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Identifying communal interaction and mobility in the peruvian central coast through strontium isotope analysis of human individuals in Huaca 20

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ABSTRACT

We present the results of strontium isotope analysis conducted on human individuals recovered at the Huaca 20 sector of the Maranga Complex; a Late Lima settlement of the Lower Rimac Valley that flourished during the Middle Horizon Epoch 1 (600–800 CE). Our aim is to evaluate the diversity of the Huaca 20 population through an integrated approach that combines contextual analysis of burials' associations, the bioarchaeological characterization of the buried individuals and the acquisition of $^{87}Sr/^{86}Sr$ compositions of individuals' tooth enamel to explore early-life values and probable geographic origins. Our results reveal a scenario of a mainly local population with a minority of foreign individuals that suggest mobility consistent with post marital residential patterns. The lack of correlation between individual's origins and a diversity of burial practices and associations (as for example, foreign umber ware ceramics) suggests that mobility might have occurred as a continuous phenomenon, which resulted in a cosmopolitan population, generated under regional interactions that occurred beyond elite control.

1. Introduction

The Middle Horizon Period (ca. 600–1000 CE) is well known for the rise of state polities like Wari and Tiwanaku, which expanded throughout the Central and South-Central Andes. Currently, there is a consensus that, rather than simple cultural imposition, this expansion dealt with cultural and social diversity, resulting in a mosaic of political strategies (Schreiber 1992, Segura 2017). It has also been argued that this period witnessed a more active role of local politics, involved in an interregional trade network (Shady 1982) or in a globalized realm (Jennings 2010). In this context, during the Middle Horizon Epoch 1 (MHE1: 600–800 CE) interregional interaction was manifested in the spread of fine wares far beyond their production zone (Castillo, 2000:8, Lau 2005:88) or the appearance of hybrid styles (Valdez 2015). This kind of evidence is usually used to state the existence of interregional networks and the economic and political strategies of regional elites.

In contrast, the involvement of commoners within the proposed interaction networks during this time has seldom been addressed, due in part to the lack of contextual information on domestic or public spaces related to these social strata and its associated material culture. Nonetheless, it is worth asking how human communities, throughout the Central Andes, were involved in the ongoing interregional networks besides the elite's agency and influence. A possibility for addressing this topic appears in the MHE1 scenario of the Peruvian Central Coast.

The MHE1 in the Central Coast is characterized by large-scale architectural complexes associated with the Late Lima phase (Fig. 1a). Within these sites, we found a repertoire of pottery characterized by an umber ware and a distinctive set of vessel shapes that differ from the common orange wares of Lima pottery (Ccencho 2012, Segura 2001:102–103, Segura, 2023:363, Vega Centeno and Palomino 2022). The singularity of this ware suggested a foreign origin, something that was confirmed by compositional analysis (Vega Centeno and Palomino 2022:339–349) and its commonalities with ceramics found in the upper sections of the Lima valleys (Goldhausen 2012:150–156).

The presence of these vessels in Lima settlements raises questions concerning how they were acquired. Was it the result of goods exchange or the result of people mobility? These questions are difficult to answer as most of the recovered ceramic sherds come from construction fills or

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other sedimentary deposits. Fortunately, umber ware ceramics have also been identified in funerary contexts, at the Huaca 20 Sector (Fig. 1b), a medium sized “neighborhood” located at the eastern edge of the Maranga Complex (Vega Centeno and Epiquién 2022). At Huaca 20, more than 800 burials revealed not only diverse ceramic wares, but a wide set of different funerary practices (Mac Kay 2006, Mauricio 2012, Chuyacama 2021). It is thus a promising context in which to address the nature and composition of Late Lima populations at a communal level and their involvement on interregional interactions. Hence, after an initial contextual analysis, we incorporated an analysis of strontium isotopes of tooth enamel from human individuals, to evaluate if such interaction included people’s mobility.

1.1. Mobility and post marital residence

The role of migration and human mobility in shaping historical processes throughout the world is becoming central in archaeological discussions (Clark et al. 2019, Gregorika 2021:604). Within current debates, mobility at an individual level, usually related to post marital residence, is also addressed, as it is a practice that serves to integrate communities, creating the conditions for the development of regional networks (Schillaci 2002:343). It also serves to address gender-based

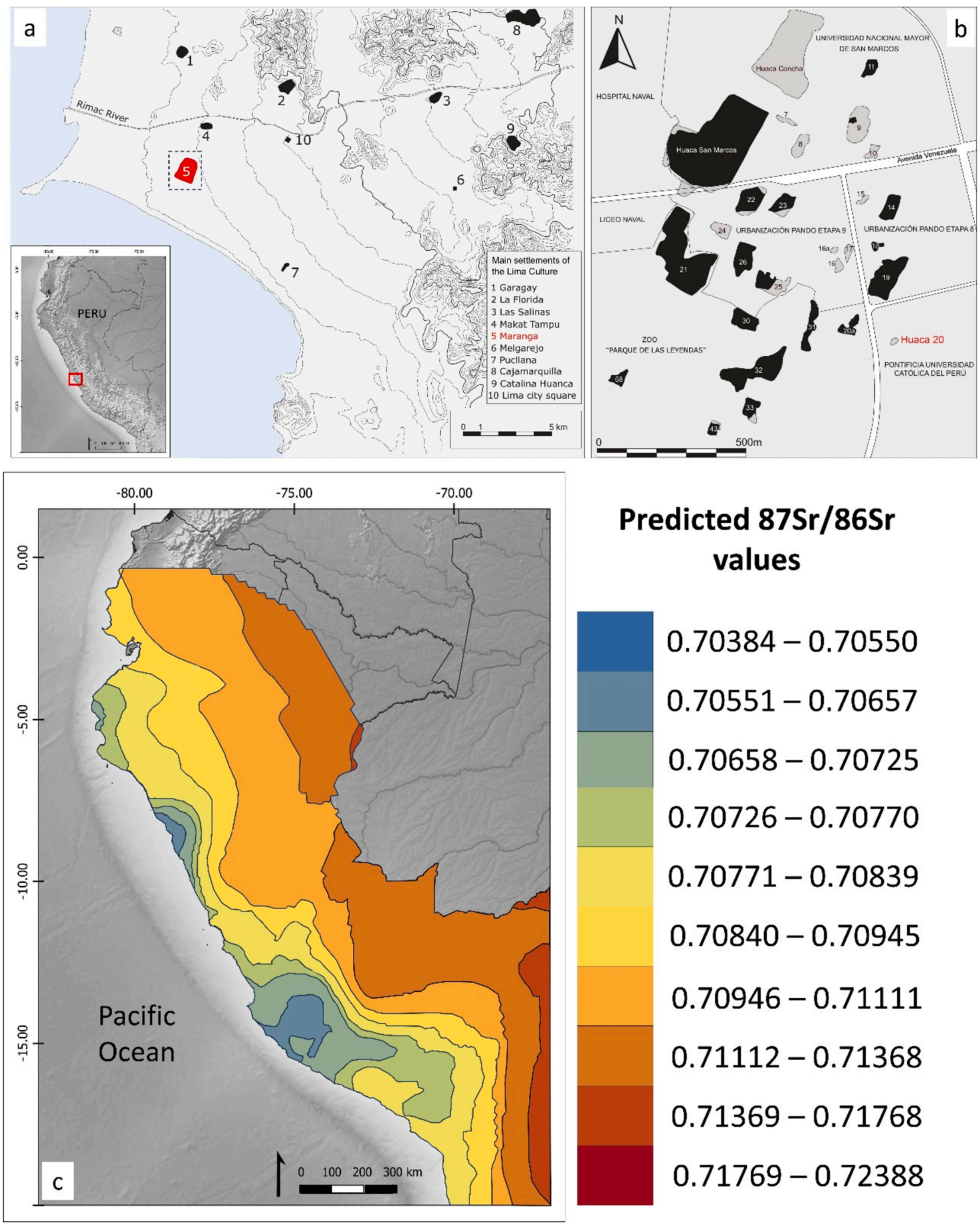

Fig. 1. A) location of huaca 20 in the lower rimac valley, central coast of peru, and other archaeological sites mentioned in this study; b) location of huaca 20 into the maranga complex; c) predicted $^{87}Sr/^{86}Sr$ isoscape for the Central Andes (redrawn from Scaffidi and Knudson, 2020: Figure 7).

practices in migration phenomena (Tung 2012:44).

Unlike discrete migration events, post marital mobility occurs as continuous behaviors, which are more complicated to identify in the archaeological record (Schillaci 2002). Some of these difficulties are starting to be solved after the incorporation of bioarchaeological approaches, and particularly the study of strontium isotopes in bones and teeth, which allowed the identification of both local and non-local individuals. Under this perspective, the discussion of patrilocal (Haaka et al. 2008, Bentley 2013, Bentley et al. 2012) and matrilocal (Bentley et al. 2005, Eerkens et al. 2014) patterns of residence with the implied patterns of mobility are currently addressed. This opens a promising scenario for expanding our comprehension of interregional dynamics at a micro social level and its implications.

We should also note that studies on post marital residential patterns have often been applied to groups of hunter-gatherers or village-farmers and have seldom been addressed in scenarios of social complexity. Hence, it is worth asking about their relevance in the development of regional interactions and the generation of cosmopolitan populations within stratified societies. The evidence at Huaca 20, at the Maranga Complex, indicates the existence of a human community with a wide variety of funerary practices, which reveals an openness to diversity. We consider that the understanding of this apparently cosmopolitan behavior will be favored by independent lines of evidence, like the origins of humans within the community through strontium isotopes.

1.2. Radiogenic strontium and the Andean region

Strontium isotope analysis is a well stablished method for the study of past human mobility in archaeology for the last 35 years. The method allows the assessment of geographical origins and patterns of residence/migration over discrete geographic areas (Bentley 2006, Bickle 2024).

Strontium has four isotopes that occur with different quantities in nature: ^{84}Sr (0.56 %), ^{86}Sr (9.87 %), ^{87}Sr (7.04 %), and ^{88}Sr (82.53 %). ^{87}Sr is a radiogenic isotope resulting from the radioactive decay of ^{87}Rb over time, with a half-life of 4.88 x 10^{10} years. Since additional ^{87}Sr is contributed from the decay of ^{87}Rb, the isotopic ratio ^{87}Sr/^{86}Sr varies according to the type and age of rocks where ^{87}Sr/^{86}Sr represents the abundance of the natural plus radiogenic ^{87}Sr relative to the non-radiogenic ^{86}Sr (Bentley 2006). Generally, older rocks have higher ^{87}Sr/^{86}Sr than younger rocks, but rocks of different types with similar ages may show different Sr isotopic ratios. In general, rocks composed of minerals with high Rb/Sr ratios (such as granites) tend to have elevated ^{87}Sr/^{86}Sr ratios ($>$ 0.710), while rocks with low Rb/Sr ratios (such as oceanic basalts) have low ^{87}Sr/^{86}Sr ratios (~0.704: Capo et al. 1998; Bentley 2006; Marsteller et al. 2017). Seawater has a current ^{87}Sr/^{86}Sr ratio of 0.7092 (Veizer 1989; Price et al. 2002).

Through weathering processes, the strontium contained in rocks enters soils, rivers, groundwater and food chains. Theoretically, because strontium is a “heavy” element, ^{87}Sr/^{86}Sr show negligible kinetic and equilibrium fractionations at environmental temperatures, thus, processes such as evaporation and precipitation, photosynthesis, or bone synthesis, do not alter the isotopic ratio reflecting the same ^{87}Sr/^{86}Sr ratio of the source (Schoeninger 2010). Nevertheless, there are several factors that can influence this process, such as the presences of volcanoes, the deepness of phreatic waters, degrees of erosion etc. (Bentley 2006). Since animals feed on a combination of resources from their ecosystem, in areas with varied geological formation, the ^{87}Sr/^{86}Sr ratios usually represent a mix of different environmental signals. Thus, an individual (a consumer) only matches the biologically available not geological Sr isotope signals (Price et al. 2002, Knudson et al. 2014, Marsteller et al. 2017, Grupe et al. 2020).

In theory, the detection of interindividual variability of ^{87}Sr/^{86}Sr ratios may allow the recognition of foreigners or “first generation” immigrants, whereas intra-individual variability can reflect potential differences of residential place over the lifetime. Both approaches provide valuable insights on the nature and scale of migration in past populations (Bentley 2006; Knudson and Torres-Rouff 2014; Copeland et al. 2016).

Studies based on strontium isotope analysis have proved its effectiveness for Andean research. This is the case of the identification of highland colonizers/settlers at the Moquegua Valley during Tiwanaku times (400–1000 CE) (Goldstein 2000), the assessment of the origins of individuals and trophy heads recovered from Nasca cemeteries (Conlee et al. 2009), and in the Wari site (Tung 2012:42–43), the multiethnic origin of individuals buried in ceremonial centers like Tiwanaku (Knudson et al. 2004), as well as the probable cosmopolitanism of Machu Picchu and other imperial settlements during the Inka period (Turner et al. 2009; Andrushko et al. 2009). In that sense, our study on Huaca 20 human remains from the Central Coast will contribute to expanding our understanding of mobility in the Andes through strontium isotope analysis.

1.3. The Central Coast during the Middle Horizon Epoch 1. The case of Huaca 20

The Peruvian Central Coast, during the MHE1 was the location of several cultural changes that imply both internal growth and external influences. It is the time of massive construction projects, which ended in large architectural complexes such as Maranga, Copacabana, Pucllana, Cajamarquilla and Catalinahuanca (Canziani 2009).

Ceramic assemblages also experienced important changes, with the proliferation of large storage jars and ollas related to large scale feasting activities (Segura 2001, Ríos 2008, Pacheco 2014). This is also the time where the Nievería style appears, depicting new vessel shapes made with a fine ware, that combines in their decoration both local and foreign motifs, whose origins can be traced to the north and south coast, but mainly to the Ayacucho region, where the Wari culture was starting to develop (Valdez 2015).

As mentioned before, recent studies have also addressed that not only Nievería ceramics might reveal foreign contacts, but also domestic, umber wares, that are frequently present in Lima sites, and seem to come from the medium or upper sections of the Lima valley (Goldhausen 2012, Vega Centeno and Palomino 2022).

Hence, ceramic data offers a suggestive scenario of interregional interaction at different levels and scales during the MHE1 period (600–800 CE, which corresponds to the Late Lima phase) in the Central Coast. To expand our comprehension of such interaction, it is necessary to work with more precise contextual data on the presence of foreign wares. The mortuary assemblage of Huaca 20, at the Maranga Complex, provides an archaeological context where ceramics and human remains can be confronted.

The Maranga Complex is a large urban settlement located in the southern margin of the lower Rimac Valley. It spreads over ca. 1.5 square kilometers and includes up to six major platform mounds and smaller structures. These structures were surrounded by courtyards, rooms and corridors that gave shape to an urban layout (Vega Centeno and Lang 2021). Huaca 20 is a sector of Maranga, located at its eastern edge. It is composed of a set of small domestic structures with basements of adobe or cobbles (Mauricio 2012, 2015; Vega Centeno and Epiquién 2022). Both architectural and contextual information suggest that Huaca 20 settlers were dedicated to several economic activities such as pottery making, food processing and fishing (Vega Centeno and Epiquién 2022, Prieto 2014).

Excavations also recovered the remains of more than 800 buried individuals that seem to correspond to Huaca 20 inhabitants. Burials were found both beneath and over the residential structures, indicating that more than one generation was buried in this zone.

Burials at Huaca 20 have revealed a significant variability in funerary treatments. Individuals may appear in extended or flexed positions, face down or face up. There is also a high variability in burial orientation, associated pottery and other funerary artifacts (Mauricio 2012, Mac Kay 2001, Chuyacama 2021). Among ceramics, the non-local umber ware cooking pots appear in some contexts and are seldom associated with other types of pottery. This scenario of diversity opens the question about the nature of Huaca 20 inhabitants. Are they from distinct places? Or are they local people imbued into cosmopolitanism? What are the implications of any of those scenarios for our comprehension of the regional dynamics during Late Lima times?

2. Materials and methods

2.1. Individuals and sampling strategy

To address these questions, we conducted a strontium isotope analysis in tooth enamel of 48 individuals exhumed from Huaca 20, dated to the MHE1 at Maranga (620–780 CE) (Vega Centeno et al. 2021). The project was approved by the Ministry of Culture of Peru (RD 000067-2023 DGM/MC). The information on age and sex was obtained from the original field reports (Rengifo et al. 2006, 2007, Ramos 2012, Villacorta 2013) and, in cases that needed clarification, the skeletal remains were reanalyzed, using morphological features of the skull and pelvis (Buikstra and Ubelaker 1994). The sample includes 29 females, 16 males, and 3 undetermined individuals (1 adult and 2 subadults).

These individuals have in common that they are buried with a cooking pot among their grave goods. The choice of individuals with cooking pots was due to the compositional and formal variability of this type of vessel. Indeed, cooking pots from our sample correspond to five different types (Fig. 2). One of them corresponds to the umber ware of non-local origin and show concave necks that are differentiated by its height (Vega Centeno and Palomino 2022). The other four correspond to orange wares and can be distinguished by the shape of their necks. Type 2 resembles umber ware vessels, while types 3, 4 and 5 show smaller or larger necks.

Our sample is also representative of the variability on individuals' positions and orientations previously described for Huaca 20. Whereas there is no clear-cut correlation between wares and individuals by sex or position in the funerary context, there are some tendencies for certain kind of funerary assemblages (Table 1, see also Supporting Information: ST1). For example, individuals buried with umber ware pots are mainly female (12 cases of 14) and, when these have more offerings than cooking pots, they are mainly spindle whorls (7 cases of 8). In contrast, there is a more balanced distribution of individuals buried with orange ware pots in terms of sex (18 female and 15 male), and the set of offerings include ground stones, bright minerals, shellfish and metal artifacts (mainly fishhooks). It should be noted that spindle whorls are also frequent on those individuals buried with cooking pots of type 2, which seems to resemble type 1 umber ware pots.

The observed trends confirm a scenario of highly diverse funerary treatments, with individuals buried in extended or flexed positions.

Fig. 2. Types of cooking pots from Huaca 20 burials.

Those buried with cooking pots also show a relatively variable set of offerings, where spindle whorls are frequent and used to be associated with females (although there are a few cases in male burials). In addition, although some correlations might be observed between ware types, sex and other kinds of offerings, the lack of clear-cut divisions among funerary patterns suggest a scenario of diversity but also of emulation and, perhaps, partial coalescence of different cultures. Hence, the sample studied becomes favorable to address the research questions outlined before regarding the degree of diversity among Huaca 20 inhabitants.

One tooth by individual was selected for $^{87}Sr/^{86}Sr$ analysis. We sampled only well-preserved teeth (those that looked more compact and non-friable) from the best-preserved burial contexts. Due to burials being located in productive land and the more recent urban expansion, most of the skeletons show poor preservation related to taphonomic damage produced by repetitive flooding events at the site (Mauricio 2015). However, this is more evident in bones, and tooth enamel, which is a tissue much more resistant than bone to diagenesis, seems to be well preserved (Pezo-Lanfranco et al. 2023, 2024b).

Because tooth enamel develops during infant and juvenile growth/development life-stages, in this study $^{87}Sr/^{86}Sr$ values are related to early infancy and childhood ages. Comparing $^{87}Sr/^{86}Sr$ ratios from different teeth and individuals, require a necessary standardization. Thus, each enamel sample, corresponding to dental crowns of different types of teeth were aged with a conventional development/eruption chart (AlQahtani et al. 2010). Then were classified by "tissular-age" into wide age-categories (i.e., Infants: 0–6 yrs; Children: >6–11 yrs; and Adolescents: >11–20 yrs). To examine residential origins and potential mobility we compared these early-life $^{87}Sr/^{86}Sr$ ratios with the expected $^{87}Sr/^{86}Sr$ values from the settlement area, the lower Rimac Valley, and neighbour regions (Slovack et al. 2009; Knudson et al. 2014; Marsteller et al. 2017; Scaffidi and Knudson 2020; Scaffidi et al. 2022).

2.2. Laboratory methods of $^{87}Sr/^{86}Sr$ measurements

After mechanical cleaning to remove remnant sediments, a longitudinal portion (a flake) of the entire tooth crown, from the occlusal third to the cemento-enamel junction, was sectioned to obtain a bulk enamel sample corresponding to the crown formation period. The sectioning was performed with a clean carbide blade attached to a Dremel MultiPro rotatory device.

To evaluate bioapatite diagenesis, enamel samples were analyzed using a FTIR Bruker ALPHA II compact spectrometer, coupled to an Eco-ATR. Spectra of 1 mg of enamel powder were collected in absorbance (A) mode with a spectral range of 400 to 4000 cm^{-1} (ν), for 100 scans and a resolution of 8 cm^{-1}. Spectra and baseline corrections were performed with OPUS 7.8 software. We assessed two indices (IRSF and C/P) according to conventional values (France et al. 2020).

Enamel samples were analyzed in the Department of Geological Sciences at the University of Cape Town, South Africa. Sample preparation followed the procedures of Pin et al. (1994) and the chemical analysis followed the procedures of Deniel and Pin (2001) modified by Copeland et al. (2008). Powdered enamel samples were weighed into 7 ml Savillex PFA beakers, 2–3 ml of 65 % HNO3 was added, the beakers closed and kept at 140 °C for 1 h. Following complete sample dissolution, the samples were dried and taken up in 1.5 ml of 2 M HNO3. The strontium fraction was then isolated following the procedure in Pin et al. (1994) using Eichrom Sr-Spec resin, and dried down, before being redissolved in 0.2 % HNO. Isolated Sr fractions were subsequently analyzed as 200 ppb Sr solutions using a NuPlasma HR MC-ICP-MS.

The enamel samples were processed alongside repeats of the in-house carbonate reference material (NM95) which yielded an average 87Sr/86Sr value of 0.7089015 ± 0.000028 (n = 24). This was in good agreement with the long-term average of this reference material at the facility of 0.708911 ± 0.000040 [2σ]; n = 414. All 87Sr/86Sr data presented are referenced to bracketing analyses of the international strontium isotope standard NIST SRM987 ($^{87}Sr/^{86}Sr$ reference value of

Table 1
Contextual Data on the burials' sample from Huaca 20.

Burial	Sex	Position	Cooking pots		Other associations				
			Ware	Type	Other vessel types	Spidle whorls	Stone	Shell	Metal
T 9	Und	Extended	Orange	2					
T 16	M	Extended	Orange	nd	X				
T 19A	M	Extended	Orange	3					
T 19B	Und	Extended	Orange	3					
T 25	F	Flexed	Umber	1					
T 27	F	Extended	Umber	1					
T 41	M	Flexed	Orange	nd					
T 44	F?	Flexed	Orange	4					
T 45	M	Extended	Orange	4					
T 47	M	Extended	Umber	1					
T 48	M	Extended	Orange	5					
T 50	F?	Flexed	Orange	3					
T 55	F?	Extended	Umber	nd					
T 57	F?	Extended	Orange	3	X				
T 62	M	Extended	Orange	3	X				
T 68	F	Extended	Orange	2		X			
T 73	M	Flexed	Orange	4			X		
T 79	F	Flexed	Umber	1	X				
T 83	M	Flexed	Umber	1	X	X			
T 84	M	Flexed	Orange	4					
T 85	M	Extended	Orange	2					
T 94	F	Extended	Umber	1					
T 101A	F?	Flexed	Orange	2	X				
T 101B	F	Flexed	Umber	1					
T 102	F	Extended	Orange	5	X		X	X	
T 107	F	Flexed	Orange	2		X			
T 114	F?	Flexed	Umber	1					
T 117	F?	Flexed	Umber	nd	X				
T 126	F	Extended	Orange		X				
T 152	F	Flexed	Orange	2		X	X	X	
T 167	F	Flexed	Orange	2		X	X	X	
T 206	F	Flexed	Orange	5		X			
T 207	F	Extended	Umber	1		X			
T 211	M	Flexed	Orange	5			X	X	X
T 215	M	Extended	Orange	5					X
T 248	M	Extended	Orange	5			X		X
T 251	Und	Flexed	Orange		X				
T 309	F	Extended	Orange	2	X				
T 313	M	Extended	Orange	3		X			
T 332	F	Extended	Orange	5		X			
T 340	F	Extended	Orange	4		X			
T 368	F	Flexed	Umber	1		X			
T 371	F?	Extended	Umber	1		X			
T 374	F	Flexed	Orange	2					
T 378	F	Flexed	Umber	1		X			
T 383	F	Flexed	Orange	2		X			
T 387	F	Flexed	Gray	5					
T 393	M	Extended	Orange	3					

Sex: M = male, F = female, Und = undetermined;?=Probable; **nd:** non-diagnostic.

0.710255). Sample values were corrected for instrumental mass fractionation using the exponential law and an $^{86}Sr/^{88}Sr$ value of 0.1194, while the isobaric ^{87}Rb interference was corrected using the measured ^{85}Rb signal and the natural $^{85}Rb/^{87}Rb$. Total procedural blanks processed with samples in this facility yielded background Sr levels < 250 pg and were therefore negligible.

2.3. Statistical analysis and integrative methods

We report $^{87}Sr/^{86}Sr$ values to the conventional six decimal places, but we use them here to the fifth decimal place for statistics (Bentley 2006). Previous paleomobility studies used $^{87}Sr/^{86}Sr$ ratios to the third decimal place to detect inter-individual variation, and to the fourth decimal place for intra-individual variability. Differences in the fifth decimal place may be unreliable due to intra-individual variability or laboratory imprecision (Knudson et al. 2016).

To identify probable non-local individuals and answer our research questions, after an exploratory analysis of $^{87}Sr/^{86}Sr$ ratios (Shapiro-Wilk test), we performed descriptive (mean, range, standard deviation) and inferential (ANOVA and Chi-square tests) analyses between groups using the SPSS v.28 package. Individuals with $^{87}Sr/^{86}Sr$ which fall within the range of the H20 average values plus and minus two standard deviations (2σ) are considered "locals", whereas individuals outside of the 2σ range are considered "non-locals" (Knudson et al. 2004, 2016).

Then, we compared the acquired $^{87}Sr/^{86}Sr$ individual's ratios with faunal data (Slovak et al. 2009; Knudson et al. 2014, Marsteller 2015, Marsteller et al. 2017), and strontium bioavailability isoscapes of the Lima Valley and the Central Coast (Knudson et al. 2014, Marsteller 2015, Scaffidi and Knudson 2020). Finally, we compare Huaca 20 values with all the available $^{87}Sr/^{86}Sr$ values from humans and fauna of the Peruvian Central Coast extracted from the South American Archeological Isotopic Database (Pezo-Lanfranco et al. 2024b). Thus, we interpret the data in terms of the observed in the archeological contexts at burial, site, and regional levels.

Human $^{87}Sr/^{86}Sr$ values reflect the biologically available strontium in the environment (e.g., plants, fauna) where individuals lived at the time of tissue development (Price et al. 2002, Grupe et al., 2020). To identify non-local individuals and their places of origin by comparison with bioavailable $^{87}Sr/^{86}Sr$ local baselines in the Peruvian Central Coast is challenging and several factors should be considered with caution. 1) The bedrock of Maranga and lower Rimac Valley correspond to Quaternary geological sediments, the middle valley corresponds to Cretaceous and Jurassic deposits, and the high sections to Mesozoic, Cenozoic and intrusive rocks (Marsteller et al. 2017). Additionaly, the Rimac Valley is particularly prone to landslides and flooding in its upper section, which can lead to a mixing of sediments and isotopic signatures in the productive soils of the lower-altitude areas, producing considerable variability and overlapping $^{87}Sr/^{86}Sr$ values (Marsteller et al. 2017, Scaffidi and Knudson 2020:14). 2) The variability of water sources in the Rimac and Lurín Valleys has been argued to explain the wide range of $^{87}Sr/^{86}Sr$ observed among human individuals (Slovak et al. 2009, Marsteller et al. 2017), but recent research suggests that predicted water values account for only 7 % of this variability (Scaffidi et al. 2020). 3) Although there are significant differences in $^{87}Sr/^{86}Sr$ between soils from highlands and lower sections, the values do not always match with the fauna signals of those regions (Slovak et al. 2009, Knudson et al. 2014, Marsteller 2015, Marsteller et al. 2017).

The predictive isoscape (Fig. 1c) used for comparisons in this study is based on $^{87}Sr/^{86}Sr$ values from human, faunal and botanical archaeological samples, which provide more accurate estimates of bioavailable strontium for human mobility assessments than bedrock, productive soils, or water in this region (Knudson et al. 2014, Scaffidi and Knudson 2020). The values of $^{87}Sr/^{86}Sr$ for the lower Lurin Valley and the lower Rimac Valley, where Huaca 20 is located, range from 0.70726 to 0.70770; for the middle and upper sections of the Rimac Valley and the coastal area of Ancon, to the north, the $^{87}Sr/^{86}Sr$ values range from 0.70771 to 0.70839; and for the upper sections of Chillón Valley, to the north, range between 0.70840 and 0.70945 (Scaffidi and Knudson 2020: Fig. 7).

3. Results

3.1. Interindividual variations of strontium ratios

The $^{87}Sr/^{86}Sr$ results from 48 individuals of Huaca 20 are presented in Table 2. According to the "tissular age" of the teeth sampled these

Table 2
Burial features and tooth enamel $^{87}Sr/^{86}Sr$ values from Huaca 20 individuals (n = 48) examined in this research.

Burial	Sex	Age Category	Age-range (years)	Material	Tooth (crown)*	Tissue age (years)	$^{87}Sr/^{86}Sr$	s.d.
T9	Und	Infant	1–5	Enamel	Lower LM1	0.4–3.5	0.706949	0.000010
T16	M	Middle Adult	±35	Enamel	Lower RM1	0.4–3.5	0.707292	0.000013
T19A	M	Adult	nr	Enamel	Upper RPm2	3.5–6.5	0.706925	0.000010
T19B	Und	Infant	1–5	Enamel	Upper Li1	0.2	0.707490	0.000012
T25	F	Young Adult	±25	Enamel	Lower LPm1	2.0–5.5	0.707137	0.000012
T27	F	Adult	nr	Enamel	Upper LM1	0.4–3.5	0.707208	0.000012
T41	M	Young Adult	±33	Enamel	Lower LM1	0.4–3.5	0.707202	0.000011
T44	F?	Adult	nr	Enamel	Upper RM2	2.5–8.0	0.707805	0.000015
T45	M	Adult	nr	Enamel	Upper RI2	0.8–5.0	0.707135	0.000012
T47	M	Adult	nr	Enamel	Lower Pm	2.0–6.5	0.707238	0.000013
T48	M	Adult	nr	Enamel	Lower RM2	2.5–8	0.706932	0.000010
T50	F?	Adult	nr	Enamel	Lower M3	8.5–14.0	0.707140	0.000011
T55	F?	Adult	nr	Enamel	Lower RM2	2.5–8.0	0.707289	0.000012
T57	F?	Adult	nr	Enamel	Lower LM2	2.5–8.0	0.707240	0.000009
T62	M	Adult	nr	Enamel	Fragment of molar	0.4–8.0	0.707277	0.000014
T68	F	Young Adult	±25	Enamel	Lower Pm	2.5–6.5	0.707424	0.000013
T73	M	Adult	nr	Enamel	Upper Canine	0.7–5.0	0.707355	0.000011
T79	F	Young Adult	25–35	Enamel	Upper LI1	0.4–4.5	0.707137	0.000011
T83	M	Adult	±30	Enamel	Upper RI1	0.4–4.5	0.707280	0.000016
T84	M	Young Adult	±33	Enamel	Lower Canine	0.4–5.0	0.707177	0.000011
T85	M	Middle Adult	±35	Enamel	Lower Pm	2.0–6.5	0.707306	0.000009
T94	F	Middle Adult	±35	Enamel	Upper RM1	0.4–3.5	0.707233	0.000010
T101A	F?	Adult	nr	Enamel	Lower RM1	0.4–3.5	0.707185	0.000011
T101B	F	Adult	nr	Enamel	Lower RPm2	2.5–6.5	0.706943	0.000010
T102	F	Middle Adult	30–45	Enamel	Upper Pm1	2.5–6.0	0.707515	0.000010
T107	F	Young Adult	21–24	Enamel	Upper M3	8.5–14.0	0.707405	0.000011
T114	F?	Adult	nr	Enamel	Upper Pm	2.5–6.5	0.707353	0.000014
T117	F?	Adult	nr	Enamel	Lower RPm1	2.0–6.5	0.707339	0.000012
T126	F	Adult	nr	Enamel	Upper Pm	2.5–6.5	0.707350	0.000011
T152	F	Young Adult	25–35	Enamel	Lower M2	2.5–8.0	0.707128	0.000012
T167	F	Young Adult	25–32	Enamel	Upper M3	8.5–14.0	0.707181	0.000010
T206	F	Middle Adult	±45	Enamel	Upper LM1	0.4–3.5	0.707178	0.000011
T207	F	Young Adult	26–32	Enamel	Upper RI1	0.4–4.5	0.707098	0.000011
T211	M	Young Adult	20–25	Enamel	Upper LM3	8.5–14	0.707414	0.000013
T215	M	Middle Adult	35–40	Enamel	Lower LM2	2.5–8.0	0.707436	0.000012
T248	M	Young Adult	23–29	Enamel	Upper RPm	2.5–6.5	0.707501	0.000012
T251	Und	Young Adult	25–35	Enamel	Upper RM3	8.5–14.0	0.707182	0.000012
T309	F	Adult	nr	Enamel	Lower LM3	8.5–14.0	0.707340	0.000010
T313	M	Adult	nr	Enamel	Upper Canine	0.7–5.5	0.707435	0.000013
T332	F	Adult	nr	Enamel	Upper RM1	0.4–3.5	0.707762	0.000010
T340	F	Young Adult	25–35	Enamel	Lower LPm1	2.0–5.5	0.707289	0.000009
T368	F	Adult	nr	Enamel	Lower RM1	0.4–3.5	0.706926	0.000013
T371	F?	Adult	nr	Enamel	Upper RM2	2.5–8.0	0.707451	0.000010
T374	F	Adult	nr	Enamel	Upper RM3	8.5–14.0	0.707264	0.000011
T378	F	Middle Adult	30–45	Enamel	Upper LM2	2.5–8.0	0.707306	0.000012
T383	F	Young Adult	25–35	Enamel	Lower RM1	0.4–3.5	0.707553	0.000013
T387	F	Young Adult	25–35	Enamel	Upper LM1	0.4–3.5	0.707253	0.000009
T393	M	Young Adult	17–25	Enamel	Upper LM1	0.4–3.5	0.707284	0.000010

Sex: M = male, F = female, Und = undetermined;?=Probable; Adult: adult individual without age-range estimation. **nr:** age-range not reported.
* In anthropological notation. Colors represent the zones of isoscape as defined in the Fig. 1c (based on Scaffidi and Knudson 2020: Fig. 7).

$^{87}Sr/^{86}Sr$ values correspond to early-life periods, from infancy to early adolescence. Our ATR-FTIR analysis and assessment of structural integrity of enamel in Huaca 20 samples using two indexes (IRSF and C/P) and conventional values (France et al. 2020) suggests well preserved enamel samples (see Supporting Information: ST2 for FTIR-ATR raw data and indexes).

The $^{87}Sr/^{86}Sr$ values of Huaca 20 show normal distribution (Shapiro-Wilk W = 0.959, df = 48, p = 0.088), varying from 0.706925 to 0.707805 with a mean value of 0.707276 ± 0.000189 (1σ). The expected limits for local individuals range from 0.70709 to 0.70747 at 1σ, and from 0.70671 to 0.70766 at 2σ.

Only two individuals outside of the 2σ threshold can be reliably classified as non-locals. These individuals are both female (T332 and T44). However, when we evaluate the range of 1σ, there are another 9 individuals that could potentially be non-locals (Fig. 3). Among them, the individuals T9 (und), T19A (F), T368 (F), T101B (F), and T48 (M) have values below 1σ (0.7069–0.7071), and the individuals, T19B (F), T102 (F), T248 (M), and T383 (F) have values above 1σ (0.7075–0.7077).

The individuals outside 2σ (non-local) have $^{87}Sr/^{86}Sr$ values consistent with the predicted isoscape from the *yunga* region, possibly at higher altitudes to the east, such as the middle or upper sections of the Rimac Valley or the highlands. In contrast, the potential non-local individuals, above and below 1σ, have $^{87}Sr/^{86}Sr$ values congruent with the lower section of the Rimac Valley but also with other coastal regions to the north (Chillón Valley) and south (Lurín Valley), near modern Lima city, in maximum radius < 100 km (Fig. 1c; Scaffidi and Knudson 2020: Fig. 7, Scaffidi et al. 2020: Fig. 5).

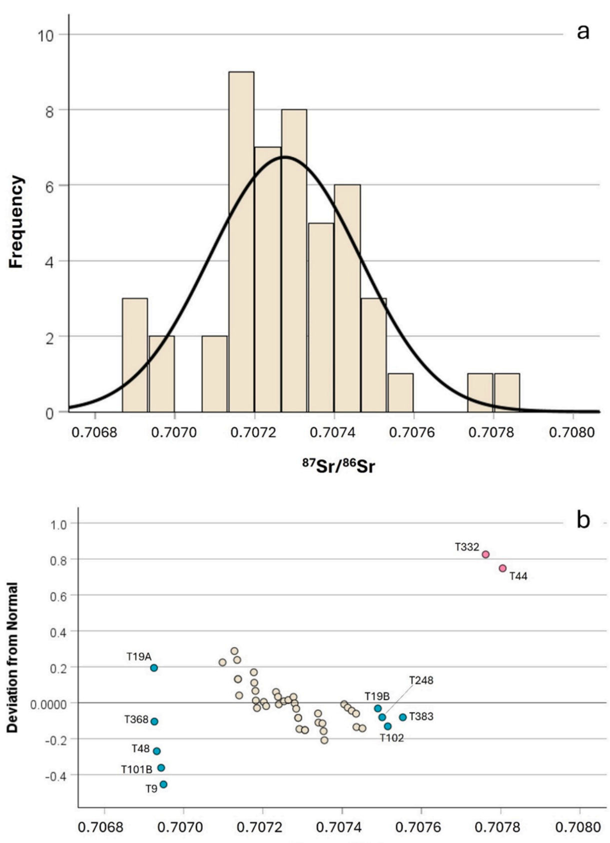

Fig. 3. a) Frequency histogram of $^{87}Sr/^{86}Sr$ values of Huaca 20 individuals and curve of normality. b) Graphic Q-Q without trend. In red, the outliers (above 2σ). In turquoise potential non-local individuals (above and below1σ).

3.2. Contextual analysis

The available regional records of $^{87}Sr/^{86}Sr$ values (Knudson et al. 2014; Scaffidi et al. 2020; Scaffidi and Knudson 2020), confirm the local origins of most Huaca 20 individuals (77 % of the sample). The individuals with divergent values might have come from the nearby highlands or from other valleys to the south or far north. To explore the nature of this non-local presence in Huaca 20, contextual data is required (Fig. 4 and Table 3).

It is noteworthy that a subadult (T9, detected after a review of the skeletal remains) is one of the potential non-local individuals. In addition, when compared by sex, the non-local presence appears to be mainly female (8 cases from 10 adults), whereas the same group was predominantly disposed in an extended position (7 cases of 11). Among the 11 cases, only two appear in association with umber ware cooking pots (T19A and T368). In the other 9 cases, the four types of orange ware cooking pots are present. Finally, it should be noted that the relative proportions of extended vs flexed position, or umber vs orange wares in the local individuals do not vary significantly when compared with the non-local ones. Hence, only sex appears to be a variable correlated with the non-local presence (Supporting Information: ST3).

In our sample, however, the number of females (n = 29, 60.4 %) is almost double that of males (n = 16, 33.3 %). To address this potential bias related to sex distribution, we compared the proportion of potential non-locals by the total number of individuals, and also by sex group. Although the difference is not statistically significant for the entire sample (F = 8/29 vs M = 2/16; Yates' chi-square = 0.625; df = 1; p = 0.429), it is significant when we examine only the subset of potential non-locals (F = 8/11 vs M = 2/11; Yates' chi-square = 4.583; df = 1; p = 0.032). This suggests the possibility of a patrilocal residence pattern.

3.3. Regional comparisons

Analyses of soil and small mammals of low mobility from the Lima region provide approximate thresholds of bioavailable strontium values for comparisons. The $^{87}Sr/^{86}Sr$ mean and range values of Huaca 20 (0.70728 ± 0.00019) are consistent with modern agricultural soils from the Lima area with $^{87}Sr/^{86}Sr$ mean values of 0.70722 ± 0.00036 (ranging from 0.7065 to 0.7077; Knudson et al. 2014), but not with $^{87}Sr/^{86}Sr$ mean values of 0.70774 ± 0.00018 (range from 0.7076 to 0.7079) of soils from archaeological cemeteries at Ancón, 35 km to the north (Slovak et al. 2009).

Huaca 20 $^{87}Sr/^{86}Sr$ values are higher than the values of *Cavia porcellus, cuy* specimens from Pachacamac, in the lower Lurin Valley, that have mean values of 0.70684 ± 0.00016 (ranging from 0.7047 to 0.7075) (Marsteller 2015: Table 6.1, Table 6.2, Appendix D), and *cuy* bones from Ancón with values of 0.70654 ± 0.00012 (ranging from 0.7064 to 0.7067) (Slovak et al. 2009).

When we compare Huaca 20 strontium isotope values with other populations from the region (Fig. 5), such as the roughly contemporaneous population of Ancón Miramar (Middle Formative, 550–1000 CE; Slovak et al. 2009) and the later Yschma populations (Late Intermediate Period, 1000–1470 CE) from Armatambo (a coastal settlement, 15 km southeast) and Rinconada Alta (an inland site, 15 km east; Marsteller et al. 2017), Huaca 20 exhibits lower mean values and greater homogeneity which are statistically significant in all the comparisons (p < 0.004). However, there is substantial overlap between the values of all the sites.

The comparison also confirms that the diet was based on regional plants with lower proportion of marine products (Pezo-Lanfranco et al. 2024a), different from the diet of Armatambo and Ancón, that have $^{87}Sr/^{86}Sr$ closer to the value of ocean water 0.07092 (Veizer 1989).

In summary, the $^{87}Sr/^{86}Sr$ values of Huaca 20 sample individuals reveal a relatively homogeneous population. Based on previously published Andean $^{87}Sr/^{86}Sr$ data, the potential geographic origins of outlier individuals are the middle or upper Rimac Valley. For all the other

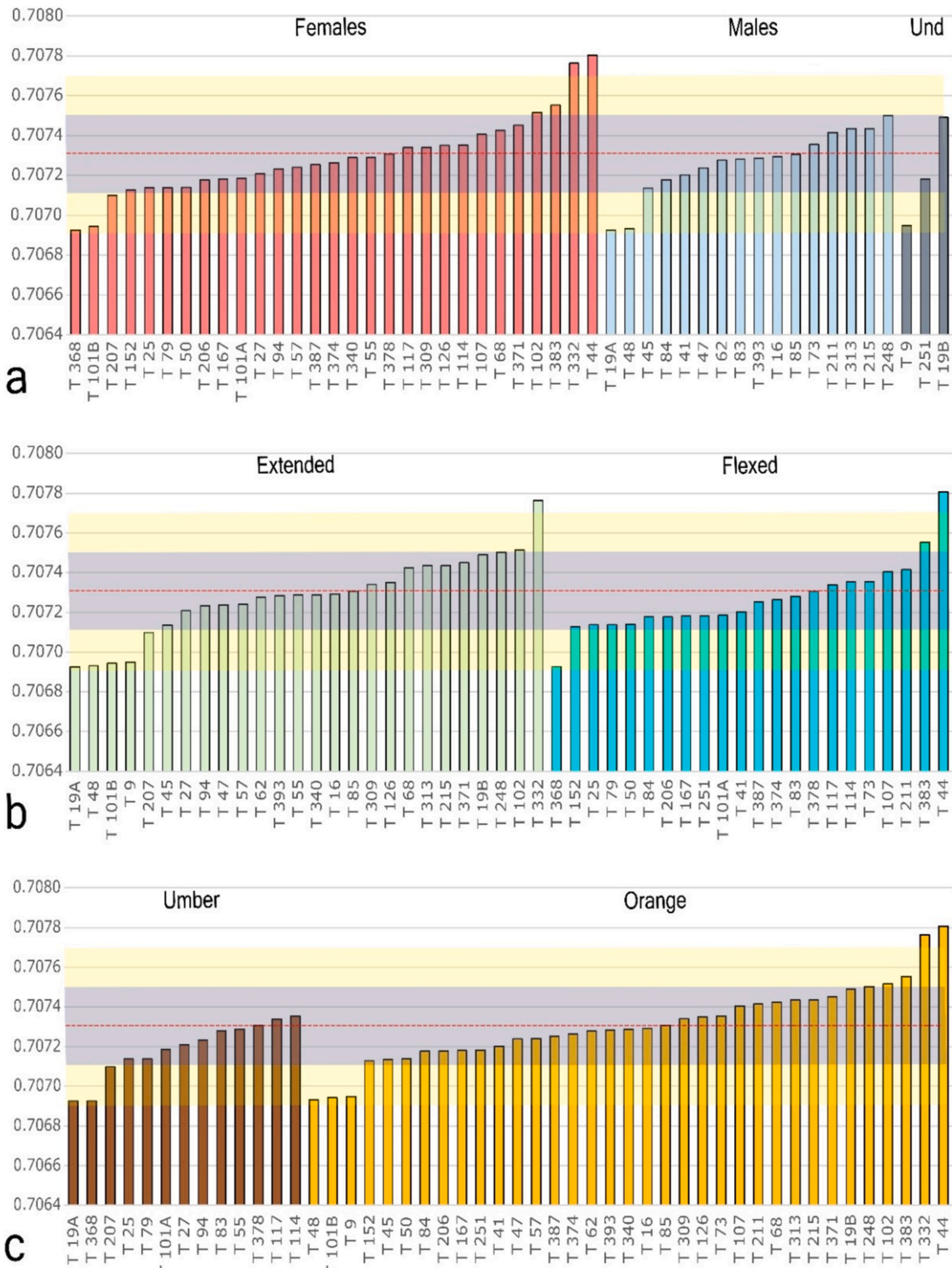

Fig. 4. Strontium isotope values acoording to a) Sex; b) position of the individual into the funeray context; c) type of ware of ceramic vessels. Red dashed line is the H20 mean; the yellow shaded area represents 2σ and the blue area represents 1σ.

individuals, the "potentially non-locals", the values fall within or near the ranges of predicted isoscape and water sources of the lower Rimac Valley (Knudson et al. 2014, Scaffidi et al. 2020, Scaffidi and Knudson 2020). Alternatively, some "local" individuals might also originate from regions with overlapping values, such as other settlements within the same geological setting or from more distant areas with similar baseline signals.

4. Discussion

The new strontium isotope data reveal the presence of 11 potentially non-local individuals (23 % of the sample) within a mainly local population at Huaca 20. In addition, no correlation has been detected between these individuals and certain kind of funerary treatments or offerings. This does not correspond with a scenario of mobility or migration of discrete social units nor fits a scenario of migrants' identity

Table 3
Mean $^{87}Sr/^{86}Sr$ values according to features of funerary contexts from Huaca 20.

	n	min.	max.	$\bar{x}$	σ
Sex					
Male	16	0.706925	0.707501	0.707261	0.00016
Female	29	0.706926	0.707805	0.707291	0.00020
Undetermined	3	0.706949	0.707490	0.707210	0.00027
Burial (type)					
Extended	26	0.70693	0.70776	0.70728	0.00020
Flexed	22	0.70693	0.70781	0.70727	0.00018
Ware*					
Umber	13	0.70693	0.70735	0.70719	0.00014
Orange	35	0.70693	0.70781	0.70731	0.00020
Pooled sample	48	0.70693	0.70781	0.70728	0.00019

* Significant difference after ANOVA: F = 4.309; df = 2; p = 0.044.

and differentiation from the local hosts.

The resulting data can be better explained as the product of individuals' mobility, probably due to post marital residential practices. In this situation, foreigners seem to incorporate a diverse set of local practices, as it is reflected in their mortuary treatment. In addition, it is reasonable to consider that, through their incorporation into Huaca 20 community, new cultural practices might have been incorporated, with the corresponding development of a community with cosmopolitan traits.

For example, we have outlined before that umber wares were mainly associated with females buried in flexed position. Only two of these females turned out to be possible non-locals. It should be feasible to consider that, as a continuous practice, mobility due to post marital residential practices implied the displacement of certain type of non-local goods and behaviors that might have been learned or inherited by the non-local descendants, and thus, reproduced in funerary practices. In an opposite situation, individuals buried with distinct types of orange wares reveal a fast incorporation of local behaviors, as part of individuals integration into Huaca 20′s community. It is noteworthy that, rather than being from a single area, outliers might have been from at least three different origins (from north and south along the Peruvian coast and from the eastern upper sections of the Lima valley), revealing a wide network of interregional marriages, whose size and range need to be established. As mentioned before, mobility, usually related to post marital residence is an effective mean to integrate communities and develop regional networks. Apparently, inhabitants of Huaca 20 were involved in one of them.

These findings acquire relevance in expanding our understanding of the regional dynamics that were occurring during the MHE1. It has largely been recognized that Lima elite groups were engaged in long distance interactions, evidenced in the production and acquisition of Nievería vessels (Valdez 2015, Ccencho 2007). In contrast, umber ware vessels found at Lima sites speak to the movement of specific goods that does not correspond to the typical elite-like wares, but are basically utilitarian, usually labeled as "domestic wares". Finding these kinds of vessels at Huaca 20 burials shows that umber ware ceramics were accessible to non-elite people and their distribution might have occurred under inter community interaction and suggest that regional dynamics were also developing beyond the elite's domain.

In this context, the data presented here add a new dimension to understanding interregional dynamics during the MHE1: people's mobility. Huaca 20 is clearly composed mainly of local people. However, a proportion of 23 % represents a relatively high number of non-locals when considering expected or typical population dynamics (Cavazzuti et al. 2019, Bickle 2024). Although this interpretation should be viewed as a working hypothesis to be tested with larger samples, a broader, less visible migration phenomenon across the region is also plausible, especially if people were moving from areas with overlapping baseline values.

The variability in funerary treatments and the presence of non-local wares reveal a population open to different external influxes. The identified non-local individuals might be understood within these dynamics. They appear as both a factor and a result of inter community linkages. They might represent long distance marriages of possible patrilocal residence patterns that should be evaluated in future research, but also indicates previously existing bondages between distant communities.

As a continuous behavior, of around 150 years, at Huaca 20, this ended in a palimpsest of cultural practices that gave shape to local population with a high degree of cosmopolitanism, which keep receiving non-local members of different origins.

It is noteworthy that this is all occurring within a marginal sector of Maranga, possibly a support neighborhood of the proximate ritual building of Huaca Potosí Alto. Again, these results suggest that the Huaca 20 community appears to have had agency to get into interregional interaction regardless of elite demands or requirements. It opens another perspective to understanding the elite-commoners relationship during this time in the Peruvian Central Coast.

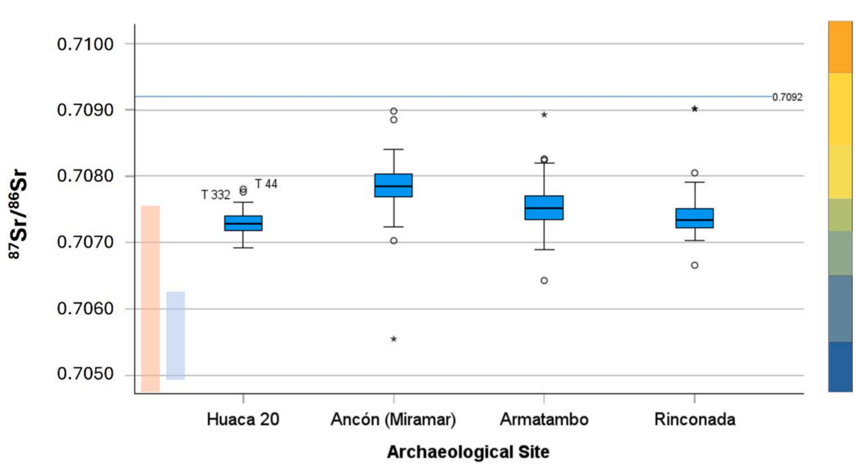

Fig. 5. Strontium isotope ratios for human tooth enamel from evaluated individuals of Huaca 20, and values from modern and archaeological fauna from the region. The colored bars on the left represent the distribution (2σ) of $^{87}Sr/^{86}Sr$ values. Pink bar: low-mobility modern fauna (i.e., Cavia porcellus fed with local plants) in the Lima region (Marsteller et al. 2017); Light blue bar: the predicted range local water (Scaffidi et al. 2020). The colored bar on the right represents the predicted $^{87}Sr/^{86}Sr$ areas of the isoscape (Scaffidi and Knudson 2020) for the Peruvian Central Coast. The continue blue line is the ocean value ($^{87}Sr/^{86}Sr$ = 0.7092; Veizer 1989).

5. Concluding remarks

Our results, although very suggestive, are still preliminary, due to the limited sample size, as well as the lack of other studies that might allow more comparative analysis. Nonetheless, they provide a new insight with which to evaluate regional dynamics during the MHE1, highlighting the agency and protagonism of local communities in those dynamics. Important considerations must be taken in order to continue in this path of research.

First, it is important to note that the reconstruction of residential mobility using strontium isotopes in the Peruvian Central Coast is challenging due to the high variability of geological formations and ecological areas, which in turn, produce a wide range of strontium isotope signatures in soils, water, fauna, and humans. Although the Huaca 20 population have relatively homogeneous $^{87}Sr/^{86}Sr$ values, caution is recommended when interpret variability in isotope values in the Peruvian Central Coast. There is a large variability and overlapping of potential water sources and soils in the Rimac and Lurín Valley regions, and some researchers have argued that strontium isotope analyses would be unreliable in identify mobility within this study region and would be useful only for interregional mobility studies (Bentley 2006; Knudson et al. 2014, Scaffidi and Knudson 2020, Scaffidi et al. 2020).

Second, the reliability of strontium isotope data from farmed fields depends on the potential addition of exogenous strontium to the system (e.g., by fertilizers like manure, seaweed or seabird guano, the ingestion of imported food or high amounts of salt, the impact of sea spray on productive landscape etc.) and differential strontium concentration [Sr] in soils and water that can introduce variation in the strontium isotope values (Evans et al. 2010, Montgomery 2010, Knudson et al. 2014, Dalle et al. 2022). Thus, flora and fauna possibly provide better estimates of bioavailable strontium for human palaeomobility assessments in this region (Knudson et al. 2014, Scaffidi and Knudson 2020). In this sense, the effect of marine resources on the diets at Huaca 20 (Pezo-Lanfranco et al. 2024a), especially if they were salt-processed (e.g., dry-salted fish, *charqui*) introduces a potential complicating factor that should be considered with caution (Lahtinen et al. 2021, Dalle et al. 2022).

Finally, in Huaca 20, $^{87}Sr/^{86}Sr$ values are relatively homogeneous, however, they overlap with values from other relatively near or distant regions of the Central Andes (see Knudson et al. 2014). Similar values between highland and lower altitudes, could be due to geological processes of erosion and transportation (i.e., flooding, landslides) of sediments from higher altitudes to the alluvial floodplain of Lima, especially during severe El Niño events (Bentley 2006; Marsteller 2015), roughly configurating a phenomenon of equifinality.

Authors contributions

RVC and LPL designed research; LPL collect the samples, LPL and PlR performed laboratory research; RVC, LPL, PlR and ACC analyzed data and wrote the paper.

CRediT authorship contribution statement

Rafael Vega Centeno: Writing – review & editing, Writing – original draft, Visualization, Validation, Resources, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Luis Pezo-Lanfranco:** Writing – review & editing, Writing – original draft, Visualization, Validation, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Petrus le Roux:** Methodology, Formal analysis, Data curation. **André Carlo Colonese:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Methodology, Investigation, Funding acquisition, Data curation.

Declaration of competing interest

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

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Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jasrep.2024.104889.

Data availability

Data will be made available on request.

References

AlQahtani, S.J., Hector, M.P., Liversidge, H.M., 2010. Brief communication: the London atlas of human tooth development and eruption. Am. J. Phys. Anthropol. 142, 481–490.
Andrushko, V.A., Buzon, M.R., Simonetti, A., Creaser, R.A., 2009. Strontium isotope evidence for prehistoric migration at Chokepukio, Valley of Cuzco, Peru. Lat. Am. Antiq. 20, 57–75.
Bentley, A.R., 2006. Strontium isotopes from the earth to the archaeological skeleton: review. J. Archeol. Method Theory 13 (3), 135–187.
Bentley, A.R., 2013. Mobility and the diversity of Early Neolithic lives: Isotopic evidence from skeletons. J. Anthropol. Archaeol. 32 (3), 303–3012.
Bentley, A.R., Pietrusewsky, M., Douglas, M.T., Atkinson, T.C., 2005. Matrilocality during the prehistoric transition to agriculture in Thailand? Antiquity 79, 65–881.
Bentley, A.R., Bickle, P., Fibiger, L., Nowell, G.M., Dale, C.W., Hedges, R.E.M., Hamilton, J., Wahl, J., Francken, M., Grupe, G., Lenneis, E., Teschler-Nicolah, M., Arbogast, R., Hofmann, D., Whittle, A., 2012. Community differentiation and kinship among Europe's first farmers. Proc. Natl. Acad. Sci. 109 (24), 9326–9330.
Bickle, P., 2024. Gender, mobility, and kinship in European prehistory. In: Moen, M., Pedersen, U. (Eds.), *The Routledge Handbook of Gender Archaeology*. Routledge, London.
Buikstra, J., Ubelaker, D. (Eds.) (1994). *Standards for Data Collection from Human Skeletal Remains*. Arkansas Archeological Survey Research Series, No.44. Fayetteville, Arkansas.
Canziani, J., 2009. *Ciudad y territorio en los Andes: contribuciones a la historia del urbanismo prehispánico*. Fondo Editorial de la Pontificia Universidad Católica del Perú, Lima.
Capo, R.C., Stewart, B.W., Chadwick, O.A., 1998. Strontium isotopes as tracers of ecosystem processes: Theory and methods. Geoderma 82 (1–3), 197–225.
Castillo, L.J., 2000. La Presencia Wari en San José de Moro. Boletín De Arqueología PUCP 4, 149–179.
Cavazzuti, C., Skeates, R., Millard, A.R., et al., 2019. Flows of people in villages and large centres in Bronze Age Italy through strontium and oxygen isotopes. PLoS One 14 (1), e0209693.
Ccencho, J., 2012. Algunas contribuciones para el entendimiento de la vajilla Alfar Pucllana marrón doméstica Lima. Investigaciones Sociales 16 (28), 321–332.
Ccencho, J. (2007). *El alfar Pucllana Nievería. Cambios registrados en una vajilla ceremonial y sus implicancias sociales*. Cuadernos de Investigación/INC 1,17–34, Instituto Nacional de Cultura, Lima.
Chuyacama, J., 2021. *Individuos en posición extendida e individuos en posición flexionada: Hacia una comprensión de los diferentes tratamientos funerarios hallados en el sitio de*

Huaca 20, ubicado en el interior del Campus PUCP (Maranga - Cultura Lima). Tesis De Licenciatura. Pontificia Universidad Católica del Perú, Lima.

Clark, J.J., Birch, J.A., Hegmon, M., Mills, B.J., Glowacki, D.M., Ortman, S.G., Dean, J.S., Gauthier, R., Lyons, P.D., Peeples, M.A., Borck, L., Ware, J.A., 2019. Resolving the migrant paradox: Two pathways to coalescence in the late precontact U.S. Southwest. J. Anthropol. Archaeol. 53, 262–287.

Conlee, C.A., Buzon, M.R., Gutierrez, A.N., Simonetti, A., Creaser, R.A., 2009. Identifying foreigners versus locals in a burial population from Nasca, Peru: an investigation using strontium isotope analysis. J. Archaeol. Sci. 36, 2755–2764.

Copeland, S.R., Sponheimer, M., le Roux, P.J., Grimes, V., Lee-Thorp, J.A., de Ruiter, D. J., Richards, M.P., 2008. Strontium isotope ratios (87Sr/86Sr) of tooth enamel: a comparison of solution and laser ablation MCICPMS methods. Rapid Commun. Mass Spectrom. 22, 3187–3194.

Copeland, S.R., Cawthra, H.C., Fisher, E.C., Lee-Thorp, J.A., Cowling, R.M., Le Roux, P.J., Marean, C.W., 2016. Strontium isotope investigation of ungulate movement patterns on the Pleistocene Paleo-Agulhas Plain of the Greater Cape Floristic Region, South Africa. Quat. Sci. Rev. 141, 65–84.

Dalle, S., Snoeck, C., Sengeløv, A., et al., 2022. Strontium isotopes and concentrations in cremated bones suggest an increased salt consumption in Gallo-Roman diet. Sci. Rep. 12, 9280. https://doi.org/10.1038/s41598-022-12880-4.

Deniel, C., Pin, C., 2001. Single-stage method for the simultaneous isolation of lead and strontium from silicate samples for isotopic measurements. Anal. Chim. Acta 426, 95–103.

Eerkens, I.W., Barfod, G.H., Leventhal, A., Jorgenson, G.A., Cambra, R., 2014. Matrilocality in the Middle Period in Francisco Bay? New Evidence from Strontium Isotopes at CA-SCL-287. J. Calif. Gt. Basin Anthropol. 34 (2), 205–221.

Evans, J.A., Montgomery, J., Wildman, G., Boulton, N., 2010. Spatial variations in biosphere 87Sr/86Sr in Britain. J. Geol. Soc. 167, 1–4.

France, C.A.M., Sugiyama, N., Aguayo, E., 2020. Establishing a preservation index for bone, dentin, and enamel bioapatite mineral using ATR-FTIR. J. Archaeol. Sci. Rep. 33, 102551.

Goldhausen, M. (2012). Spätformativ- und regionalzeitliche Besiedlungim Trockental Orcón-Pacaybambaban der Zentralen Küste von Peru (450 v.Chr. – 750 n.Chr.). PhD dissertation. Freien Universität Berlin, Berlin.

Goldstein, P., 2000. Communities Without Borders: The Vertical Archipelago and Diaspora Communities in the Southern Andes. In: Canuto, M.A., Yaeger, J. (Eds.), *The Archaeology of Communities: A New World Perspective*. Routledge, London, pp. 182–209.

Gregorika, L.A., 2021. Moving forward: a bioarchaeology of mobility and migration. J. Archaeol. Res. 29, 581–635.

Grupe, G., Klaut, D., Otto, L., et al., 2020. The genesis and spread of the early Fritzens-Sanzeno culture (5th/4th cent. BCE)–Stable isotope analysis of cremated and uncremated skeletal finds. J. Archaeol. Sci. Rep. 29, 102121.

Haaka, W., Brandta, G., de Jongb, H.N., Meyera, C., Ganslmeierc, R., Heydb, V., Hawkesworthd, C., Pikeb, A.W.G., Mellerc, H., Alta, K.W., 2008. Ancient DNA, Strontium isotopes, and osteological analyses shed light on social and kinship organization of the Later Stone Age. Proc. Natl. Acad. Sci. 105 (47), 18226–18231.

Jennings, J., 2010. Becoming Wari: Globalization and the Role of the Wari State in the Cotahuasi Valley of Southern Peru. In: Jennings, J. (Ed.), Beyond Wari Walls: Regional Perspectives on Middle Horizon Peru. University of New Mexico Press, Albuquerque, pp. 37–56.

Knudson, K.J., Price, T.D., Buikstra, J.E., Blom, D.E., 2004. The use of strontium isotope analysis to investigate tiwanaku migration and mortuary ritual in Bolivia and Peru. Archaeometry 46, 5–18.

Knudson, K.J., Torres-Rouff, C., 2014. Cultural diversity and paleomobility in the andean middle Horizon: radiogenic strontium isotope analyses in the San Pedro de Atacama oases of northern Chile. Lat. Am. Antiq. 25, 170–188.

Knudson, K.J., Webb, E., White, C., Longstaffe, F.J., 2014. Baseline data for andean paleomobility research: a radiogenic strontium isotope study of modern peruvian agricultural soils. Archaeol. Anthropol. Sci. 6, 205–219.

Knudson, K.J., Stanish, C., Lozada, M.C., Faull, K.M., 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. J. Archaeol. Sci. Rep. 5, 590–597.

Lahtinen, M., Arppe, L., Nowell, G., 2021. Source of strontium in archaeological mobility studies—marine diet contribution to the isotopic composition. Archaeol. Anthropol. Sci. 13, 1. https://doi.org/10.1007/s12520-020-01240-w.

Lau, G., 2005. Core-periphery relations in the Recuay hinterlands: economic interaction at Chinchawas, Peru. Antiquity 79, 78–99.

Mac Kay, M. (2006). Contextos funerarios lima de la Huaca 20: Reconstrucción del ritual funerario y la vida cotidiana del valle del Rímac en los inicios del Horizonte Medio. Tesis de Licenciatura. Pontificia Universidad Católica del Perú. Lima.

Marsteller, S.J., Knudson, G.K., Gordon, J., Anbar, A., 2017. Biogeochemical reconstructions of life histories as a method to assess regional interactions: stable oxygen and radiogenic strontium isotopes and Late Intermediate Period mobility on the Central Peruvian Coast. J. Archeol. Sci.: Rep. 13, 535–546.

Marsteller, S. J. (2015). *Community Identity and Social Diversity on the Central Peruvian Coast: A Bioarchaeological Investigation of Ychsma Diet, Mobility, and Mortuary Practices (c. AD 900–1470)*. PhD. dissertation. Arizona State University, Tucson.

Mauricio, A. (2015). El cementerio de Huaca 20: Patrones y fases funerarias Lima. In F. Fernandini et al. (Eds.). *Huaca 20 un sitio Lima en el antiguo complejo Maranga*Pontificia Universidad Católica del Perú. Lima. pp. 114-136.

Mauricio, A. (2012). The Huaca 20 Site in the Maranga Complex: Human-Environment Interactions, Household Activities, and Funerary Practices on the Central Coast of Peru. MSc. dissertation, University of Maine.

Montgomery, J., 2010. Passports from the past: Investigating human dispersals using strontium isotope analysis of tooth enamel. Ann. Hum. Biol. 37, 325–346.

Pacheco, G., 2014. P*roducción de chicha de maíz en Huaca San Marcos*. Universidad Nacional Mayor de San Marcos, Lima, Tesis de Licenciatura.

Pezo-Lanfranco, L., Mut, P., J., Chávez, J. C., Fossile, T., Colonese, A. C., Fernandes, R. (2023). South American Archaeological Isotopic Database (SAAID_V.20_2023) *CORA Repositori de Dades de Recerca* https://doi.org/10.34810/data602.

Pezo-Lanfranco, L., Vega-Centeno, R., Aliaga-Rodríguez, G., Comes, P., Colonese, A.C., 2024a. Preadult diets in the prehistoric Lima-city: Stable isotopes from Huaca 20 (620–780 CE), Maranga Complex, Peru. J. Archaeol. Sci.: Rep. 58, 104723.

Pezo-Lanfranco, L., Mut, P.J., Chávez, J., J, C., Fossile, T., Colonese, A.C., Fernandes, R., 2024b. South American archaeological isotopic database, a regional-scale multi-isotope data compendium for research. Sci. Data 11, 336. https://doi.org/10.1038/s41597-024-03148-9.

Pin, C., Briot, D., Bassin, C., Poitrasson, F., 1994. Concomitant separation of strontium and samarium-neodymium for isotopic analysis in silicate samples, based on specific extraction chromatography. Analytica Chimica Acta 298, 209–217.

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, 117–136.

Prieto, G., 2014. La pesca prehispánica de la Costa Central: Una revisión necesaria a partir de los nuevos datos provenientes del barrio de pescadores del sitio Huaca 20, Complejo Maranga. *Boletín De Arqueología PUCP* 18, 129–157.

Ramos, N., 2012. *Informe Final del Proyecto de Rescate Arqueológico Huaca 20-Primera Etapa*. Ministerio de Cultura, Lima.

Rengifo, C., Prieto, G., Mauricio, A. (2006). *Proyecto Arqueológico Huaca 20-Complejo Maranga. Informe de Temporada 2005.* Instituto Nacional de Cultura, Lima.

Rengifo, C., Prieto, G., Mauricio, A., Olivera, C. (2007). *Proyecto Arqueológico Huaca 20-Complejo Maranga. Informe de Temporada 2006.* Instituto Nacional de Cultura, Lima.

Ríos, R., 2008. *Restos de actividades rituales en la segunda etapa constructiva de una plaza Lima Tardío: un caso en Pucllana*. Universidad Nacional Mayor de San Marcos, Lima, Tesis de Licenciatura.

Scaffidi, B. K., Kamenov, G. D., Sharpe, A. E., Krigbaum. J. (2022). Non-Local Enemies or Local Subjects of Violence?: Using Strontium (87Sr/86Sr) and Lead (206Pb/204Pb, 207Pb/204Pb, 208Pb/204Pb) Isobiographies to Reconstruct Geographic Origins and Early Childhood Mobility of Decapitated Male Heads from the Majes Valley, Peru. *Journal of Archaeological Method and Theory*, https://doi.org/10.1007/s10816-021-09519-5.

Scaffidi, B.K., Knudson, K.J., 2020. An archaeological strontium isoscape for the prehistoric Andes: understanding population mobility through a geostatistical meta-analysis of archaeological 87Sr/86Sr values from humans, animals, and artifacts. J. Archaeol. Sci. 117, 105–121.

Scaffidi, B.K., Tung, T.A., Gordon, G., Alaica, A.K., González La Rosa, L.M., Marsteller, S. J., Dahlstedt, A., Schach, E., Knudson, K.J., 2020. Drinking Locally: A Water 87Sr/86Sr Isoscape for Geolocation of Archeological Samples in the Peruvian Andes. Front. Ecol. Evol. 8, 281.

Schillaci, M.A., Stojanowki, C.M., 2002. A Reassessment of Matrilocality in Chacoan Culture. Am. Antiq. 67 (2), 343–356.

Schoeninger, M.J., 2010. Diet reconstruction and ecology using stable isotope ratios. In: Larsen, C.S. (Ed.), *A Companion to Biological Anthropology*. Blackwell Companions to Anthropology. Willey-Blackwell, Oxford, UK, pp. 445–464.

Schreiber, K., 1992. *Wari Imperialism in Middle Horizon Peru*. University of Michigan Press, Ann Arbor.

Segura, R., 2001. *Rito y Economía en Cajamarquilla: Investigaciones Arqueológicas en el Conjunto Arquitectónico Julio C*. Pontificia Universidad Católica del Perú, Lima, Tello.

Segura, R., 2017. Repensando la interacción cultural durante la hegemonía wari: modelos interpretativos y evidencia funeraria en la costa central del Perú. In: Vega Centeno, R. (Ed.), *Repensar El Antiguo Perú. Aportes Desde La Arqueología*. Pontificia Universidad Católica del Perú, Lima, pp. 277–314.

Segura, R. (2023). *Andean urban processes and the experience of the environmental social interplay: the case of Cajamarquilla, Peruvian Central Coast (ca. AD 650-1400)*. PhD. Dissertation, Southerin Illinois University, Carbondale.

Shady, R., 1982. La cultura Nievería y la interacción social en el Mundo Andino en la Época Huari. *Arqueológicas* 19, 5–108.

Slovak, N.M., Paytan, A., Wiegand, B.A., 2009. Reconstructing middle Horizon mobility patterns on the coast of Peru through strontium isotope analysis. J. Archaeol. Sci. 36 (1), 157–165.

Tung, T. A. (2012). The Bioarchaeology of Migration. *The SAA Archaeological Record*, May, 42–45.

Turner, B.L., Kamenov, G.D., Kington, J.D., Armelagos, G.J., 2009. Insights into immigration and social class at Machu Picchu, Peru based on oxygen, strontium, and lead isotopic analysis. J. Archaeol. Sci. 36, 317–332.

Valdez. R. (2015). Revisión de la definición del estilo Nievería: Un estudio de los materiales recuperados por Max Uhle, Louis M. Stumer y la Misión Arqueológica Italiana. Tesis de Licenciatura, Pontificia Universidad Católica del Perú, Lima.

Vega Centeno, R., Epiquién, L. (2022). Desigualdades y heterogeneidades en la conformación de espacios residenciales dentro del Complejo Lima de Maranga. El caso del Sector Huaca 20. In J. García Targa, & J. M. Medina, (Eds.). *La Casa Arqueológica. Estudios de caso en la Antigüedad.* BAR Publishing. Oxford. pp. 213–226.

Vega Centeno, R., Lang, R.C., 2021. Análisis micromorfológicos para la reconstrucción de actividades en el Complejo Arquitectónico de Maranga-Lima. *Chungará* 53, 573–593.

Vega Centeno, R., Palomino, E., 2022. Los alfares marrones de los sitios lima. Implicancias de una aproximación arqueométrica a su proveniencia. Revista Del Instituto Riva Agüero 7, 329–367.

Vega Centeno, R., Toledo, C., Huamán, L., Alexandrino, G., 2021. Examen de un Perfil Estratigráfico Lima en Maranga. Lat. Am. Antiq. 32 (3), 655–661.
Veizer, J., 1989. Strontium isotopes in seawater through time. Annu. Rev. Earth Planet. Sci. 1, 141–167.
Villacorta, L. (2013). *Proyecto de Rescate Arqueológico en el sitio arqueológico Huaca 20, Complejo Maranga, campus de la Pontificia Universidad católica del Perú. Temporada 2012–2013. Informe Final.* Ministerio de Cultura, Lima.