bone and teeth

All isotopic and statistical results for Qızqala and Plovdağ are presented in **Figure 7** and Table 2.

Qızqala. The human dental enamel and bone bulk samples from the Qızqala individuals had an $^{87}Sr/^{86}Sr$ range of 0.70660-0.70767 (mean=0.70741 ± 0.00025, 1σ, n=19) and $\delta^{18}O_{dw(VSMOW)}$ range of -12.2‰ to -4.2‰ (mean=-8.6 ± 2.2‰, 1σ, n=19). Looking at the M3 sequence for each individual (**Fig. 8**), all individuals from Qızqala had an $^{87}Sr/^{86}Sr$ range of 0.70727-0.70765 (mean=0.70747 ± 0.00011, 1σ, n=32). and $\delta^{18}O_{dw(VSMOW)}$ range of -14.8‰ to -2.5‰ (mean=-8.6 ± 2.6‰, 1σ, n=42).

Examining the isotopic results by burial group and individual, the Qızqala individuals had diverse radiogenic strontium ratios and stable oxygen values both within and between individuals.

Burial Group I. In examining each individual in Burial Group I, Individual CR2.Sk1 exhibited little variability in strontium isotope ratios across all sampled elements that were similar to local highland ratios (**Fig. 8b).** However, they had greater variability in oxygen isotope values with elevated values at the beginning and end of life while the M3 series has two fluctuations between values similar to that of highland zones. CR2.Sk2 also had low diversity in strontium isotope ratios across all sampled elements, corresponding to local highland ratios (**Fig. 8c)**. Oxygen isotope values showed greater variability in the M3 series with two fluctuations between ^{18}O-depleted and -enriched values. CR3.Sk1 had low strontium isotope ratios at birth, which fell outside local bioavailability ranges as well as elevated oxygen isotope values (**Fig. 8d)**. Over the course of the M3 series, CR3.Sk1's strontium isotope ratios changed from resembling non-local ranges to reflecting ratios within the local environment at Qızqala. Oxygen isotope values exhibited two fluctuations between ^{18}O-enriched and -depleted. During the final decade of life, this individual had strontium isotope ratios within the local lowland ranges and moderately enriched oxygen isotope values. Similarly, CR3.Sk2 began life with non-local strontium isotope ratios and lower oxygen isotope values (**Fig. 8e)**. Both strontium isotope ratios and oxygen isotope values reflected fluctuations over the M3 series, while strontium isotope ratios remained within non-local ranges. However, the final decade of life for this individual exhibits strontium ratios within local highland ranges with moderately lower oxygen isotope values. Unlike the others in burial CR3, Sk3 had strontium isotope ratios within local highland ranges and lower oxygen isotope values (**Fig. 8f)**. Over the M3 series, this individual's strontium isotope ratios fluctuated between local highland and non-local ranges with two fluctuations in oxygen isotope values. This individual's bone samples fell within local isotopic ranges.

Burial Group II. CR6, who had no preserved dentition, had femoral shaft ratios within local bioavailability ranges for strontium and oxygen. The female adult in CR7 had higher strontium isotope ratios and elevated oxygen isotope values at the beginning and last decade of life that fell within local lowland ranges (**Fig. 8g)**. Over the sequential series, values fluctuated twice between highland and lowland ranges. Similarly, the adult male in CR8 exhibited strontium isotope ratios and oxygen isotope values corresponding to local lowland values at the beginning and last decade of life (**Fig. 8h)**. During sequential series, strontium ratios and oxygen values fluctuated twice between lowland and highland ranges. CR12 exhibited minimal isotopic variation over all elements and the M3 sampling series with values within local lowland ranges (**Fig. 8a)**.

The individual from the isolated CC4 burial had the lowest radiogenic strontium isotope ratios of all individuals analyzed at Qızqala with a range of 0.70660-0.70679 (mean=0.70672 ± 0.00007, 1σ, n=5). All values were similar across the sampled elements (femoral shaft, rib shaft, I1, I2, and C) and fell outside the local range, more closely resembling younger geologies in regions further north in the South Caucasus, but not represented in the Şərur region. CC4 had mean $\delta^{18}O_{dw(VSMOW)}$ values ranging from -10.8‰ to -7.9‰ (mean=-8.8± 1.0‰, 1σ, n=5).

Burial group comparison. Burial Group I yielded lower $^{87}Sr/^{86}Sr$ ratios and larger standard deviation for bulk samples compared to Group II with a range of 0.70721-0.70756 (mean=0.70741 ± 0.00010, 1σ, n=8). The Group I M3 sequence also exhibits lower ratios relative to Group II with a range of 0.70721-0.70750 (mean=0.70738 ± 0.00010, 1σ, n=17). Bulk and sequential $\delta^{18}O_{dw(VSMOW)}$ values were elevated relative to Group II with a range of -14.8‰ to -2.5‰ (mean=-8.3 ± 2.4‰, 1σ, n=8) and -14.8‰ to -2.5‰ (mean=-8.3 ± 2.7‰, 1σ, n=27), respectively. Burial Group II had higher bulk bone and enamel $^{87}Sr/^{86}Sr$ ratios compared to Group I with a range of 0.70756-0.70767 (mean=0.70761 ± 0.00003, 1σ, n=6). The M3 series also presented higher ratios compared to Group I with a range of 0.70745-0.70765 (mean=0.70756 ± 0.00005, 1σ, n=15) relative to Group 1. Bulk bone and enamel $\delta^{18}O_{dw(VSMOW)}$ values were lower with a range of -12.2‰to -4.3‰ (mean=-9.0 ± 3.3‰, 1σ, n=6). The M3 sequence had a range of -11.6‰ to -4.6‰ (mean=-9.3 ± 2.3‰, 1σ, n=15), respectively.

The distribution of $^{87}Sr/^{86}Sr$ results from the Qızqala sample were statistically different across burial groups for bulk bone (rib and femur) and dental samples (M1) representing residential mobility (Kruskall-Wallis, P=0.001, n=19). The distribution of $^{87}Sr/^{86}Sr$ results from the M3 series was not statistically different (Mann-Whitney U, P=0.216, U=246, n=32). There was also no significant difference in the distribution of $\delta^{18}O_{dw(VSMOW)}$ values for bulk sampled elements (Kruskall-Wallis, P=0.681, n=19), as well as across the M3 series (Mann-Whitney U, P=0.131, U=145, n=42).

Plovdağ The Plovdağ sample exhibited a bulk bone and enamel $^{87}Sr/^{86}Sr$ range of 0.70672-0.70814 (mean=0.70749 ± 0.00028, 1σ, n=16) and $\delta^{18}O_{dw(VSMOW)}$ range of -13.6‰ to -4.8‰ (mean= -8.1 ± 2.1‰, 1σ, n=16) for all elements. The Plovdağ sequential M3 samples **(Fig. 9)** had an $^{87}Sr/^{86}Sr$ range of 0.70672-0.70775 (mean = 0.70747 ± 0.00027, 1σ, n=56) and $\delta^{18}O_{dw(VSMOW)}$ range of -16.3‰ to -2.3‰ (mean=-8.5 ± 2.5‰, 1σ, n=57).

The distribution of $^{87}Sr/^{86}Sr$ results from the Qızqala population was significantly narrower than the Plovdağ population across both bulk and sequential samples. Bulk bone and M1 samples, which measure residential mobility (Kruskall-Wallis, P= 0.012, n=36), and sequential M3 samples, which measure seasonal mobility (Kruskall-Wallis, P= 0.028, n=87), were significantly less variable than among individuals from Plovdağ. There was no significant difference in the distribution of $\delta^{18}O_{dw(VSMOW)}$ values for bulk sampled elements (Kruskall-Wallis, P= 0.274, n=36), and the M3 series (Kruskall-Wallis, P= 0.823, n=100).

5 DISCUSSION

5.1 Establishing Multilayered Regional Bioavailability

The isotopic results from environmental samples collected in Naxçıvan mirrored the geological and altitudinal diversity of this region. Radiogenic strontium isotope bioavailability exhibited a wide range of ratios across the territory as well as within morphostructural zones.

Bioavailability studies in neighboring regions reveal similarly complex geology over relatively small areas (Chazin, 2017; Chazin, Gordon, & Knudson, 2019; Marshall, 2014). By focusing on localized sub-regional patterns in the Şərur Valley it was possible to distinguish between the lower strontium ratios from the highland soils and higher ratios from the lowland soils. However, the mixed and churned nature of alluvial-pluvial soils in the river basin produced isotopic uniformity over large areas, which complicated distinguishing between different lowland zones along the Aras River. Increasingly collaborative bioavailability datasets across transnational borders and predictive modeling of erosion will be required to improve resolution in the Aras River Basin for future studies in this region.

The strong negative correlation (R^2= 0.9, p= 0.05 ; n=23) between oxygen isotope values and elevation across Naxçıvan suggested that stable oxygen isotope analysis may be a useful tool for differentiating water sources by altitude. Human oxygen isotope values were occasionally elevated as well as more ^{18}O-depleted than regional baselines established by this study. Because water samples were collected during a single season, they did not account for seasonal fluctuations in oxygen isotope values due to temperature and precipitation changes, which may account for these results. Supplemental comparison to estimated modern annual $\delta^{18}O_{mw}$ values using the Waterisotopes Database, which modeled predicted minimum and maximum values for the Şərur region, accounted for some human values that were outside of the collected water range. This may suggest that seasonal fluctuations in bioavailable stable oxygen may influence human oxygen values. Unfortunately, it is difficult to account for additional anthropogenic influences on dietary water such as boiling, stored or otherwise processed liquids, processes which preferentially deplete ^{16}O resulting in elevated $\delta^{18}O_{dw(VSMOW)}$ values (Brettell et al., 2012). It is not possible to differentiate these complex climatic and anthropogenic influences on isotopic values with the resolution and scope of this study.

It is also important to note that it is inherently problematic to define past isotopic baselines using modern hydrological resources. Future goals of this will work will aim to pursue collaborations aimed at integrating paleoclimatic models for establishing local isotopic baselines for archaeological populations.

5.2 Assessing the Scale and Temporality of Mobility at Qızqala

Setting aside the less common architectural features of Qızqala, the funerary, ceramic, metallurgical, lithic, and ornamentation traditions represented at Qızqala closely overlap with the broader cultural sphere in the South Caucasus. These features and traditions have been overwhelmingly associated with the practice of mobile pastoralism in this region. The ritual and aesthetic similarities would predict that the people of Qızqala may have also had similar subsistence behaviors as their regional neighbors characterized by high isotopic variability corresponding to seasonally recurrent movement.

However, strontium isotope ratios from Qızqala were significantly less variable when compared to contemporaneous individuals from Plovdağ. Most isotopic ratios from the Qızqala sample fell within the local (both lowland and highland) strontium isotope baseline ranges while individuals from Plovdağ more regularly exhibited ratios outside of the surrounding geologies of the Gilançay Valley. Strontium isotope ratio variability at Qızqala diminishes further if CC4, a likely non-local individual, is excluded from the sample.

Individuals from both Qızqala and Plovdağ shared a similar mean and degree of variation in $\delta^{18}O_{dw(VSMOW)}$ values. The lack of correspondence with strontium isotope ratios highlighted the importance of treating stable oxygen isotope values with caution when interpreting geographic origins. Stable oxygen isotope values are a proxy for climatic and dietary factors, which do not necessarily overlap with discrete geographic localities. The close similarity in climate and altitude between these two sites may be explained by similar distributions of bioavailable $\delta^{18}O$ values in local water sources. For this reason, oxygen isotope values add vertical dimensionality to the landscape, which is a critical consideration in mountainous regions like the South Caucasus.

Results suggested that individuals at Qızqala had more locally constrained movements during the developmental periods represented by the sampled elements. However, it is also important not to exclude other possible factors, which complicate the interpretation of results from isotopic analysis. For example, individuals may have acquired isotopic ratios resembling the local Qızqala environment from other geologically similar areas as well. The local isotopic ratios of the Şərur region are not unique to this area alone. The stylistic and technological characteristics of material objects from Qızqala closely correspond to cultural traditions found across the South Caucasus to the north and west of this site, suggesting a consistent level of interaction or communication that may have been facilitated by movement. It is possible, this potential movement may be masked by similarities environmental isotope values in other regions. Moreover, the circulation and transportation of food and drink from non-local areas may also have an impact on isotopic values.

Given the small number of individuals in this study, it was not possible to conclusively state that the Qızqala population overall was less mobile compared to regional counterparts. However, these results revealed the first direct evidence for the diverse mobility strategies employed by MBA peoples heretofore invisible in the archaeological record of the region. Expanding the sample size regionally will be an area for development as archaeological human skeletal collections in Azerbaijan continue to grow.

In addition to the scale of movement, the seasonality of mobility is a fundamental aspect of pastoral transhumance. The fluctuations in strontium isotope ratios and oxygen isotope values across the M3 sampling series were interpreted as seasonal isotopic changes occurring at three to four-month increments. Specifying the season represented by each sample was not presently possible. Traditionally, zooarchaeological isotopic studies employing sequential sampling strategies rely on seasonal fluctuations in $\delta^{18}O$ precipitation reflected in enamel by consumption during grazing (see Balasse, 2002; Bernard et al., 2009; Britton, Grimes, Dau, & Richards, 2009; Julien et al., 2012). However, human water consumption is less directly influenced by precipitation because humans predominantly access water from natural bodies (i.e. rivers, lakes, springs), groundwater through wells, and as processed liquids (i.e. boiled food, beer, wine, milk, etc.). Correspondingly, $\delta^{18}O$ values of the individuals from Qızqala exhibit a more erratic pattern over the course of the intra-tooth series than would be expected of a seasonal curve.

Current ecology and pastoralist practices in the region offer clues to explain isotopic fluctuations over the M3 series. During dry summer months, the warmer lowland environments of the Şərur Valley are depleted of vegetation, and present-day cattle, sheep, and goat herders take their animals to graze in the cooler and more verdant highland pastures in the surrounding foothills and mountains. Based on personal observation in the field, many modern-day herders of the valley make this journey on a daily basis, while a few spend weeks away from the village. The historical record supports a similar, yet inverted pattern during the second millennium BCE in neighboring Mesopotamia where during the arid summer, herds rotated in the pastures of fertile river valleys surrounding villages and cities. During the cooler months of depleted vegetation, herds had access to highland pastures in the steppes (Cribb, 2004; Szuchman, 2009).

Experiences with Mobility and Patterns of Shared Behavior at Qızqala. Underlying the diminished scale of mobility at Qızqala is a complex picture of individual behavior that reflects shared and diverse patterns of movement. Each individual exhibited unique patterns of mobility that, in turn, spoke to varied approaches to movement at Qızqala.

The two individuals in highland burial CR2 exhibited similar degrees of fluctuation in

$\delta^{18}O$ values, possibly suggestive of local, seasonally recurrent highland transhumance. Compared to neighboring burials CR3 and CR4, this burial was relatively less elaborately furnished with ceramic jars and bowls, and a juvenile sheep or goat. Yet, they shared similar patterns of annual isotopic fluctuation with neighboring CR3, particularly CR3-Sk2, which also held similar ceramic wares, a juvenile sheep or goat and a juvenile canid. Even though the individuals in CR2 were originally local to the Qızqala area, they shared seasonal isotopic fluctuations as well as similar mortuary contexts. Ceramic styles, juvenile fauna and close proximity within this large cemetery space suggested social proximity in life.

The three, more mobile individuals in burial CR3 did not exhibit significant differences in their strontium ratios across all elements (p=0.078). Their isotopic profiles did not fall within Şərur Valley ranges, but were ranges reflected in the broader Aras River Basin. They also exhibited isotopic fluctuations suggesting recurrent, seasonal mobility. While they shared the same elaborate burial space, each individual was commemorated differently through a unique assemblage of accompaniments. These accompaniments were placed close to the body and suggested that they were aspects of individual identity either of the deceased and/or perception of the deceased's identity by mourners. CR3-Sk1, the primary burial, wore ornate beaded jewelry and faced a quiver of finely worked obsidian arrows. CR3-Sk2 and CR3-Sk3 received fewer traditionally high-status accompaniments in the form of two juvenile fauna and a worked shell pendent, respectively. CR3-Sk1 exhibited characteristics of a high status, elite figure who commanded funerary resources in the form of labor needed to construct an elaborate burial space as the primary inhumation and the symbolic power of high-status objects produced from materials originating from great distances. Despite the differences in their demonstrated status through mortuary commemoration, CR3-Sk2 and CR3-Sk3 shared similar mobility behaviors with CR3-Sk1 that suggested they were unified around shared routine behaviors that influenced their ultimate deposition and unified commemoration in CR3.

Individuals from the densely organized lowland Group II burials exercised a significantly lesser degree of residential mobility than those in the highland Group I (Strontium: p=<0.001; Oxygen: p=<0.001, see results for details), but exhibited no significant difference in seasonal mobility (Strontium p=0.216; Oxygen p=0.131, see results for details). In this group and among all excavated burials, CR8 was the largest and most amply furnished burial with great quantities of burial accompaniments, weaponry, and evidence of peri-mortem violent trauma. CR8 had fluctuating isotopic results that corresponded between local highland and lowland ranges. CR8 was constructed as a foundational burial while surrounding burials CR6, CR7, CR12, and CR13 were subsequently placed around it in petal-like formation with shared cromlech stones. A smaller, but unique assemblage of artifacts placed in close proximity to the body accompanied each burial surrounding CR8. While receiving fewer objects, they too had access to high status items such as obsidian, bronzes, and carnelian. For example, CR6 and CR7 contained quivers with obsidian tipped arrows and bronze spear, which mirrored the selection of weaponry found in CR8. The ornately furnished burial and militaristic and/or hunt-related features of CR8 suggested that this individual occupied an elite status that commanded shared social identity among those with similar mobility patterns and identities related to warfare.

In contrast, the individual in CC4 exhibited potentially high mobility in a different sense than the other individuals at Qızqala with evidence of non-local origin and long-distance movement to Qızqala in the final years before death. Yet, this individual, who experienced pre- and peri-mortem violence, was bound by the hands and feet and buried in a simple pit burial outside of the wall with no accompanying objects, an unusual form of funerary treatment for this period. In order to test that this individual was not associated with an earlier or later period, radiocarbon dating of this burial to 1885-1743 calBC supported its association with the MBA (Gopnik 2016). This supported the idea that while people who engaged in short-distance horizontal mobility as well as local vertical mobility had access to material funerary resources, a person originating from outside of the vicinity of the Şərur region commanded no authority and was not allocated the materials and labor expected of local funerary tradition.

5.3 Shared Movement, Cooperation, and Social Complexity

The patterns evident in isotopic results from Qızqala begin to illuminate the diversity underlying regional characterizations of mobile pastoral economy. From the perspective of funerary features and traditions alone, Qızqala exhibits many similar qualities to other MBA cemetery sites across the South Caucasus (Belli & Bahsaliyev, 2001; Kushnareva, 1997; Rubinson, 1977). On a regional scale, monumental and ostentatious displays of MBA *kurgan* burials highlight elite privilege and the importance of ancestral authority among the politically fragmentary mobile pastoral tribes that occupied the region. MBA tribal elites commanded authority over labor and materials to remove economic resources from general circulation for individual veneration in death. This authority and hierarchical structure were validated and perpetuated by the community who enacted the elaborate funerary rites to construct these large-scale burial features and apportion valuable material resources, such as weaponry, draught animals, transportation technology, and jewelry. Contrasts in the elaboration of funerary assemblages and burial architecture indicate an increase in social inequality, with emphasis on males engaged in militaristic activities (Smith, 2015). Moreover, situating highly visible burial features in highland pasturelands suggests a cultural landscape simultaneously supporting subsistence and ritual activities (Swerida & Nugent, 2019). These regional perspectives on MBA communities speak to important political and economic trends on a regional scale. However, the individual-level lived experiences and pastoral practices evident in isotopic results highlights the necessity to complement this perspective with a bottom-up approach that elaborates on social dynamics and practices underpinning regional processes.

The presence of MBA domestic and monumental architecture in association with the Qızqala cemetery also demands reconsideration of the diversity of sociopolitical organization during this period in the South Caucasus. The Qızqala individuals exhibited a lower degree of mobility than hypothesized when compared to individuals at Plovdağ, where settlement was likely ephemeral. While this difference seemingly supports classical Near Eastern perspectives that mobility is antithetical to political complexity, the Qızqala individuals still exhibited diverse expressions of movement that highlighted aspects of shared community identity in funerary tradition despite diverse behaviors in life. Regularized and shared movement within a group serves as a significant unifying feature of community identity and solidarity. Mobility, in this sense, may serve as a proxy for close social relationships. McCorriston (2013) argued that social complexity among mobile pastoralist communities was rooted in evoking group solidarity. Rather than controlling economic resources, such as agricultural surplus, which is a later phenomenon in established complex societies, leaders control the coordination of people. This group solidarity can be then formalized through shared ritual activities such as communal pilgrimage involving gatherings at monuments around which participants solidify social relationships through rituals such as feasting and sacrifice. The presence of monumental *kurgans* that would have required a large number of participants for their construction and were subsequently revisited with some regularity in an area that likely served as highland pastures may speak to pastoral transhumance as being intrinsically connected to the continuation of funerary rituals and perpetuation of a community identity linked to memory and place. In this sense the pasturelands were a critical component in shaping local community and culture and fomenting dispersed authority systems, perhaps as strongly as more centralized activities that took place within the walls of the settlement.

As a group, individuals at Qızqala shared similar patterns of localized seasonal mobility between Burial Groups I and II. Mobility strategies shared within a community, at the same period of time—in this case 8-11 years of age—suggests a socially dictated and perpetuated behavior for elite and non-elite alike. The proximity of individuals and burials to one another in the cemetery present groupings along lines of similarity in residential mobility behaviors. These similarities share a spatial relationship through burial groupings and exclusionary practices. The physical and ritual exclusion of CC4, with divergent residential movement patterns, indicates ritual rules dictating belonging in the community.

Moreover, diminished mobility also does not imply isolation. Frachetti (2009, 2012) argued that mobile pastoralist economies were pivotal for the formation of complex networks of political and economic interaction across Eurasia because the nature of pastoral practice conditioned spaces for exchange and communication. The representation of many non-local materials and objects in burial assemblages supports that Qızqala was connected to a broader network of interaction and trade in the South Caucasus. The individuals sampled from Qızqala for isotopic analysis cannot be clearly connected to other parts of the South Caucasus isotopically, but potential similarities in geological and climatic features of non-local environments to the local environment may have masked longer-distance movement. Moreover, lower variability in the M3 series may suggest that there may have been a division of labor for long-distance movement that may not have included older children, the developmental period represented by the M3 series. It is possible, that older individuals were involved with long-distance seasonal movement. While not clearly represented isotopically, it is likely these interactions took place in some capacity through the exchange of cultural materials and information with communities in the neighboring regions of the broader South Caucasus.

Moreover, as a large, prominent walled settlement Qızqala may have served as a node or focal point for smaller, more mobile communities in the region. Its position along a major mountain corridor would have likely supported this role. The architecture and positioning of complex settlement sites paired with more localized seasonal mobility practices may have served to harness the social and economic relationships facilitated by mobility, allowing for the expansion of sovereignty to a growing populace that fostered emergent complex settlement systems at Qızqala and the broader Aras River Basin.

6 CONCLUSIONS

This article has presented a geological and climatic framework for radiogenic strontium and stable oxygen isotope analysis for mobility in the South Caucasus. In conjunction with a multi-element and sequential sampling approach to the study of human skeletal remains, this study sheds light on short-term mobility that details individual-scale experiences with seasonally recurrent, highland lowland, and long/short distance scales.

Results suggested that individuals from Qızqala had a more limited scale of movement over their lifetimes, as might be expected of a population associated with a walled complex settlement with less reliance on intensive, long-distance pastoral transhumance. Yet, many individuals at Qızqala maintained a degree of local and regional mobility that both reflects movement associated with short-range residential mobility and seasonal movement patterns, supporting the continued importance of pastoral transhumance in an emergent complex settlement system, albeit in a less intensive and more localized approach on the spectrum of mobile pastoralist movement. Furthermore, the differential treatment of individuals with local and regional mobility compared to long-distance movement reinforces the idea that membership was negotiated in the Qızqala community through sense of social cohesion around shared behavior.

The small number of individuals presented in this study limited conclusive inferences about population mobility in this region due to the possibility of sampling bias. I aimed to mitigate this issue through selecting a representative sample of excavated burials from across different areas within the cemetery and by integrating a comparative collection from Plovdağ. This approach also had a number of benefits in the level of granularity on behavior over individual lifetimes. Detailing individual behaviors revealed often-invisible aspects of past lifeways. For mobile populations and those who leave fewer material records of their lives, this detail presented the opportunity to highlight the roles of underrepresented mobile populations.

The goal of future research should address how patterns of mobility relate to regional trends on a wider scale in the South Caucasus, which experienced major sociopolitical changes at the hand of mobile pastoralist populations. Because there is growing evidence to suggest that the Aras River Basin supported a network of settlements, it is critical to develop a better understanding of how these communities were sustained and their channels of interaction on a broader regional scale. Similarly, collaborators on the Naxçıvan Archaeological Project are advancing complementary spatial, petrographic, zooarchaeological, and palæobotanical analyses at Qızqala. In combination with these studies, this research contributes to increasingly unified and multifaceted perspectives on the practice and ecology of Bronze Age pastoralism and emergent social complexity in South Caucasus.

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LITERATURE CITED

Abibullaev, A. (1963). Nekotorye Itogi Izucheniya Kholma Kyultepe V Azerbaidzhane. *Sovetskaya Arkheologiya*, 3, 157–168.

Alizadeh, A., Güliyev, I., Kadirov, Z., & Eppelbaum, L. (2016). *Geosciences of Azerbaijan: Volume 1: Geology*. Cham: Springer. doi: 10.1007/978-3-319-27395-2

Alizadeh, K., Maziar, S., & Mohammadi, M.R. (2018). The End of the Kura-Araxes Culture as Seen from Nadir Tepesi in Iranian Azerbaijan. *American Journal of Archaeology*, 122(3), 463–477. doi: 10.3764/aja.122.3.0463

Al Qahtani, S.J., Hector, M.P., & Liversidge, H.M. (2014). Accuracy of dental age estimation charts: Schour and Massler, Ubelaker and the London Atlas. *American Journal of Physical Anthropology*, 154(1), 70-78. doi: 10.1002/ajpa.22473

Bairamov, A.A., Aliyev, G.I., Hasanov, G.M., Hasanov, H., Hasanov, T.A., Ismail-Zadeh, A.J., Kangarli, T.N., Korobanov, V.V., Mamedov, A.I., Mamedov, A.V., Mustafayev, H.V., Nagiyev, A.N., Narimanov, A.A., Rustamov, M.I., & Zamanov, Y. (2008). *Geological Map of Azerbaijan Republic*. F. Ahmedbeili, T.N. Kangarli, I, Tagiyev, K, Yusifzadeh, & Y, Zamanov (Eds.). Baku: National Academy of Sciences of Azerbaijan Republic, Geology Institute.

Balasse, M. (2002). Reconstructing dietary and environmental history from enamel isotopic analysis: Time resolution of intra-tooth sequential sampling. *International Journal of Osteoarchaeology*, 12(3), 155–165. doi: 10.1002/oa.601

Barberena, R., Durán, V.A., Novellino, P., Winocur, D., Benítez, A., Tessone, A., & Knudson, K.J. (2017). Scale of human mobility in the southern Andes (Argentina and Chile): A new framework based on strontium isotopes. *American Journal of Physical Anthropology*, 164(2), 305–320. doi: 10.1002/ajpa.23270

Barth, F. (1961). *Nomads of South Persia: The Basseri tribe of the Kamseh Confederacy*. London: George Allen & Unwin, Oslo University Press.

Bates, D.G. & Lees, S.H. (1977). The Role of Exchange in Productive Specialization. *American Anthropologist*, 79, 824-828. doi: 10.1525/aa.1977.79.4.02a00040

Baxşəliyev, V., Ristvet, L., Gopnik, H., Swerida, J., & Nugent, S. (2016). Qızqalası Yaşayış Yerində 2015-ci Ildə Aparılan Arxeoloji Araşdırmalar. *Azərbaycan MEA-nın Xəbərləri Ictimai elmlər seriyası*, 2, 178–198.

Belli, O. & Bahşaliyev V. (2001). *Nahçıvan Bölgesi'nde orta ve son tunç çağı boya bezemeli çanak çömlek kültürü = Middle and late bronze age painted pottery culture in the Nakhichevan Region*. Istanbul:Arkeoloji ve Sanat Yayınları.

Belli, O. & Sevin, V. (1999). *Nahçıvan'da arkeolojik araştırmalar, 1998 = Archaeological survey in Nakhichevan, 1998*. Istanbul: Arkeoloji ve Sanat Yayınları.

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

Bernard, A., Daux, V., Lécuyer, C., Brugal, J.P., Genty, D., Wainer, K., Gardien, V., Fourel, F., & Jaubert, J. (2009). Pleistocene seasonal temperature variations recorded in the $\delta^{18}O$ of Bison priscus teeth. *Earth and Planetary Science Letters*. 283, 133–143. doi: 10.1016/j.epsl.2009.04.005

Blumenthal, S.A., Cerling, T.E., Chritz, K.L., Bromage, T.G., Kozdon, R., & Valley, J.W. (2014). Stable isotope time-series in mammalian teeth: In situ $\delta^{18}O$ from the innermost enamel layer. *Geochimica et Cosmochimica Acta*. 124, 223–236. doi: 0.1016/j.gca.2013.09.032

Bowen, G.J. (2018). *The Online Isotopes in Precipitation Calculator*, Version 3.1. Retrieved from http://www.waterisotopes.org.

Bowen, G.J., Wassenaar, L.I. & Hobson, K.A. (2005). Global application of stable hydrogen and oxygen isotopes to wildlife forensics. *Oecologia* 143, 337-348. doi: 10.1007/s00442-004-1813-y

Bowen, G.J. & Wilkinson, B. (2002). Spatial distribution of $\delta^{18}O$ in meteoric precipitation. *Geological Society of America Bulletin*, 30(4), 315–318. doi: 10.1130/0091-7613(2002)030<0315:SDOOIM>2.0.CO;2

Boyde, A. (1967). The development of enamel structure. *Proceedings of the Royal Society of Medicine*. 60, 923–928.

Brettell, R., Montgomery, J., & Evans, J. (2012). Brewing and stewing: the effect of culturally mediated behaviour on the oxygen isotope composition of ingested fluids and the implications for human provenance studies. *Journal of Analytical Atomic Spectrometry* 27, 778–785. doi: 10.1039/c2ja10335d

Britton, K., Grimes, V., Dau, J., & Richards, M.P. (2009). Reconstructing faunal migrations using intra-tooth sampling and strontium and oxygen isotope analyses: a case study of modern caribou (Rangifer tarandus granti). *Journal of Archaeological Science*. 36, 1163–1172. doi: 10.1016/j.jas.2009.01.003

Cappa, C.D., Hendricks, M.B., DePaolo, D.J., & Cohen, C. (2003). Isotopic fractionation of water during evaporation. *Journal of Geophysical Research*. 108, 4525. doi: 10.1029/2003JD003597

Chase, B., Meiggs, D., Ajithprasad, P., & Slater, P.A. (2014). Pastoral land-use of the Indus Civilization in Gujarat: faunal analyses and biogenic isotopes at Bagasra. *Journal of Archaeological Science*, *50*, 1-15. doi: 10.1016/j.jas.2014.06.013

Chazin, H. (2017). Tracing Late Bronze Age Pastoralists in the South Caucasus: a preliminary zooarchaeological and isotopic investigation from the Tsaghkahovit Plain, Armenia. In: A.R.V. Miller & C.A. Makarewicz (Eds.), *Isotopic Investigations of Pastoralism in Prehistory*. Abingdon: Routledge, 105–120. doi: 10.4324/9781315143026

Chazin, H., Gordon G.W., & Knudson, K.J. (2019). Isotopic perspectives on pastoralist mobility in the Late Bronze Age South Caucasus. *Journal of Anthropological Archaeology*. 54, 48-67. doi: 10.1016/j.jaa.2019.02.003.

Chenery, C.A., Pashley, V., Lamb, A.L., Sloane, H.J., & Evans, J.A. (2012). The oxygen isotope relationship between the phosphate and structural carbonate fractions of human bioapatite. *Rapid Communications in Mass Spectrometry*. 26, 309–319. doi: 10.1002/rcm.5331

Clauer, N. & Chaudhuri, S. (1992). *Isotopic signatures and sedimentary records*. Lecture Notes in Earth Sciences, Berlin: Springer, 43.

Coplen, T.B., Kendall, C., & Hopple, J. (1983). Comparison of stable isotope reference samples. *Nature*, 302(5905), 236. doi: 10.1038/302236a0

Copeland, S.R., Sponheimer, M., de Ruiter, D.J., Lee-Thorp, J.A., Codron, D., le Roux, P.J., Grimes, V. & Richards, M.P. (2011). Strontium isotope evidence for landscape use by early hominins. *Nature*, 474(7349), 76. doi: 10.1038/nature10149

Cribb, R. (2004). *Nomads in archaeology*. Cambridge: Cambridge University Press. doi: 10.1017/CBO9780511552205

Dansgaard, W. (1964). Stable isotopes in precipitation. *Tellus*, 26(4), 437–468. doi: 10.1111/j.2153-3490.1964.tb00181.x

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

Epstein, S. & Mayeda, T. (1953). Variation of O^{18} content of waters from natural sources. *Geochimica et Cosmochimica Acta*, 4(5), 213–224. doi: 10.1016/0016-7037(53)90051-9

Ericson, J.E. (1985). Strontium isotope characterization in the study of prehistoric human ecology. *Journal of Human Evolution*, 14(5), 503–514. doi: 10.1016/S0047-2484(85)80029-4

Faure, G. (1986). *Principles of isotope geology*. New York, NY: John Wiley & Sons.

Faure, G. & Powell, J.L. (1972). *Strontium isotope geology*, New York, NY: Springer. doi: 10.1007/978-3-642-65367-4

Frachetti, M.D. (2009). *Pastoralist landscapes and social interaction in Bronze Age Eurasia*. Berkeley and Los Angeles, CA: University of California Press.

Frachetti, M.D. (2012). "Multiregional emergence of mobile pastoralism and nonuniform institutional complexity across Eurasia." *Current Anthropology*, 53(1), 2-21. doi: 10.1086/663692

Gopnik, H. (2016). Grounded: A Late Bronze Age fortress on the Şərur Valley floor, Naxçıvan. *Presented at The 81st Annual Meeting of the Society for American Archaeology*. Orlando, FL. tDAR id: 404891.

Gosz, J.R., Brookins, D.G., & Moore, D.I. (1983). Using strontium isotope ratios to estimate inputs to ecosystems. *BioScience*, 33(1), 23–30. doi: 10.2307/1309240

Grimstead, D.N., Nugent, S., & Whipple, J. (2017). Why a Standardization of Strontium Isotope Baseline Environmental Data Is Needed and Recommendations for Methodology. *Advances in Archaeological Practice*, 5(2), 184-195. doi: 10.1017/aap.2017.6

Halilov, T. & Yavan, C. (2014). Nahçivan'in Erken Demir Çaği Kültürü. *Turk Dünya Arastırmaları*, May 2014 (210), 179-187.

Hammer, E. (2014). Highland fortress-polities and their settlement systems in the southern Caucasus. *Antiquity*, 88(341), 757–774. doi: 10.1017/S0003598X00050675

Herrmann, J.T. & Hammer, E.L. (2019). Archaeo-geophysical survey of Bronze and Iron Age fortress landscapes of the South Caucasus. *Journal of Archaeological Science: Reports*, 24, 663-676. doi: 10.1016/j.jasrep.2019.02.019

Hill, P.A. (1998). Bone remodeling. *British Journal of Orthopaedics*, 25, 101-107. doi: 10.1093/ortho/25.2.101

Hillson, S. (1996). *Dental anthropology*. Cambridge: Cambridge University Press. doi: 10.1017/CBO9781139170697

Honeychurch, W., Wright, J., & Amartuvshin, C., (2009). Re-Writing Monumental Landscapes as Inner Asian Political Process: Monuments, Metals, and Mobility: Trajectories of Complexity in the Late Prehistory of the Eurasian Steppe. In B. Hanks and K. Linduff (Eds.), *Monuments, Metals, and Mobility: Trajectories of Complexity in the Late Prehistory of the Eurasian Steppe*. Cambridge: Cambridge University Press.

Honeychurch, W. (2014). Alternative Complexities: The Archaeology of Pastoral Nomadic States. *Journal of Archaeological Research*, 22(2), 277-326. doi: 10.1007/s 10814-014-9073-9

————. (2015). *Inner Asia and the Spatial Politics of Empire: Archaeology, mobility, and culture contact*. New York, NY: Springer. doi: 10.1007/978-1-4939-1815-7

Hüseynov, N. & Malikov, B. (2009). Regularity of distribution of precipitation at the airdromes of Azerbaijan Republic. *Advances in Geosciences*, 20, 9–12. doi: 10.5194/adgeo-20-9-2009

IAEA/WMO (2015). *Global Network of Isotopes in Precipitation*. The GNIP Database. Retrieved from: https://nucleus.iaea.org/wiser.

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

İbrahimli, B. (2007). Naxçıvan Bölgəsinin Tunc Dövr Qəbir Abidələrind Ənənvilik. *Azərbaycan Arxeologiyası*, 3(4), 36-43.

İbrahimli, B. (2017). Gilançay Vadisi Abidələrində Daş Örtüklərin Meydana Gəlməsi və Inkişafı Tarixindən. *Azərbaycan Arxeologiyası*, 20(2), 57-68.

İbrahimli, B., Qədirzadə, Q., & Xəlilov, T. (2011). Plovdağ Yaşayış Yerində Aparılmış Arxeoloji Qazıntılar. *AAT*, 161-169.

İbrahimli, B., Qədirzadə, Q., & Xəlilov, T. (2012). Plovdağın Aşkar Edilmiş III Nekropolu *AAT*, 150-154.

İbrahimov, B. (2005). *İkinci Plovdağ nekropolu 2003-2004-cü illərdə aparılmış arxeoloji və etnoqrafik tədqiqatların yekunlarına həsr olunmuş elmi sesiyanın materialları*. Baku: AAT.

Julien, M., Bocherens, H., Burke, A., Drucker, D.G., Patou-Mathis, M., Krotova, O., & Péan, S. (2012). Were European steppe bison migratory? ^{18}O, ^{13}C and Sr intra-tooth isotopic variations applied to a palaeoethological reconstruction. *Quaternary International*, 271, 106–119. doi: 10.1016/j.quaint.2012.06.011

Khazanov, A.M. (1984). *Nomads and the Outside World*. Cambridge: Cambridge University Press.

Khanzadian, E.V., Mkrtchian, K.A., & Parsamian, E.S. (1973). *Metsamor.* Yerevan: Akademiya Nauk Armianskoe SSR.

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

Koch, P.L. (1998). Isotopic Reconstruction of Past Continental Environments. *Annual Review of Earth and Planetary Sciences*, 26(1), 573–613. doi: 10.1146/annurev.earth.26.1.573

Kohl, P.L. (1992). The Kura-Araxes "Chiefdom/State," The problems of evolutionary labels and imperfect analogies. In G.L. Possehl (Ed.), *South Asian archaeology studies,* New Delhi: Oxford and IBH Pub. Co., 223–232.

Kohl, P.L. (2009). Origins, Homelands and Migrations: Situating the Kura-Araxes Early Transcaucasian 'Culture' within the History of Bronze Age Eurasia. *Tel Aviv*, 36(2), 241–265. doi: 10.1179/033443509x12506723940686

Kohl, P.L. & Lyonnet, B. (2008). By Land and By Sea: The Circulation of Materials and Peoples, ca. 3500–1800 BC. In E. Olijdam and R.H. Spoor (Eds.), *Intercultural*

Relations Between South Southwest Asia Studies in Commemoration of E.C.L. During Caspers, 29–42.

Kohn, M.J., Schoeninger, M.J., & Valley, J.W. (1998). Variability in oxygen isotope compositions of herbivore teeth: reflections of seasonality or developmental physiology? *Chemical Geology*, 152, 97–112. doi: 10.1016/S0009-2541(98)00099-0

Knudson, K.J., Pestle, W.J., Torres-Rouff, C., & Pimentel, G. (2012). Assessing the Life History of an Andean Traveller through Biogeochemistry: Stable and radiogenic isotope analyses of archaeological human remains from northern Chile. *International Journal of Osteoarchaeology*, 22(4), 435–451. doi: 10.1002/oa.1217

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

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

Krzemińska, E., Sołtysiak, A., & Czupyt, Z. J. (2017). Reconstructing seasonality using $\delta^{18}O$ in incremental layers of human enamel: A test of the analytical protocol developed for

SHRIMP IIe/MC ion microprobe. *Geological Quarterly*, *61*(2), 370-383. doi: 10.7306/gq.1354

Kushnareva, K.K. (1997). *The southern Caucasus in prehistory: stages of cultural and socioeconomic development from the eighth to the second millennium B.C.* Philadelphia, PA: University of Pennsylvania Museum.

Lattimore, O. (1940). *Inner Asian Frontiers of China*. New York, NY: American Geographical Society.

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

Lowenstam, H.A. & Weiner, S. (1989). *On biomineralization*. Oxford: Oxford University Press.

Luz, B., Barkan, E., Yam, R., & Shemesh, A. (2009). Fractionation of oxygen and hydrogen isotopes in evaporating water. *Geochimica et Cosmochimica Acta*, 73(22), 6697-6703. doi: 10.1016/j.gca.2009.08.008

Luz, B. & Kolodny, Y. (1985). Oxygen isotope variations in phosphate of biogenic apatites, IV. Mammal teeth and bones. *Earth and planetary science letters*, *75*(1), 29-36. doi: 10.1016/0012-821X(85)90047-0

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

Makarewicz, C.A., Arbuckle, B.S., & Öztan, A. (2017). Vertical transhumance of sheep and goats identified by intra-tooth sequential carbon ($\delta^{13}C$) and oxygen ($\delta^{18}O$) isotopic analyses: Evidence from Chalcolithic Köşk Höyük, central Turkey. *Journal of Archaeological Science*, *86*, 68-80. doi: 10.1016/j.jas.2017.01.003

Makarewicz, C.A. & Pederzani, S. (2017). Oxygen ($\delta^{18}O$) and carbon ($\delta^{13}C$) isotopic distinction in sequentially sampled tooth enamel of co-localized wild and domesticated caprines: complications to establishing seasonality and mobility in herbivores. *Palaeogeography, Palaeoclimatology, Palaeoecology*, *485*, 1-15. doi: 10.1016/j.palaeo.2017.01.010

Makarewicz, C.A., Pederzani, S., & Hermes, T. (2017). Ahead of the curve? Implications for isolating vertical transhumance in seasonal montane environments using sequential oxygen isotope analyses of tooth enamel. In A.R. Ventresca Miller and C.A. Makarewicz (Eds.) *Isotopic Investigations of Pastoralism in Prehistory*. New York, NY: Routledge, 65-84. doi: 10.4324/9781315143026

Marshall, M.E. (2014). *Subject (ed) Bodies: A Bioarchaeological Investigation of Late Bronze Age–Iron I (1500–800 BC) Armenia*. Department of Anthropology, University of Chicago. Doctoral Dissertation.

McCorriston, J. (2013). Pastoralism and Pilgrimage. *Current Anthropology*, 54, 607–641. doi: 10.1086/671818

Meiggs, D. C. (2007). Visualizing the seasonal round: a theoretical experiment with strontium isotope profiles in ovicaprine teeth. *Anthropozoologica*, *42*(2), 107-128.

Mulhern, D.M. & Van Gerven, D.P. (1997). Patterns of femoral bone remodeling dynamics in a medieval Nubian population. *American Journal of Physical Anthropology*, 104(1), 133-146. doi: 10.1002/(SICI)1096-8644(199709)104:1<133::AID-AJPA9>3.0.CO;2-S

Nirova, S., Museibova, M., Neremova, N., Nerimova, S., & Sulejmanova, M.A. (1975). Azerbajdnanskaja SSR Lannshaftnaja Karta. Moskva: Glavnoe upravlenie reodezii i kartografii pri Sovete Ministrov SSSR.

Nugent, S.E. (2017). *Pastoral Mobility and the Formation of Complex Settlement in the Middle Bronze Age Serur Valley, Azerbaijan*. Department of Anthropology, The Ohio State University. Doctoral Dissertation.

Özfırat A. (2001). *Doğu Anadolu Yayla Kültürleri : M.Ö. II. binyıl*. Istanbul: Arkeoloji ve Sanat Yayınları.

Palumbi, G. & Chataigner, C. (2014). The Kura-Araxes Culture from the Caucasus to Iran, Anatolia and the Levant: Between unity and diversity, a synthesis. *Paléorient*, 40, 247–260.

Pollard, A.M., Pellegrini, M., & Lee-Thorp, J.A. (2011). Technical note: Some observations on the conversion of dental enamel $\delta^{18}O_p$ values to $\delta^{18}O_w$ to determine human mobility. *American Journal of Physical Anthropology*, 145, 499–504. doi: 10.1002/ajpa.21524

Porter, A. (2012). *Mobile pastoralism and the formation of Near Eastern civilizations: Weaving together society*. Cambridge: Cambridge University Press. doi: 10.1017/CBO9780511895012

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

Price, T. D., Meiggs, D., Weber, M. J., & Pike-Tay, A. (2017). The migration of Late Pleistocene reindeer: isotopic evidence from northern Europe. *Archaeological and Anthropological Sciences*, *9*(3), 371-394. doi: 10.1007/s12520-015-0290-z

Proctor, L., & Lau, H. (2016). Reconstructing Land-Use and Agropastoral Production during the Middle Bronze Age of the Southern Caucasus: Preliminary Results from Qızqala, Autonomous Republic of Naxçıvan, Azerbaijan. *Presented at the 81st Annual Meeting of the Society for American Archaeology*. Orlando, FL. tDAR id: 405127

Ramirez Rozzi, F.V. (1994). Enamel growth markers in hominid dentition. *Microscopy and Analysis*, 21-23.

Reid D.J. & Dean, M.C. (2006). Variation in modern human enamel formation times. *Journal of Human Evolution*, 50, 329–346. doi: 10.1016/j.jhevol.2005.09.003

Reitsema, L.J. & Vercellotti, G. (2012). Stable isotope evidence for sex- and status-based variations in diet and life history at medieval Trino Vercellese, Italy. *American Journal of Physical Anthropology*, 148(4), 589–600. doi: 10.1002/ajpa.22085

Ristvet, L., Baxşəliyev V, & Aşurov S. (2011). Settlement and Society in Naxçıvan: 2006 Excavations and Survey of the Naxçıvan Archaeological Project. *Iran Antiqua*, 46, 1–53. doi: 10.2143/IA.46.0.2084412

Rothman M.S. (2005). Transcaucasians: Settlement, migration, and trade in the Kura-Araxes periods. *Archäologische Mitteilungen aus Iran und Turan*. 37, 53–62.

Royer, A., Daux, V., Fourel, F., & Lécuyer, C. (2017). Carbon, nitrogen and oxygen isotope fractionation during food cooking: Implications for the interpretation of the fossil human record. *American Journal of Physical Anthropology*. 163, 759-771. doi: 10.1002/ajpa.23246

Rubinson, K. (1977). The Chronology of the Middle Bronze Age Kurgans at Trialeti. In L. Levine and T. Cuyler Young, Jr. (Eds.) *Mountains and Lowlands: Essays in the Archaeology of Greater Mesopotamia*. Malibu, CA: Undena Publications, 235-250.

Sagona A. (2014). Rethinking the Kura-Araxes Genesis. *Paléorient*, 40(2), 23-46.

Salesse, K., Dufour, É., Castex, D., Velemínský, P., Santos, F., Kuchařová, H., Jun, L., & Brůžek, J. (2013). Life history of the individuals buried in the St. Benedict Cemetery (Prague, 15th-18th Centuries): Insights from ^{14}C dating and stable isotope ($\delta^{13}C$, $\delta^{15}N$, $\delta^{18}O$) analysis. *American Journal of Physical Anthropology*, 151(2), 202–214. doi: 10.1002/ajpa.22267

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

Sillen, A., Hall, G., Richardson, S. & Armstrong, R., 1998. $^{87}Sr/^{86}Sr$ ratios in modern and fossil food-webs of the Sterkfontein Valley: implications for early hominid habitat preference. *Geochimica et Cosmochimica Acta*, *62*(14), 2463-2473. doi: 10.1016/S0016-7037(98)00182-3

Smith, A.T. (2005). Prometheus unbound: Southern Caucasia in prehistory. *Journal of World Prehistory*, 19(4), 229–279. doi: 10.1007/s10963-006-9005-9

————. (2012). The Caucasus and the near East. In D.T. Potts (Ed.), *A Companion to the Archaeology of the ancient Near East*. New York, NY: John Wiley & Sons, 668-686. doi: 10.1002/9781444360790

————. (2015). *The Political Machine: Assembling Sovereignty in the Bronze Age Caucasus*. Princeton, NJ: Princeton University Press. doi: 10.2307/j.ctt1dr3558

Smith A.T. & Rubinson, K.S. (2003). *Archaeology in the borderlands: investigations in Caucasia and beyond*. Los Angeles, CA: Cotsen Institute of Archaeology.

Smith, T.M., Olejniczak, A.J., Reid, D.J., Ferrell, R.J. & Hublin, J.J. (2006). Modern human molar enamel thickness and enamel–dentine junction shape. *Archives of Oral Biology*, 51(11), 974-995. doi: 10.1016/j.archoralbio.2006.04.012

Sneath, D. (2007). The decentralised state: nomads, complexity and sociotechnical systems in Inner Asia. In S. Kohring and S. Wynne-Jones (Eds.), *Socialising Complexity: Structure, Interaction and Power in Archaeological Discourse*. Oxford: Oxbow, 228-244.

Stein, M., Starinsky, A., Katz, A., Goldstein, S.L., Machlus, M. & Schramm, A. (1997). Sr-isotopic, chemical and sedimentological evidence for the evolution of Lake Lisan and the Dead Sea. *Geochimica et Cosmochimica Acta*, 61, 3975– 3992.

Swerida, J. & Nugent, S.E. (2019). Fashioned identity in the Şərur Valley, Azerbaijan: Kurgan CR8. In M. Cifarelli (Ed.), *Fashioned Selves: Dress and Identity in Antiquity*. Oxford: Oxbow, 9-24.

Szuchman, J. (Ed.). (2009). *Nomads, tribes, and the state in the ancient Near East: Cross-disciplinary perspectives*. Chicago, IL: Oriental Institute of the University of Chicago.

Teitelbaum, S.L. (2000). Bone resorption by osteoclasts. *Science*, 289, 1504. doi: 10.1126/science.289.5484.1504

Towers, J., Gledhill, A., Bond, J., & Montgomery, J. (2014). An Investigation of Cattle Birth Seasonality using $\delta^{13}C$ and $\delta^{18}O$ Profiles within First Molar Enamel. *Archaeometry*, *56*, 208-236. doi: 10.1111/arcm.12055

Trueman, C. N., & Tuross, N. (2002). Trace elements in recent and fossil bone apatite. *Reviews in mineralogy and geochemistry*, 48(1), 489-521.

Zazzo, A., Bendrey, R., Vella, D., Moloney, A.P., Monahan, F.J., & Schmidt, O. (2012). A refined sampling strategy for intra-tooth stable isotope analysis of mammalian enamel. *Geochimica et Cosmochimica Acta*, 84, 1–13. doi: 10.1016/j.gca.2012.01.012

TABLE AND FIGURE LEGEND

TABLE 1 Qızqala individuals sampled for this study and contextual archaeological information.

TABLE 2 Descriptive statistics and statistical parameters of $^{87}Sr/^{86}Sr$ and $\delta^{18}O_{dw(VSMOW)}$ values from human remains by burial group and archaeological site.

FIGURE 1 Location of study area, Qızqala, and mentioned archaeological sites. Base map from Tianditu.

FIGURE 2 Map of Qızqala cemetery with *kurgans* identified by survey (n=131) and those excavated for this study. Satellite data from Google, Digital Globe.

FIGURE 3 Illustration of the CR3 burial pit displaying individuals CR3.Sk1 (right), CR3.Sk2 (center), and CR3.Sk3 (left). Illustration by Selin Nugent.

FIGURE 4 Geology map of Naxçıvan (adapted from Bairamov et al. 2008) with morphostructural zones used to develop environmental baseline sampling strategy.

FIGURE 5 Box plots summarizing $^{87}Sr/^{86}Sr$ ratios for plant samples by morpho-structural zones in Naxçıvan. Local highland and lowland ranges for the study area are highlighted first. In each plot, the central horizontal line marks the median, the shaded box represents the interquartile range, whiskers are the minimum and maximum values, and point outside of this range are outliers.

FIGURE 6 Results of $\delta^{18}O$ analysis on waters collected across Naxçıvan in relation to the source elevation. Samples suspected as potentially contaminated by anthropogenic factors identified on survey (i.e. agricultural/industrial runoff or sewage) are denoted in red.

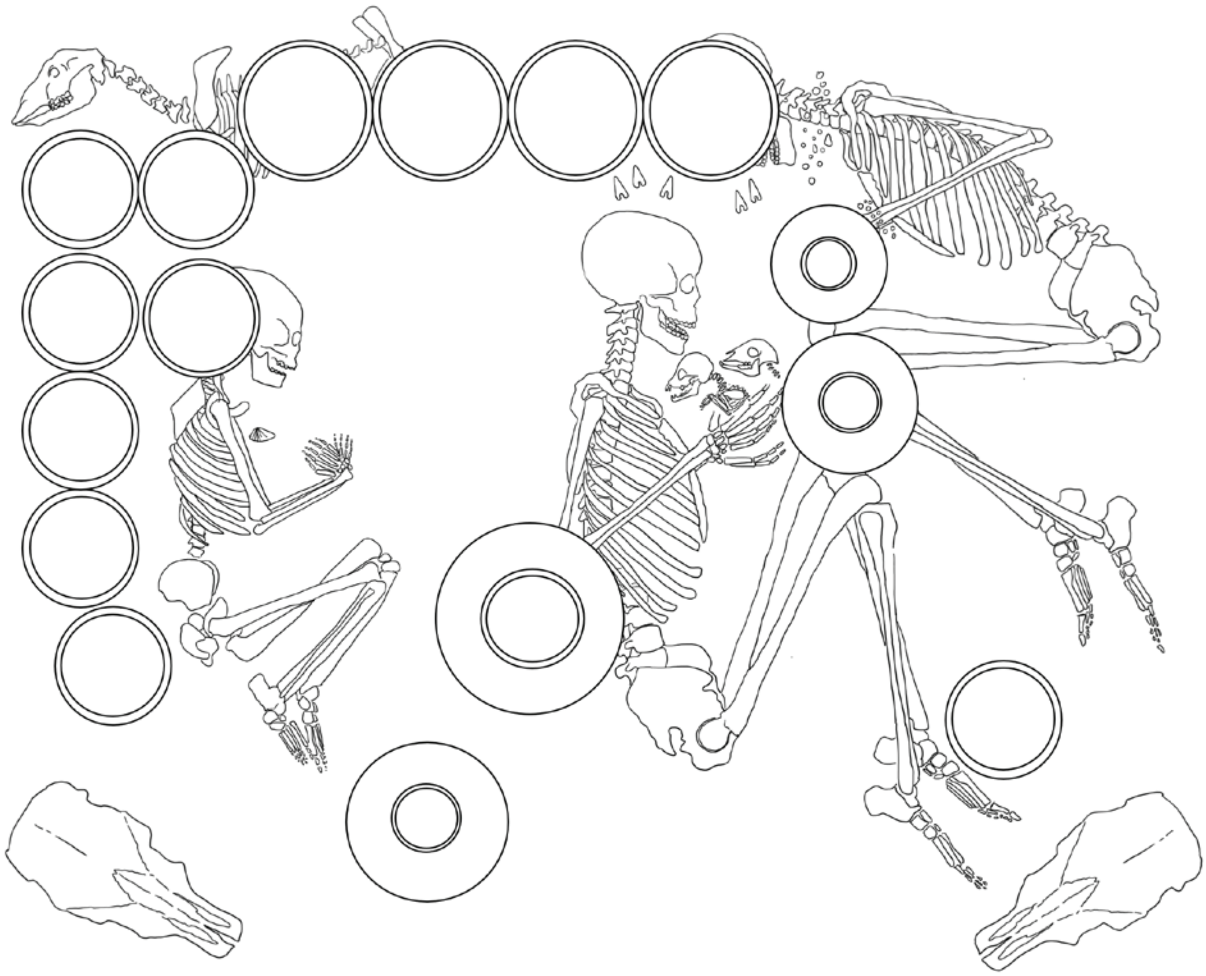
FIGURE 7 Comparison of $^{87}Sr/^{86}Sr$ and $\delta^{18}O_{dw(VSMOW)}$ values for human remains from Qızqala and Plovdağ. Local isotopic bioavailability for each site is delineated by dotted lines. Standard deviation is denoted by dark gray (1σ) and light gray (2σ) shaded bars.

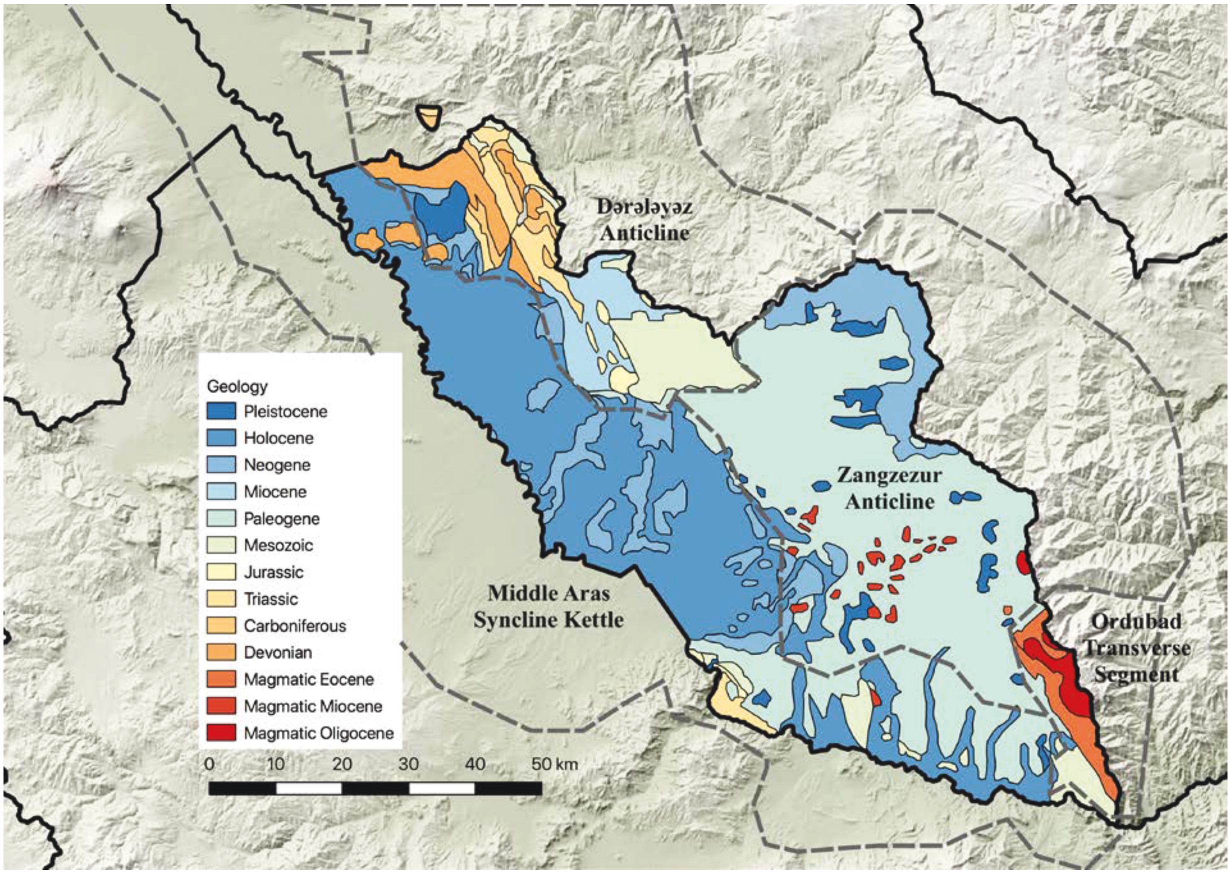
FIGURE 8 $^{87}Sr/^{86}Sr$ and $\delta^{18}O_{dw(VSMOW)}$ results for sequentially sampled M3 dental enamel from Qızqala. Sequential series commences at the apex (1) and ends at the cervix (5/6) of the tooth. Individual plots are referred to as: a) CR12; b) CR2.Sk1; c) CR2.Sk2; d) CR3.Sk1; e) CR3.Sk2; f) CR3.Sk3; g) CR7; h) CR8.

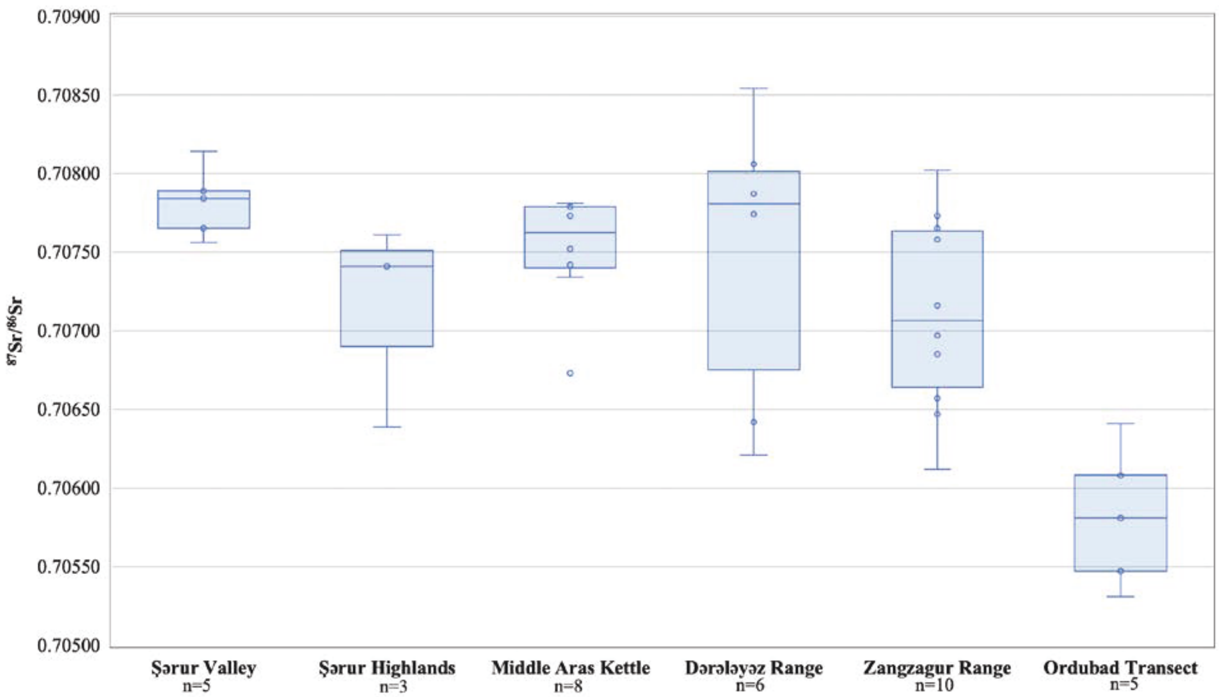
FIGURE 9 $^{87}Sr/^{86}Sr$ and $\delta^{18}O_{dw(VSMOW)}$ results for sequentially sampled M3 dental enamel from Plovdağ. Sequential series commences at the apex (1) and ends at the cervix (5/6) of the tooth.

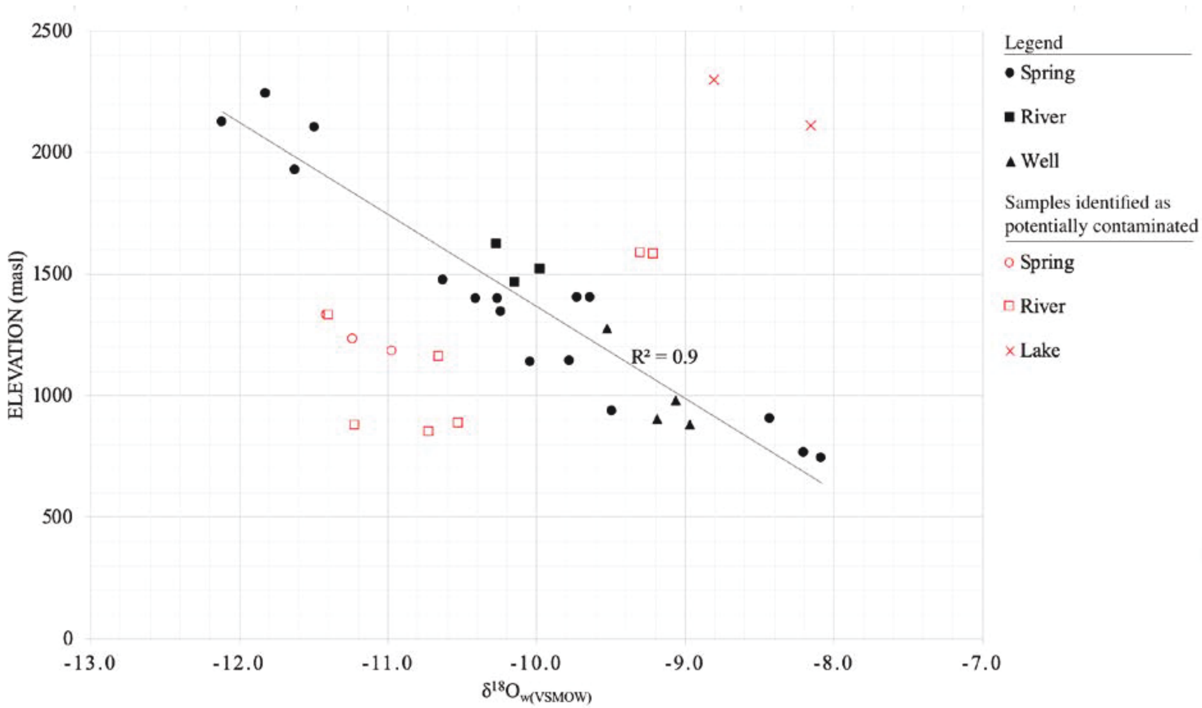

ARMENIA
LAKE
SEVAN
Metsamor
AZERBAIJAN
Mt. Ararat
Arpaçay
TURKEY
Qızqala
Dərələyəz Mountains
Aras River
Kültepe II
Zangzegur
Mountains
NAXÇIVAN
Plovdağ
IRAN
RUSSIA
CASPIAN
SEA
BLACK
SEA
GEORGIA
ARM.
AZERBAIJAN
TURKEY
AZ.
IRAN
IRAQ


Identified Kurgan
Excavated Burial (with human remains)
Excavated Feature (no human remains)
Group I
CR2, CR3,CR4
Group II
CR6, CR7, CR8, CR12, CR13
Group III
CR9, CR11
Isolated Burial
CC4
Settlement Area
0
0.2
0.4
0.6
0.8
1 km

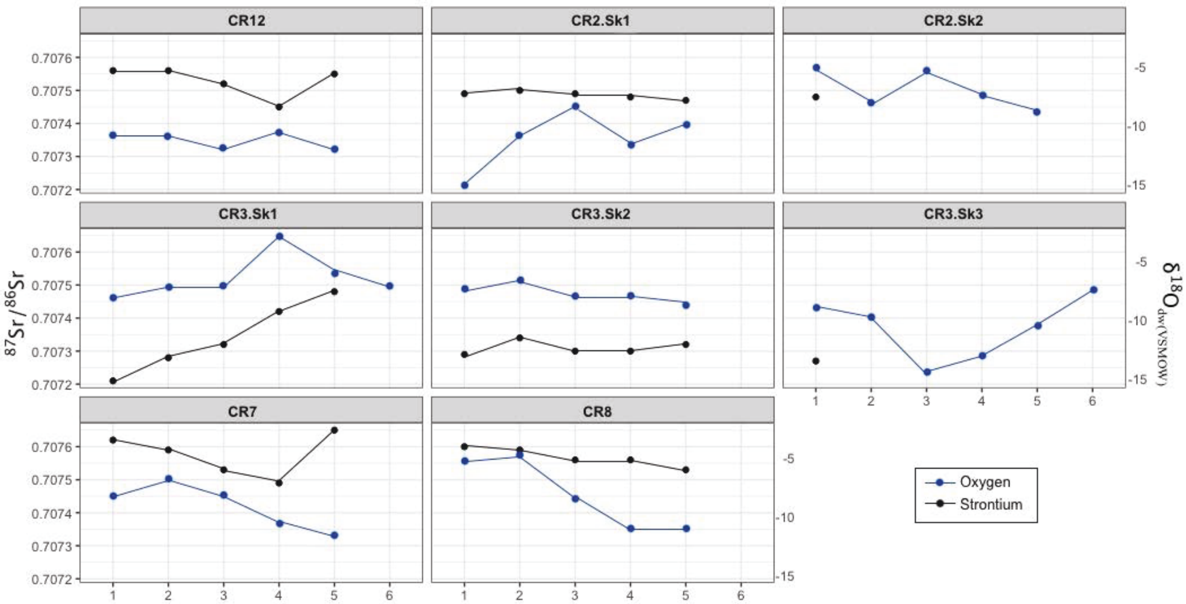



Dərələyəz
Anticline
Geology
Pleistocene
Holocene
Neogene
Miocene
Paleogene
Mesozoic
Jurassic
Triassic
Carboniferous
Devonian
Magmatic Eocene
Magmatic Miocene
Magmatic Oligocene
Zangzezur
Anticline
Middle Aras
Syncline Kettle
Ordubad
Transverse
Segment
0 10 20 30 40 50 km


0.70900
0.70850
0.70800
0.70750
0.70700
0.70650
0.70600
0.70550
0.70500
$^{87}Sr/^{86}Sr$
Şərur Valley
n=5
Şərur Highlands
n=3
Middle Aras Kettle
n=8
Dərələyəz Range
n=6
Zangzagur Range
n=10
Ordubad Transect
n=5


ELEVATION (masl)
2500
2000
1500
1000
500
0
-13.0
-12.0
-11.0
-10.0
-9.0
-8.0
-7.0
δ18Ow(VSMOW)
R² = 0.9
Legend
Spring
River
Well
Samples identified as potentially contaminated
Spring
River
Lake

Qızqala
Plovdağ
Element
M1
M3
Rib
I1
I2
C
M2
Femur
0.7080
0.7075
0.7070
$^{87}Sr/^{86}Sr$
-5
-10
-15
$\delta^{18}O_{dw(VSMOW)}$
CC4-S4
CR2.Sk2
CR2.Sk.1
CR3.Sk1
CR3.Sk2
CR3.Sk3
CR6
CR7
CR8
CR12
PD1
PD2
PD3
PD37
PD68
PD69
PD70-1
PD70-2
PD74
PD76
PD77
PD80


CR12
CR2.Sk1
CR2.Sk2
CR3.Sk1
CR3.Sk2
CR3.Sk3
CR7
CR8
$^{87}Sr/^{86}Sr$
$\delta^{18}O_{dw(VSMOW)}$
0.7072
0.7073
0.7074
0.7075
0.7076
-5
-10
-15
1
2
3
4
5
6
Oxygen
Strontium

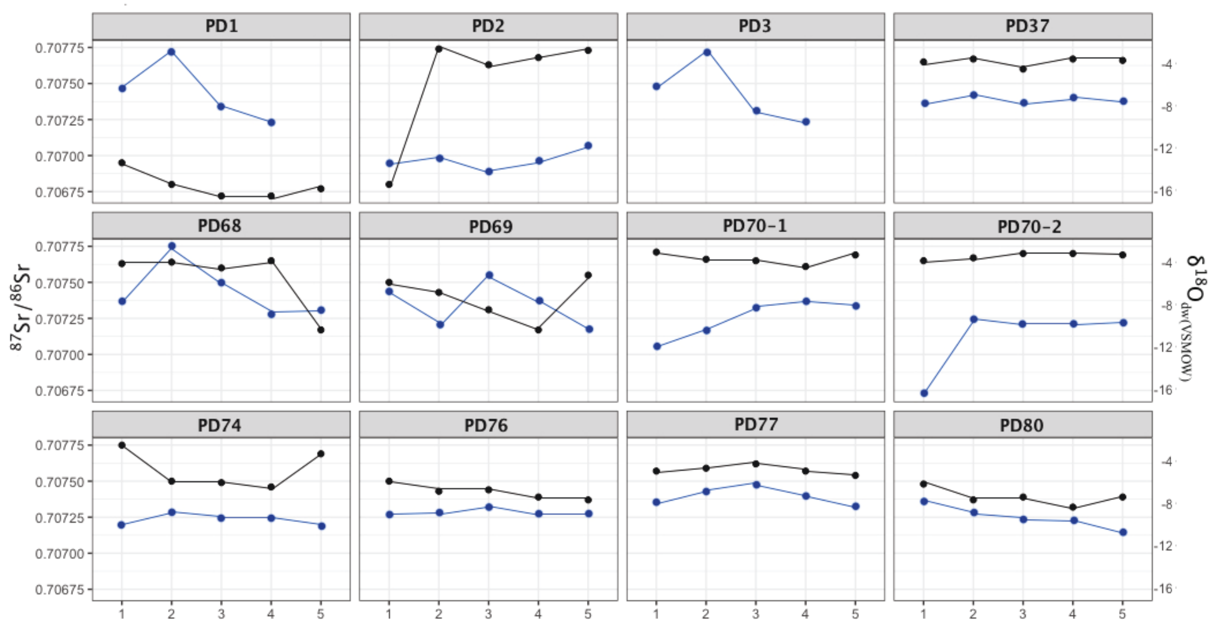
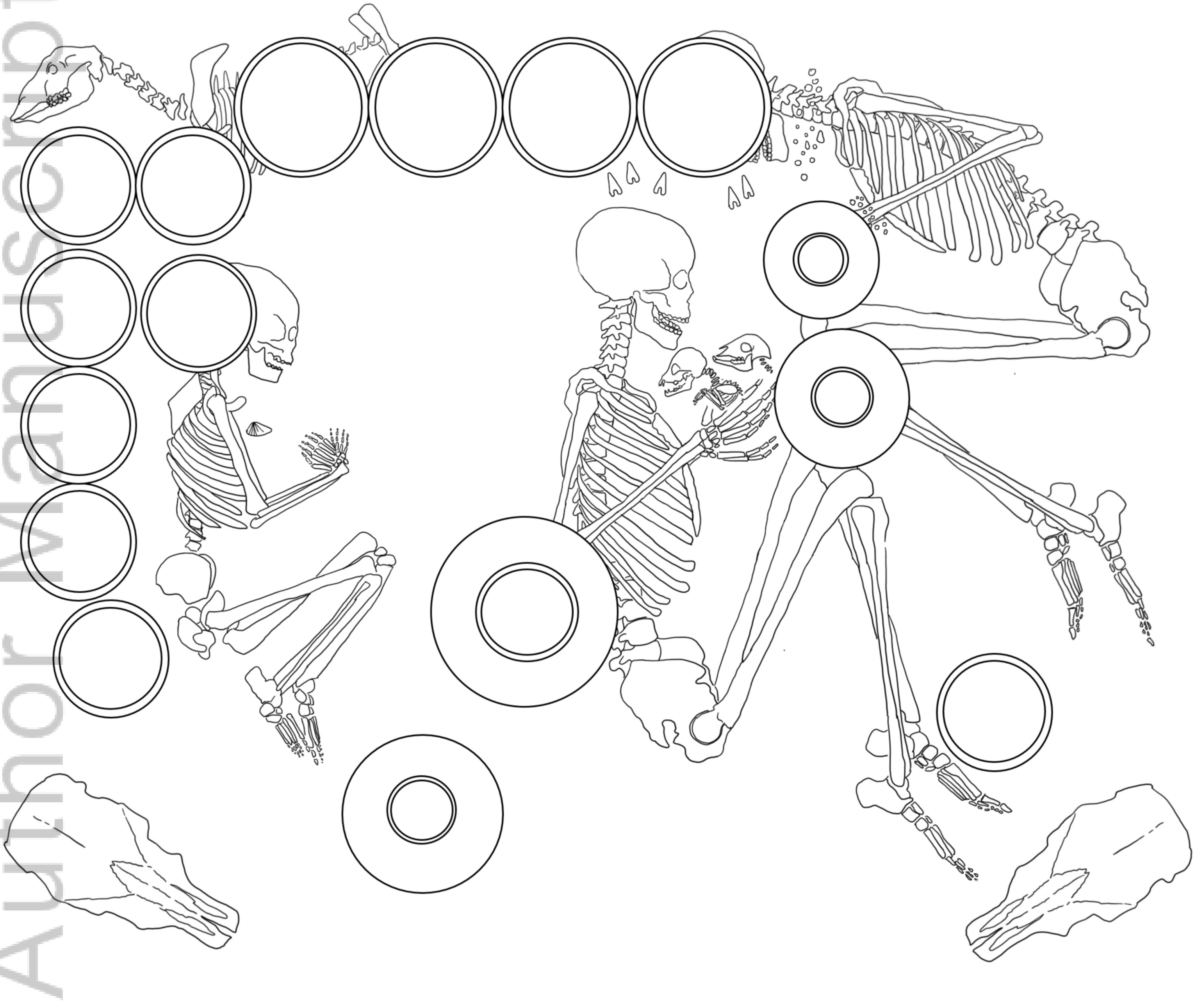

PD1
PD2
PD3
PD37
PD68
PD69
PD70-1
PD70-2
PD74
PD76
PD77
PD80
$^{87}Sr/^{86}Sr$
$\delta^{18}O_{dw(VSMOW)}$
0.70775
0.70750
0.70725
0.70700
0.70675
-4
-8
-12
-16
1
2
3
4
5

TABLE 2 Descriptive statistics and statistical parameters of $^{87}Sr/^{86}Sr$ and $\delta^{18}O_{dw(VSMOW)}$ values from human remains by burial group and archaeological site. Burial Group III was excluded because it had no preserved human remains. Statistically significant values (p<0.05) are italicized.

	$^{87}Sr/^{86}Sr$								**$\delta^{18}O$ (‰)**							
	Residential Bulk bone and dental enamel				**Seasonal** M3 Sequence				**Residential** Bulk bone and dental enamel				**Seasonal** M3 Sequence			
	Min	**Max**	**Mean**	**SD**	**Min**	**Max**	**Mean**	**SD**	**Min**	**Max**	**Mean**	**SD**	**Min**	**Max**	**Mean**	**SD**
Qızqala Burial Group	*p <0.001*				*p* = 0.216				*p* = 0.681				*p* = 0.131			
Group I	0.70735	0.70756	0.70748	0.00010	0.70721	0.70750	0.70738	0.00010	-10.1	-4.8	-8.2	1.6	-14.8	-2.5	-8.3	2.7
Group II	0.70756	0.70767	0.70761	0.00003	0.70745	0.70765	0.70756	0.00005	-12.2	-4.3	-9.0	3.3	-11.6	-4.6	-9.3	2.3
Isolated Burial	0.70660	0.70679	0.70672	0.00007	-	-	-	-	-10.8	-7.9	-8.8	1.0				
Site	*p = 0.012*				*p = 0.028*				*p* = 0.274				*p* = 0.823			
Qızqala	0.70660	0.70767	0.70741	0.00025	0.70727	0.70765	0.70747	0.00011	-12.2	-4.2	-8.6	2.2	-14.8	-2.5	-8.6	2.6
Plovdağ	0.70672	0.70814	0.70749	0.00028	0.70672	0.70775	0.70747	0.00027	-13.6	-4.8	-8.1	2.1	-16.3	-2.3	-8.5	2.5

AJPA_23956_Figure_1.tif

AJPA_23956_Figure_2.tif



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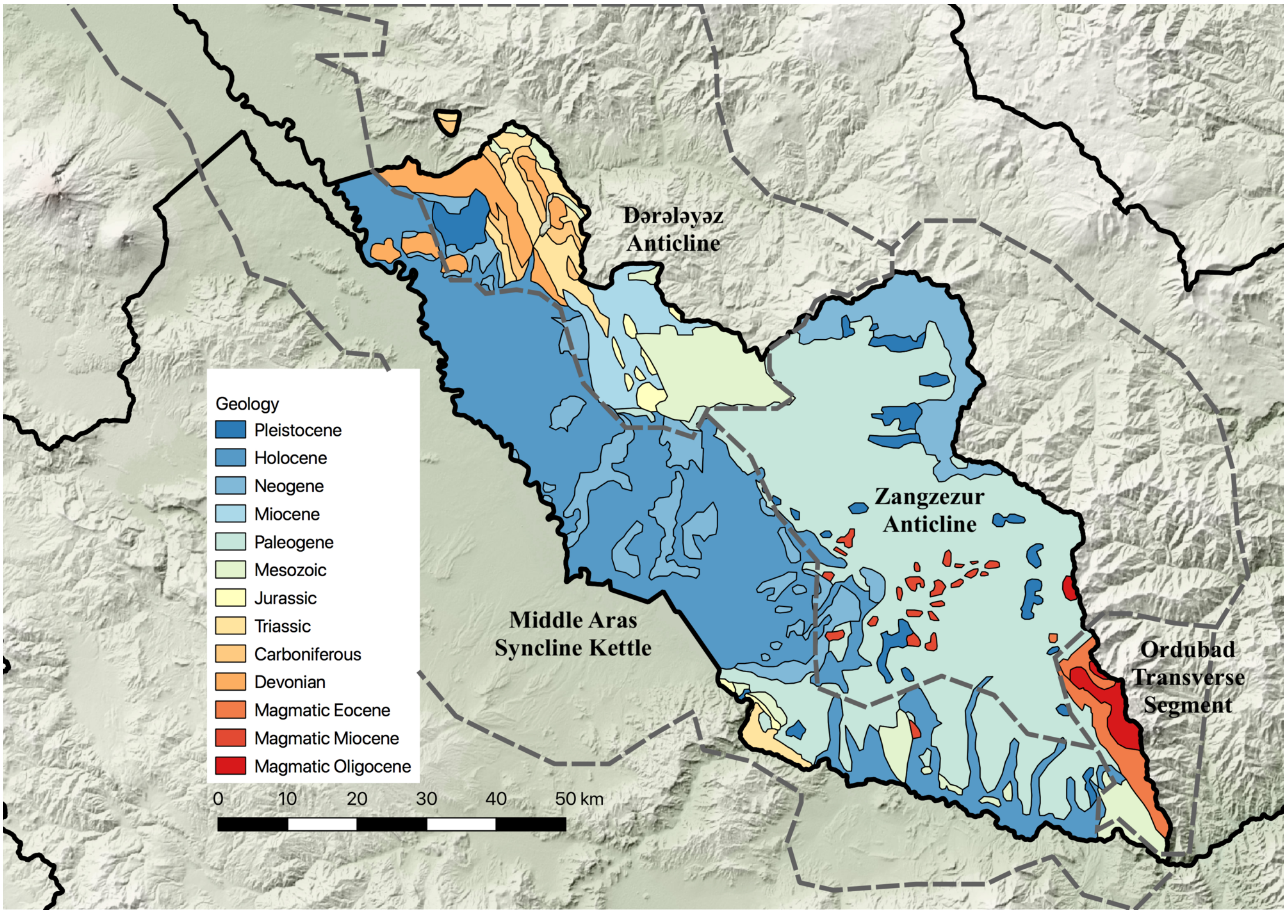

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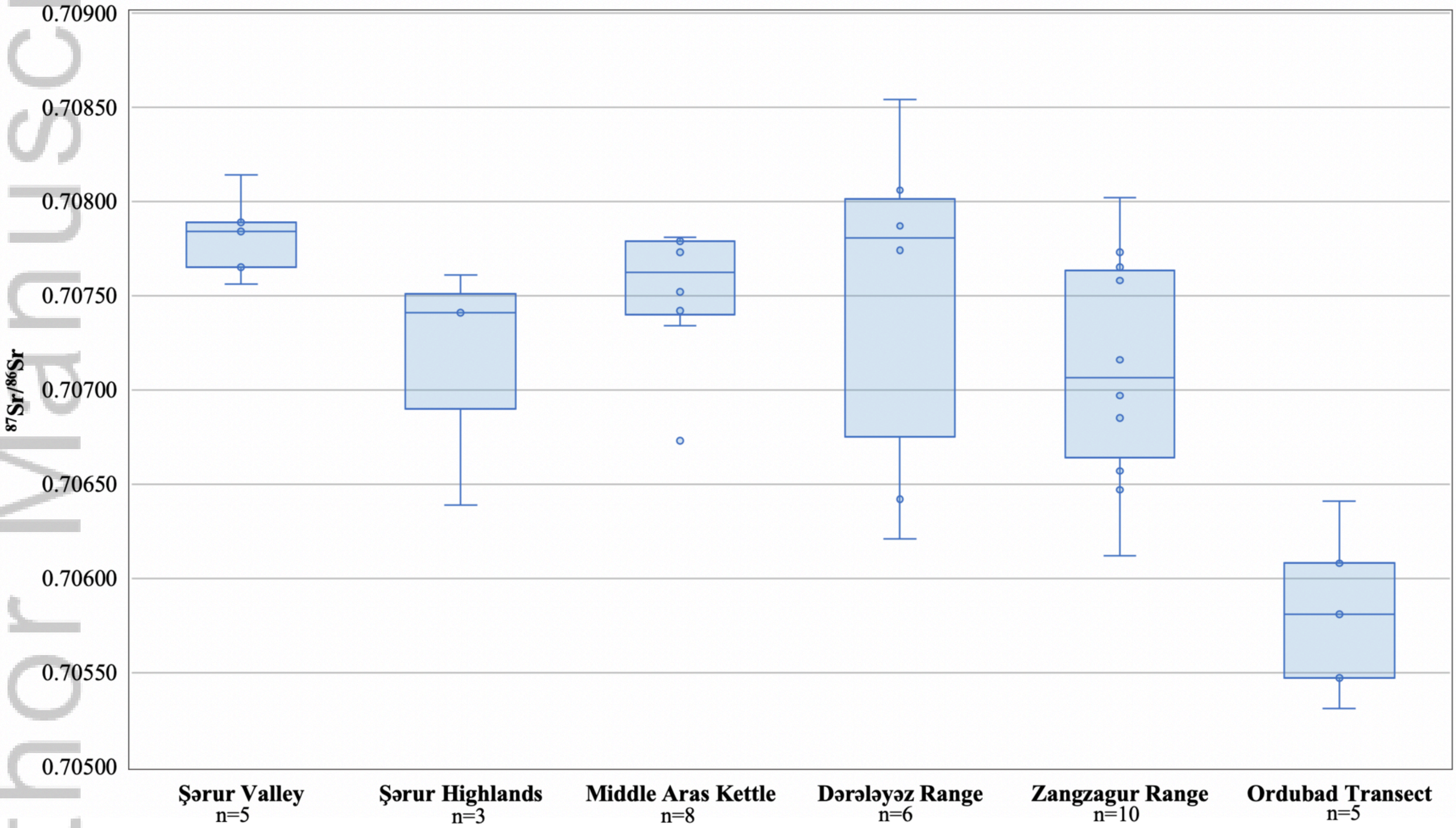

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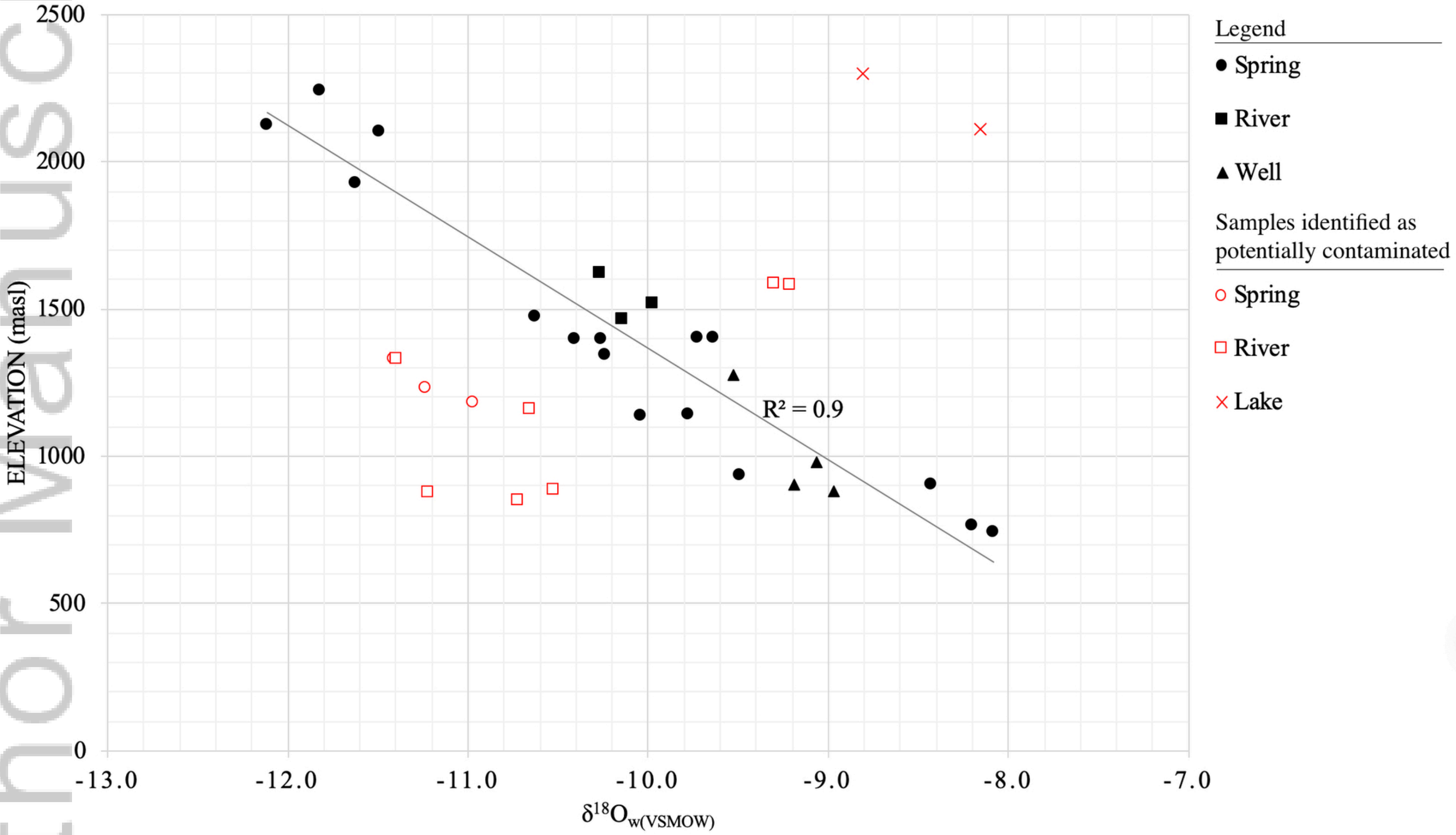

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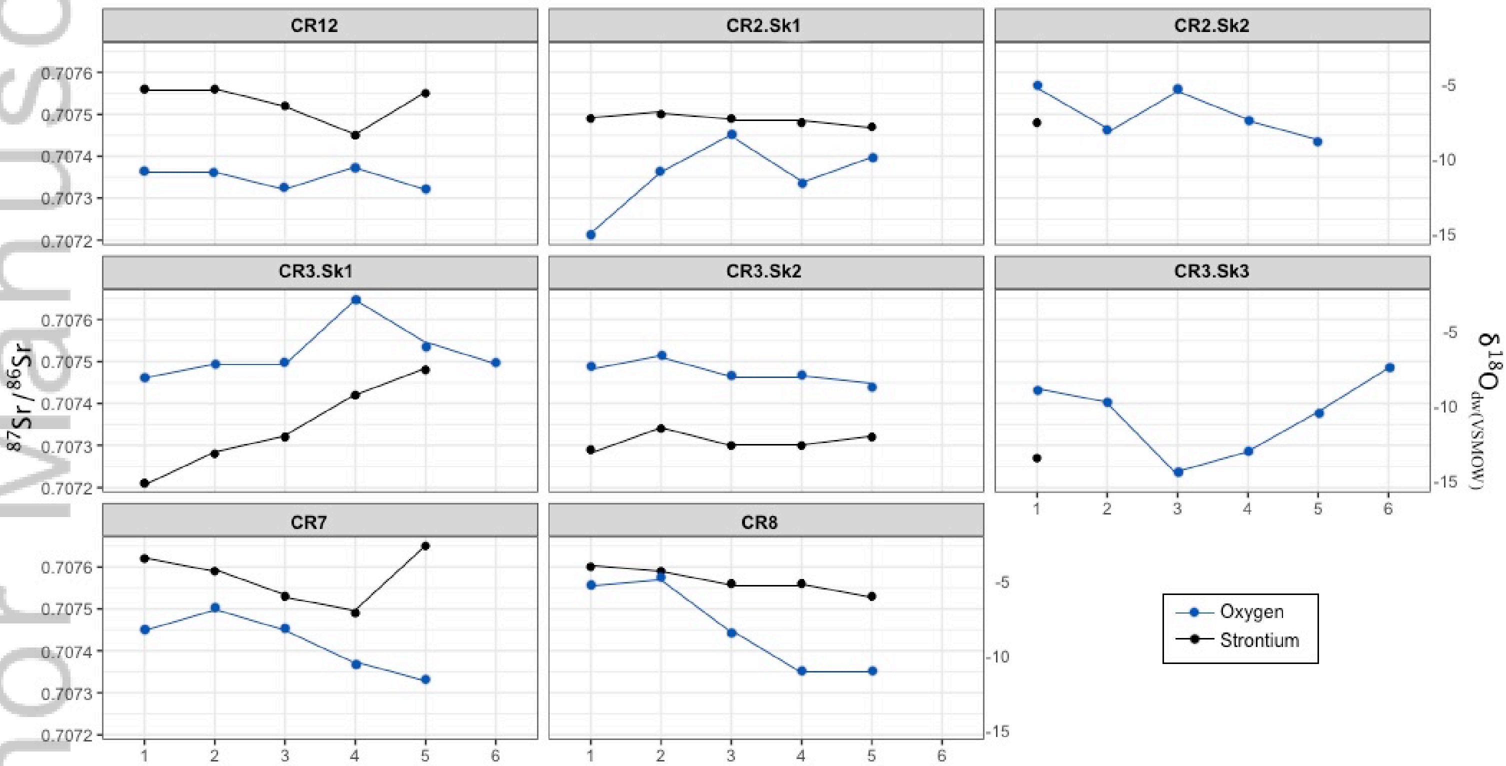

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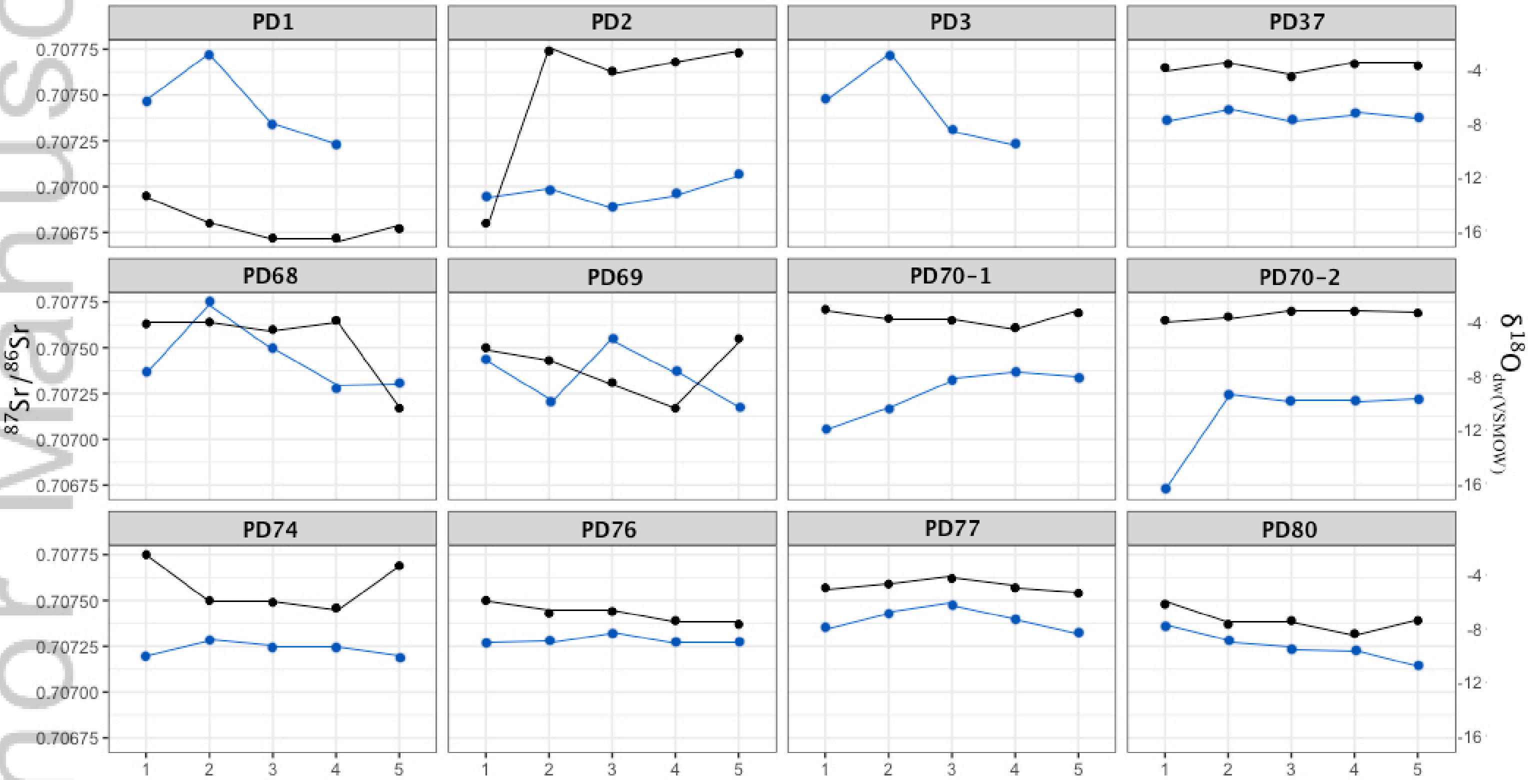

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TABLE 1 Qızqala MBA burials excavated for this study, individuals sampled for isotopic analysis, and contextual archaeological information.

Burial ID*	Skeleton ID	Area	Group	Sex	Age	Sampled Elements	Burial Description
CR2	CR2.Sk1	Highland	I	U	Adult	M1 M3 (n=5) Rib	Flexed, facing CR2.Sk2. Hands placed on the face. Surrounded by bowls and large jars
CR2	CR2.Sk2	Highland	I	U	Adult	M1 M3 (n=5) Rib	Flexed, facing CR2.Sk1. Holding a neonate caprid. Surrounded by bowls and large jars
CR3	CR3.Sk1	Highland	I	U	Adult	M1 M3 (n=5) Rib	Primary interment. Individual flexed, wears a necklace and bracelet made of assorted beads, and associated with a small cache of obsidian arrows. Accompanied by caprid remains, two cattle crania, and several bowls and jars.
CR3	CR3.Sk2	Highland	I	U	Adult	M1 M3 (n=5) Rib	Secondary interment. Individual flexed and held a neonate caprid and a neonate canid. Accompanied by caprid remains, two cattle crania, and several bowls and jars.
CR3	CR3.Sk3	Highland	I	U	16-17	M1 M3 (n=5) Rib	Secondary interment. Individual flexed and wore a burnished shell possible necklace. Accompanied by caprid remains, two cattle crania, and several bowls and jars.
CR4	No Human Remains	Highland	I	-	-	-	Disturbed burial
CR6	CR6	Lowland	II	U	Adult	Femur	Individual accompanied by small collection of bowls and jars, quiver of obsidian arrows, obsidian scraper, whetstone, and bronze pin
CR7	CR7	Lowland	II	F	30-40	M1 M3 (n=5) Rib	Individual held a small jar and bowl in each hand. Accompanied by additional bowls, a quiver with multi-colored obsidian arrows, bronze pin, and spearhead
CR8	CR8	Lowland	II	M	30-40	M1 M3 (n=5) Rib	Individual wore a bib-like beaded necklace and was surrounded by a circle of stacked bowls and jars, arrows, spearhead, many bronze pins. Burial also contains a nearly complete cattle.
CR9	No Human Remains	Highland	III	-	-	-	Disturbed burial
CR11	No Human Remains	Highland	III	-	-	-	Disturbed burial
CR12	CR12	Lowland	II	U	Adult	M1 M3 (n =5) Rib	Individual was surrounded by small bowls, a jar, a cup, a groundstone, and wore a carnelian bracelet
CR13	No Human Remains	Lowland	II	-	-	-	Likely burial, but no preserved human remains
CC4	CC4	Lowland	Isolated	M	50+	I1 I2 C Rib Femur	Simple pit with no architecture and no objects. Individual's hands and feet were bound and contained charred twigs

TABLE 2 Descriptive statistics and statistical parameters of $^{87}Sr/^{86}Sr$ and $\delta^{18}O_{dw(VSMOW)}$ values from human remains by burial group and archaeological site. Burial Group III was excluded because it had no preserved human remains. Statistically significant values ($p<0.05$) are italicized.

	$^{87}Sr/^{86}Sr$								**$\delta^{18}O$ (‰)**							
	Residential Bulk bone and dental enamel				**Seasonal** M3 Sequence				**Residential** Bulk bone and dental enamel				**Seasonal** M3 Sequence			
	Min	**Max**	**Mean**	**SD**	**Min**	**Max**	**Mean**	**SD**	**Min**	**Max**	**Mean**	**SD**	**Min**	**Max**	**Mean**	**SD**
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Group II	0.70756	0.70767	0.70761	0.00003	0.70745	0.70765	0.70756	0.00005	-12.2	-4.3	-9.0	3.3	-11.6	-4.6	-9.3	2.3
Isolated Burial	0.70660	0.70679	0.70672	0.00007	-	-	-	-	-10.8	-7.9	-8.8	1.0				
Site	*p = 0.012*				*p = 0.028*				*p* = 0.274				*p* = 0.823			
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Plovdağ	0.70672	0.70814	0.70749	0.00028	0.70672	0.70775	0.70747	0.00027	-13.6	-4.8	-8.1	2.1	-16.3	-2.3	-8.5	2.5