Non-Local Enemies or Local Subjects of Violence?: Using Strontium ($^{87}\text{Sr}/^{86}\text{Sr}$) and Lead ($^{206}\text{Pb}/^{204}\text{Pb}$, $^{207}\text{Pb}/^{204}\text{Pb}$, $^{208}\text{Pb}/^{204}\text{Pb}$) Isobiographies to Reconstruct Geographic Origins and Early Childhood Mobility of Decapitated Male Heads from the Majes Valley, Peru

Beth K. Scaffidi, et al. *[full author details at the end of the article]*

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Abstract

Throughout much of the pre-Hispanic Andes, bioarchaeological and iconographic evidence shows that the decapitation, dismemberment, and display of human heads were important aspects of ritual practices. Researchers have debated about the social identities of these decapitated heads—were they revered local ancestors, non-local enemies captured in raids or war, or locals injured in distant combat partially repatriated for home burial—answers which have distinct implications for understanding the motivations and social contexts of this practice. We describe trophy-taking and trophy-making from the Uraca cemetery in pre-Hispanic Arequipa, Peru. To determine whether these trophies were locals, we employ radiogenic isotope analyses ($^{87}\text{Sr}/^{86}\text{Sr}$, $^{206}\text{Pb}/^{204}\text{Pb}$, $^{207}\text{Pb}/^{204}\text{Pb}$, $^{208}\text{Pb}/^{204}\text{Pb}$) of tooth enamel from 37 individuals (25 non-trophies and 12 adult male trophies). To understand the degree of childhood mobility that occurred and whether that differed between individuals who became trophies and those who did not, we also examine $^{87}\text{Sr}/^{86}\text{Sr}$, $^{206}\text{Pb}/^{204}\text{Pb}$, $^{207}\text{Pb}/^{204}\text{Pb}$, $^{208}\text{Pb}/^{204}\text{Pb}$ in paired teeth from infancy/early childhood and middle childhood of 18 individuals (8 non-trophies and 10 trophies). Results show that 20% of the non-trophies and 75% of the trophies were non-local relative to modeled local $^{87}\text{Sr}/^{86}\text{Sr}$ and mean (± 2 SD) of lead isotope values. Intra-childhood differences show that the individuals who became trophies experienced more childhood mobility than non-trophy individuals. This suggests Uraca's external interactions and mobility were structured by violent intergroup raids and warfare throughout the region. Ongoing analyses will extend Uraca's residential isobiographies to adolescence and late-life, refine the expected range of isotope ratios in the region, and clarify the extent of Majes Valley mobility during the mid-first millennium CE.

Keywords Radiogenic isotopes · Strontium · Lead · Antemortem trauma · Perimortem trauma · Trophy heads · Pre-Hispanic Andes

Introduction

Throughout humanity's history, the performance of violence and violence-related ritual behavior has been profoundly structured by the social identities of the attackers, the attacked, and the audience witnessing violent acts. Whether carried out in public or in private, or as a means to achieve ritual or logistical outcomes, violence can be a performative act that derives its meaning from the culturally embedded and historically contingent circumstances of violence (Pérez, 2012; Riches, 1986; Whitehead, 2004, 2007). Among other things, violence is a way to create and express social identity and group organization (Whitehead, 2007: 59); outsiders are often defined as those against whom violence can be legitimately directed. Raiding and warfare are intrinsically motivated by the need to commit violence against the "other"—and the perpetration of warfare arises from and perpetuates the "construction of exclusionist identities" (Jabri, 1996: 120-129). The outsider is "integral to the production of group identity" (Whitehead, 2004: 69), so that violence against outsiders often structures social identities and organization within and between communities (Clastres, 1998). According to Bowman (2001: 42), identity politics can be shaped by physical violence—social identities within and beyond a community are configured and reconfigured by forming "borders which enclose an 'I' or a 'we' and (violently) excluding...others." As one example of how these differences are embodied, drawing on Clastres (1998) and Harrison's (1993) examinations of war in small-scale societies in the South American Amazon, Bowman (2001: 34-35) demonstrates how men's war cults generate a "crystallization of sociality out of what had previously been larger networks of interaction" by shifting intergroup relationships from cooperative, mutually dependent exchange, to antagonistic exchange of "bellicose rhetoric, raiders, and cut off heads."

In this study, we examine the geographic origins of decapitated heads interred with combatants in the burial community of Uraca in pre-Hispanic Arequipa, Peru, in order to determine whether they were taken in the context of the violent inter-community raids Bowman describes or some other type of community ritual—if the former, then how might the circulation of these heads have defined appositional social identities between individuals and groups, while linking communities into networks of violent exchange? We use a combination of strontium ($^{87}\text{Sr}/^{86}\text{Sr}$) and lead ($^{206}\text{Pb}/^{204}\text{Pb}$, $^{207}\text{Pb}/^{204}\text{Pb}$, and $^{208}\text{Pb}/^{204}\text{Pb}$) isotopes to determine whether decapitated and dismembered trophy heads were locally or non-locally born and compare these results with male, female, and subadult individuals who were not decapitated and transformed into trophies. Furthermore, we compare strontium values in enamel from teeth forming in infancy/early childhood and middle childhood in a subset of the Uraca sample, as a means of assessing whether individuals moved during their early lives.

In prehistoric archaeological contexts around the globe, violently transformed body parts of enemy dead were salient and contested signifiers of outsider social identity within the context of their own distinct culturally bound ritual and secular motivations and meanings (Armit, 2012; Chacon & Dye, 2007c). In the Americas, the capture, mutilation, modification, and display of body parts, including heads, jaws, scalps, and hands, were common throughout prehistory; in some cases these practices continued

beyond the Colonial era (Chacon & Dye, 2007d; Seeman, 1988). Trophy¹-taking often visibly marked domination over trophy victims as outsiders while concomitantly reifying ethnic identity for the trophy-taking group and/or social status identity for trophy-takers and trophy-makers (Chacon & Dye, 2007a, b: 641-642). In some cases, men, women, or children were captured alive, taken as prisoners, and then killed after some amount of time (Burdick, 2016; Helmke, 2020; Inomata & Triadan, 2009; Santos-Granero, 2010). In other cases, enemy heads and hands were probably removed at the combat site immediately after death and then carried back to the community for further transformation into a trophy (Berryman, 2007; Chacon & Dye, 2007c; Jacobi, 2007). Captured body parts were sometimes also fashioned into regalia to be displayed or worn on special occasions or to be used as utilitarian implements. They were worn, carried, and displayed publicly and privately as symbols of success in battle, supernatural power, and the prestige associated with successfully carrying out these grim feats (Chacon & Dye, 2007a, b).

The Social Identities of Andean Trophy Heads

In the pre-Hispanic Andes, trophy heads or trophy skulls (*cabezas trofeos* or *cabezas trofeos momificadas* in Spanish) were the most commonly taken body part—or at least, they are the most visible icons in skeletal assemblages and in the iconographic corpus. This practice began as early as 1300 BCE in ancient Peru (Tung, 2007a), and the curation of skulls continues into the present in some parts of the Andes (Allen, 2012; Arnold & Hastorf, 2008; Sallnow, 1987). Skeletonized (defleshed) or mummified (fully fleshed) trophy heads have been documented in Peru along the Central and South Coasts, the northern Highlands (Chavín de Huántar), the North Coast, the South-Central Highlands, and in the Bolivian Altiplano (Tung, 2007a). By far, the most abundant examples are documented in the Nasca drainage and the southern Peruvian coast, where over 151 trophies have been documented from excavations and museum collections (Tung, 2007a: 490).

Andean trophies are commonly characterized as decapitated crania or skulls with the posterior and/or inferior portions of the cranium removed and a perforation drilled at various locations on the superior cranium where a cord was threaded through for displaying or carrying the head (Andrushko, 2011; Browne et al., 1993; Forgey & Williams, 2005; Garrido & Morales, 2019; Kellner, 2006; Proulx, 1989, 1999; Proulx, 2001; Scaffidi, 2018, 2020b; Silverman & Proulx, 2002; Tung, 2007a, 2008; Tung & Knudson, 2010; Verano, 1995; Verano, 2003; Williams et al., 2001). In some cases, heads were completely defleshed, and this may have occurred gradually as they were used and reused by many generations of ritual practitioners (Scaffidi, 2020b; Verano,

¹ Lozada et al. (2018: 187-188) argue against using the word “trophy” to describe processed heads in the pre-Hispanic Andes, since it implies violent warfare and collection of enemy heads on battlefields. While this paper aims to understand whether decapitated heads were taken from locals or non-locals in order to clarify their social identity, we use the term “trophy head” as the best descriptor of the social contexts of head processing practices in the archaeological contexts at Uraca. As we argue throughout, violent treatment of the heads and the overall cranial trauma rate at the Uraca site support the interpretation that the Uraca heads were taken during intergroup violence. For consistency’s sake, we focus the literature review and discussion on heads that were likely taken in similar violent contexts. Therefore, we use the trophy head terminology throughout, although we recognize that not every disembodied head in the Andes should be interpreted as a trophy.

2018). In other cases, facial tissues and hair were painstakingly curated—the mouth was pinned shut and flayed skin was stuffed with cotton to preserve the victim's countenance—they would have been identifiable by name, even in death (Browne et al., 1993; Guillén, 1992; Silverman & Proulx, 2002; Verano, 1995, 2003). By the Colonial period, chroniclers documented the use of trophies as *huayos* or masks that still retained the appearance of the individual, which were strung up for public ceremonies and worn in public dances (Salomon & Urioste, 1991). The head (especially the mouth and eyes) is viewed as the locus of an individual's vital life force and animating essence in Amerindian ontology (Arnold & Hastorf, 2008; Hastorf, 2018; Proulx, 1999); as such, the head was a potential source of great power and danger, necessitating caution, care, and even supernatural protection while manipulating the head's flesh and bone and handling and curating the head throughout different phases of its use-life (Scaffidi, 2020b).

Anthropologists have argued over whether Andean trophy heads represent the violently decapitated and ritually transformed bodies of enemies from other communities captured during inter-community warfare, natal community members killed on the battlefield, or the lovingly prepared heads of revered ancestors curated by their natal community. The Peruvian archaeologists who first reported trophies in the early 1900s initiated over a century of lively debate about the functions of trophy-taking and the social identities of decapitated individuals. Relying primarily on Nasca ceramic iconography depicting male warriors with trophies hanging from their belts or hands, Max Uhle argued disembodied heads were trophies of enemies of war (Uhle, 1914). Tello (1918) while not entirely discounting Uhle's theory emphasized that trophies could also have served as powerful objects of religious and political symbolism—objects divinely ordained to satiate the gods and a divine cosmological mandate, not just the violent whims of man. Tello observed the presence of female and child trophies whose crania were modified with a local form of cranial vault modification. He relied on this evidence to argue that at least in some cases, Andean trophies were taken from local people who died or had been sacrificed rather than from enemies of war.

Building on this debate, anthropologists have continued to examine age at death and biological sex estimates to understand the motives and meaning of trophy-taking across ancient Andean communities. When trophies are all adult males, they are generally interpreted as enemy men captured during intergroup warfare or raids (Proulx, 1989, 2001; Silverman & Proulx, 2002; Verano, 1995, 2018). In contrast, when the trophy sample is more heterogenous (comprised of males, females, and subadults), the religious aspects of ritual practice are often emphasized. Guillén (1992) argues that the intense preparation of heads and the attention to preserving facial features is suggestive of an ancestor cult rather than warfare. In a similar vein, studies of trophy samples with females, males, and subadults have emphasized decapitated heads as communal sacrifices offered to the gods to promote agricultural fertility (Coelho, 1972; Drusini & Baraybar, 1991; Neira Avendaño & Coelho, 1972). Other studies, however, recognize that the presence of female and subadult trophies does not preclude that the heads were taken during violent warfare or raids (Forgey & Williams, 2005; Williams et al., 2001). For example, in a study from the Wari city of Conchopata, Tung and colleagues (Tung, 2012; Tung & Knudson, 2008, 2010) acknowledge the possibility that some child trophies were taken from within the community as honored sacrifices. They also compellingly argue that female and subadult heads were sometimes taken from foreign

locations. These non-local heads may have served as social substitutes for adult males from their natal communities, allowing the Wari to display domination over the subjugated bodies of non-compliant groups—regardless of their specific individual identities—during episodes of militaristic conquest.

More recently, bioarchaeologists have recognized the diversity of trophy-taking practices throughout time and across regions of the pre-Hispanic Andes, examining how the motivations for those practices are neither mutually exclusive nor timeless. Some Nasca specialists argue that the function of dismembered heads changed through time. There was a shift in trophy head iconography from an association with mythical beings, fertility, and plant themes in the first part of the Early Intermediate Period (“EIP,” *ca.* 100–750 CE), to association with specific warriors or shamans with weaponry by the late EIP and into the Middle Horizon (*ca.* 600–850 CE), reflecting the increasing secularization and militarization of trophy heads (Browne et al., 1993; Silverman, 1993; Silverman & Proulx, 2002). Conlee (2007) reports that the demographic profile of Nasca heads shifted through time from all ages and both sexes to mostly adult males by the late Nasca to Wari era transition.

The social identities of those targeted for their heads may also have become more flexible with time as the practice came to encompass insiders as well as outsiders. Lozada et al. (2018) recently argued that in the Vitor Valley of Arequipa just before the Wari era, trophy heads were taken from natal combatants killed in distant battles when it was impossible to repatriate the entire body. They contend that processing fractures on one trophy and the diversity of processing techniques show they were made expediently and without a proper toolkit at or near the battle site, before being transported back to the Vitor Valley for curation and eventual burial. The practice of transporting a killed warrior’s head back to the community has been documented in South American groups. Among the Mundurucú in the Amazon, where the head was worn around the necks of familial members and honored several times per year before eventual burial (Horton, 1948). Similar decapitation and curation of honored dead killed in combat may have been practiced in the Andes. In the alternative, heads may have been taken from individuals who grew up within and had ties to the trophy-taking community but at the time of decapitation were living—voluntarily or as prisoners—in other communities.

Many Andeanists now share the interpretation that trophies were generally taken during violent conflict and agree that violent dismemberment and ritual practices likely fulfilled multiple, overlapping cosmological purposes (Becker & Alconini, 2018; Blom & Couture, 2018; Browne et al., 1993; Hastorf, 2018; Lozada et al., 2018; Scaffidi, 2020b; Tung, 2012; Verano, 2018). The meanings, motivations, and methods of trophy-taking were likely as idiosyncratic as the circumstances of each victim’s death and the different ritual and artistic choices made by warriors, shamans, and trophy artisans across time throughout the Andes. Understanding the geographic origins of trophy victims, along with their sex, age at death, early childhood mobility, and history of violence throughout life, can shed light on the social meanings and circumstances underlying the practice and the social identities and lived experiences of those whose heads were taken.

To contribute empirically to the debate, a few studies have mobilized archaeological chemistry to understand the geographic origins (Finucane, 2008; Knudson et al., 2009; Knudson & Tung, 2007, Tung & Knudson, 2008, 2010) or ancestral background

(Forgey, 2006, 2011) of pre-Hispanic Andean trophies. Tung (2007a) first suggested strontium isotopes would be useful for determining whether decapitated heads were taken from locally or non-locally born individuals, reasoning that non-local trophy victims are more likely to have been prisoners of war taken from outside groups. Here we follow suit, asking whether 12 trophy heads from the Lower Majes Valley of Arequipa, Peru, show local or non-local radiogenic tooth enamel signatures in teeth that formed during their infancy and early childhood. We use strontium and lead isotopes to determine whether these decapitated and ritually transformed adult males grew up locally or beyond their natal Majes Valley, relative to the non-trophy heads in the burial sample. We also use these radiogenic isotopes to examine early childhood mobility in the trophy and non-trophy head subsamples. Determining whether these trophy victims were locals or not and whether they traveled as children not only clarifies how their geographic and social identities structured their risk for violent death and decapitation, but it also sheds light on the nature of inter-community interaction(s) and the role of violence against geographic outsiders versus insiders in the crystallization of communal identities.

Regional Contexts: Southern Andean Trophy Cults and the Uraca Heads

Evidence for trophy-taking practices in the southern Andes (Fig. 1) comes from the bioarchaeological analysis of heads and their depictions in carvings, etched in petroglyphs, painted on ceramics, and woven into intricate textile designs. This theme is common in the artistic traditions of the southern and south-central Andes, but Nasca ceramic iconography provides by far the best visual record of trophy-taking and trophy-making rituals. Early Nasca ceramic art depicts disembodied heads in isolation, in association with symbols of fertility like plants and bean stalks, or in association with anthropomorphic beings interpreted as spiritual deities or human shamans (Browne et al., 1993; Proulx, 1989; Silverman, 1993; Silverman & Proulx, 2002). By the late Nasca period, trophies are more commonly associated with imagery of warfare and militarism. Late Nasca ceramic scenes on sculptural or serving vessels (Proulx, 1989, 1999; Proulx, 2000, 2001, 2006; Silverman & Proulx, 2002) and instruments like *antaras* (pan flutes) (Carmichael, 2015) and drums (Carmichael, 2019) depict male human or anthropomorphized spiritual beings garbed in intricately patterned tunics, decorated with animal skins, holding heads from their hands, wearing them integrated into headwear or hanging from their belts, or taking them into their mouths. Although Tello (1918: 57-58) and Williams et al. (2001) observed female and subadult trophy heads in the mid-to-late Nasca collections they studied, if late Nasca ceramic scenes depict real events, trophy-taking and use was increasingly restricted to male, high-status practitioners as violent intergroup conflict wore on over time (Silverman & Proulx, 2002).

Nasca trophies were prepared in a variety of different ways but most show the purposeful removal of a portion of the occipital bone and perforation at the mid-frontal bone for a carrying cord to be threaded through (Gonzales Ruiz, 2014; Kellner, 2006; Verano, 1995; Williams et al., 2001). There are variations in the amount of the occipital removed, the placement of the perforation on the frontal bone, the degree of defleshing,

and the removal and manipulation of the hair. Another characteristic of Nasca trophy preparation is the closing of the mouth by piercing both lips with cactus spines.

In contrast, Wari iconography from the Ayacucho Basin during the Middle Horizon (Fig. 1) depicts head-taking in an exclusively militaristic context. In one ceramic urn depiction, front and side facing, painted men with elaborate headdresses clutch staffs terminating in decapitated heads (with cervical vertebrae still attached), while other images show war chiefs or rulers subjugating bound prisoners on their knees (Tung, 2007a: 497). The victims have stylized facial features and wear unique headwear, jewelry, face painting, and clothing (Tung, 2007a) and would have been recognizable to spectators as specific subjugated rulers from other communities. Wari trophies from Conchopata were taken from male, female, and subadult individuals (Tung & Knudson, 2008, 2010) and were somewhat uniform in the method of preparation. Wari trophy preparers standardized trophy-taking by drilling the perforation near the osteological landmark of bregma, on the superior frontal bone, and by removing only a small portion of the occipital by expanding the foramen magnum (Tung, 2007a, 2012). This practice reflects a change from pre-Wari trophy processing evidenced by four trophies recovered from Nawimpukio in the Ayacucho Basin, where small perforations were present on a variety of locations, cranial vault bones were cut in a variety of locations, and facial bones were removed in most cases—only one trophy retained facial bones (Finucane, 2008). Tung (2012) argues that the later Wari era standardization of trophy-making at Conchopata reflects a restriction of the practice to ritual practitioners of the

Fig. 1 The location of the study site of Uraca relative to regions and sites with trophy heads mentioned in this text; inset shows EIP and MH cultural centers and sites (italicized) mentioned in the text. Reference grid is in latitude/longitude relative to the WGS 1984 datum

Wari Empire, which became formalized as an imperial activity. Compared to this regimented imperial practice in the Wari heartland, variable processing techniques in other parts of the southern Andes might suggest that those trophies were prepared by a variety of people—shamans, combatants, or other community members—and perhaps taken and used in a variety of different contexts.

Trophy-taking was also practiced in the Middle Horizon by Tiwanaku-affiliated people in the highland Lake Titicaca region. Isolated, disembodied heads, heads being held by anthropomorphized or humanoid agents, and decapitator figures are depicted in Tiwanaku stone work, ceramics, and textiles (Blom & Couture, 2018; Janusek, 2004; Baitzel & Trigo Rodríguez, 2019; see summary in Becker & Alconini, 2018: 238). Three isolated crania from the site of Wata Wata in the Kallawayá region of Bolivia support the interpretation that this imagery depicts violent treatment of enemy heads rather than ancestor veneration. The three trophies are an adult male and two possible females, all of which display violent cranial injuries and intensive defleshing of the skull flesh and eyes. One individual's attached cervical vertebra illustrates multiple beheading attempts (Becker & Alconini, 2015, 2018).

Because Nasca, Wari, and Tiwanaku were major cultural influences for Arequipa communities (Fig. 1), trophy-taking practices in Arequipa valleys likely shared common motives, meanings, and processing techniques with these distant groups. The representation of trophies appears in portable and wearable art, as evidenced by designs documented in ceramics and textiles at *yunga*² and coastal sites (Fig. 2). At the Majes Valley site of La Real, an isolated, sideways head is depicted on a ceramic scene (Huamán López, 2013: 91). At the site of Cabezas Achatadas in the coastal portion of the Majes-Camaná drainage, archaeologists recovered a woven textile decoration in the form of a human head with falling hair and fringed decorations in the form of human heads (Cardona Rosas, 2002: 62). In the neighboring Sihuas Valley, Sihuas 1 and 2 style woven textiles are fringed with “cut” human head figures and actual human hair (Haeberli, 2001: 103). Also in the Sihuas Valley, excavations at a Wari enclave, Quilcapampa, recovered a Wari-style ceramic vessel of a prisoner bound with a rope around his neck and hands tied behind his back (Huamán López et al., 2021: 261). These decorative themes suggest that violent decapitation of prisoners was practiced, or at least promoted, among many communities in the Arequipa *yunga* and coast.

Trophy head imagery is even more common in the petroglyph canon of the Majes and neighboring valleys (Jennings et al., 2019; Núñez Jiménez, 1986; van Hoek, 2010, 2013; Wołoszyn et al., 2019) (Fig. 2). Although these boulder carvings cannot be dated and they can be interpreted quite differently by different researchers, taken together, they provide ample circumstantial evidence that trophy-taking was a pervasive practice with deep significance to the people who carved these boulders. Maarten van Hoek describes at least 36 examples of trophy heads from Majes and Camaná Valley rock art sites, which he classifies into four types: isolated heads, anthropomorphic figures carrying heads, zoomorphic figures carrying heads, and depictions of two figures “disputing” over heads (2013, 2010). Several depictions of trophy-taking are present at the largest petroglyph site in Peru, *Toro Muerto*, which is only a 2-km walk from

² Throughout this paper, elevation-based classifications are from Peruvian geographer Pulgar Vidal's (1981) eco-zones (Fig. 4). Following Scaffidi and Knudson (2020), these eco-zones are simplified here as *chala* (coast) from 0 to 500 masl, *yunga* from 500 to 2300 masl, and highland (above 2300 masl).

Fig. 2 Map of Arequipa *yunga* sites (italicized) with the locations of trophy heads and examples of trophy head imagery encountered throughout the region. Quilcapampa images are courtesy of Willy Yépez Álvarez. Figures 2 a and c have been enhanced with the DStretch app (by John Hammon) to make the carvings more legible

Uraca (Scaffidi & Tung, 2020: 8; Scaffidi, 2018; van Hoek, 2010, 2013; Núñez Jiménez, 1986; Wołoszyn et al., 2019). These include the image of a human-like figure holding a decapitated head by the hair from the right hand (Fig. 2a) and an image of a feline holding a head by the hair from its mouth (Fig. 2b). Across the river at Pitis, an associated concentration of petroglyph panels may depict a warrior or elite person in fine clothing holding a human head from the right hand (Fig. 2c).³ Another panel shows a camelid figure holding a decapitated head (van Hoek, 2010, 2013). In the Sihuas Valley, there is a carving of a raptor holding a head from its talons (Fig. 2d) and another camelid figure with a tail terminating in a head (Fig. 2e). At the petroglyph sites of Chillihuay and Illomas to the west of the Majes Valley, there are numerous panels showing isolated heads (Jennings et al., 2019). Finally, in the Caravelí Valley in the far western reaches of Arequipa, petroglyph scenes include possible isolated trophies (e.g.,

³ Scaffidi's interpretation of the imagery from Pitis depicting a person with its right hand terminating in a trophy head is contested by van Hoek (2020), who argues this scene depicts only a hand. Scaffidi and team did not trace this petroglyph. However, given the multiple petroglyphs illustrated here that show the right hand terminating in a trophy head, the similarity of this head to other stylized trophy depictions in the area, the sheer quantity of trophy head scenes documented in the region, and the extensive evidence for actual human trophy heads described here, we maintain that this is more likely than not to be a trophy head depiction, although we recognize the limitations inherent in interpreting rock art imagery. We are hopeful that advances in remote sensing technology and documentation of additional petroglyphs in the region can offer further clarity in the future.

Fig. 2f) and a masked human wearing a headdress, holding a trophy from the right hand (Fig. 2g).

Direct evidence of trophy-taking practices is also apparent from decapitated human trophy heads interred at sites throughout Arequipa (Fig. 2). So far, trophy heads have only been recovered from archaeological contexts in coastal and *yunga* zones in Arequipa—trophy-taking does not seem to have been a practice of highland people, or at least, skeletal and iconographic evidence of these practices have not yet been uncovered in the highlands. Trophy heads have been excavated or documented in the Acari (Valdez, 2009a, b, 2012), Majes-Camaná (Disselhoff, 1969; Jennings et al., 2015; Scaffidi, 2018, 2020b; Tung, 2007a, 2012, 2013), Vitor (Lozada et al., 2018), and Sihuas Valleys (Haeblerli, 2001, 2009) (Fig. 2). Headless bodies have also been recovered from Acari (Valdez, 2009a, b) and Camaná sites (Disselhoff, 1969)—these missing heads may have also become trophies.

Except for the decapitated heads from the coast at Camaná, trophies and trophy imagery are largely constrained to a middle-elevation path linking *yunga* sites in these valleys with the Nasca and Wari regions to the north, and other important EIP and MH sites in the Wari and Tiwanaku spheres of influence to the south and east (Jennings et al., 2018; Jennings & Reid, 2021; Scaffidi, 2015, 2018; Williams, 2009). The heads and their depictions, concentrated along this major mid-elevation route, comprised a kind of trophy head corridor linking these communities together into a network of shared, violent practices with important ritual and sociopolitical significance. Reconstructing the geographic origins and mobility of the trophy victims can give clues as to who was permitted or obligated to participate in these violent rituals and shed light on which Arequipa communities interacted throughout the EIP and Middle Horizon.

The Uraca Site and Intergroup Violence

Trophy-taking practices at Uraca in the Lower Majes Valley can be understood within the context(s) of this broader southern Peruvian tradition. Uraca was excavated in 2014 by the Lower Majes Valley Archaeological Project (directed by Scaffidi), during which at least 165 individuals were recovered, including 20 decapitated trophy heads. Uraca is a cemetery-only site located on the hillsides of the west margin of the Majes River. AMS dates from camelid retainers, non-trophy head individuals, and trophy heads show the site was in use from the late EIP into the early Middle Horizon (*ca.* 200–750 CE) (for an in-depth description of AMS methods and dates, please see Scaffidi, 2018; Scaffidi & Tung, 2020). However, two of the trophy heads date to the first century BCE to the first century CE. These earlier dates and the evidence of re-tooling for those trophy heads suggest that these heads do not represent the date of use for the cemetery generally but rather that they were reused over hundreds of years before final burial at Uraca (Scaffidi, 2020a, b).

The Uraca cemetery is a 45-min walk from the *Toro Muerto* petroglyph site, which was a critical node in a complex network of inter-zonal routes with ritual and logistical importance (Scaffidi, 2018) that connected to regional pre-Wari and Wari era roads linking the Wari imperial heartland with settlements in its southernmost reaches (Jennings & Reid, 2021; Reid, 2018; Williams, 2009). In fact, *yunga* zones on the western slopes of the Andes are known for agricultural productivity and the exchange

of livestock, food, people, and things between the coast and highlands (Browman, 1975, 1980; Núñez & Dillehay, 1979; Szremski, 2017). This kind of exchange between different elevations was practiced at least by the Colonial era, forming a kind of “vertical exchange” between eco-zones which maintained specialized crops and trade items, establishing relationships with complementary communities that produced what they could not (Murra, 1972). Given the importance of *yunga* zones in facilitating inter-zonal exchange and the importance of *Toro Muerto* and associated travel routes, we expected radiogenic isotope data to show that Uraca individuals were highly mobile during their lifetimes. We also expected to identify a high proportion of non-local, first-generation migrants who may have traveled frequently to this *yunga* community for trading and ended up staying in the community to die and be buried there.

However, unlike other *yunga* communities in the Majes and neighboring valleys (Bedregal et al., 2015; Huamán López, 2013; Jennings, 2013; Jennings et al., 2015; Owen, 2007; Tung, 2007b, 2012), Uraca’s grave goods show very little artistic influence of distant Wari and Nasca cultures (Scaffidi, 2018). Extraordinarily high levels of intergroup violence might have limited Uraca’s connections to nearby and distant communities (Scaffidi & Tung, 2020). Of 100 adult non-trophy individuals observable for cranial trauma, 67 (67%) showed cranial trauma—the highest reported rate of cranial injury during the EIP or Middle Horizon in southern Peru (Scaffidi & Tung, 2020). Of those with cranial wounds, 61% exhibited evidence of multiple blows. Five adult males died around the time of their cranial injuries, and two of these males had two lethal cranial injuries each; one of the fatal wounds was a decapitation blow to the posterior right neck (Scaffidi & Tung, 2020). Previously published cranial wound characteristics (Scaffidi, 2018; Scaffidi & Tung, 2020) for the non-trophy head individuals sampled for radiogenic isotope analysis are summarized in Table 1.

This endemic violence is important to understand for two reasons. First, this high cranial trauma rate, combined with a disproportionately high number of young to middle adult males buried at Uraca (Scaffidi & Tung, 2020; Scaffidi, 2018), suggests burial at Uraca was restricted to combatant males and associated females and subadults. Second, antemortem (healed/sublethal) and perimortem (unhealed/lethal⁴) cranial wounds suggest Uracans were engaged in persistent and repeated intergroup violence throughout their lifetimes, sometimes as the perpetrators, and other times as the victims (Scaffidi & Tung, 2020). These violent engagements undoubtedly structured many aspects of social organization, ritual practices, intergroup exchange, and regional mobility.

Evidence of Intergroup Violence from the Uraca Trophy Heads

Additional evidence for endemic violence at Uraca can be gleaned from the adult male trophies recovered from the site. Of the 165 individuals recovered, 12% were categorized as trophies. There were nine trophy heads and four unarticulated, defleshed mandibles recovered from the southernmost burial location, Sector I (Fig. 3). There

⁴ As discussed in prior work (Scaffidi & Tung, 2020), perimortem wounds, characterized by lack of healing, were not necessarily the mechanism of death or the only mechanism of death—soft tissue wounds are not necessarily observable in bone. However, since they occurred around the time of death, they are designated here as lethal wounds.

Table 1 Sex, age at death, and cranial wound characteristics for the 25 non-trophy individuals included in this study

Individual	Burial sector	Age (years)	Sex	Cranial wound description ^a
0004	I	15–18	Probable male	None
0008	I	27–45	Female	None
0009	I	25–40	Male	None
0010	I	20–30	Male	Healed nasal fracture Perimortem fracture, left parietal Perimortem ring fracture, left occipital
0012	I	35+	Probable Female	None
0031	I	30–50	Male	Healed depression fracture, right parietal Perimortem depression fracture, right parietal
0035	I	25–35	Male	Healed depression fracture, left frontal
0036	I	15–20	Female	None
0037	I	30–50	Male	Healed fracture, nasal bones 2 healed fractures, left frontal
0038	I	15–18	Probable Female	None
0048	I	25–55	Male	None
0051	I	25–35	Male	None
0053	I	30–40	Male	Healed sharp force injury, right frontal Perimortem depression fracture, left occipital Perimortem chop mark, left occipital condyle
0060	I	18–30	Female	Healed depression fracture, right frontal
0061	I	30–40	Male	Healed depression fracture, right frontal Healed fracture, left nasal Healed fracture, right zygomatic
0086	I	30–40	Female	Healed depression fracture, right frontal
0090	I	30–55	Male	Perimortem depression fracture, right parietal
0106	I	1–4	Subadult	None
0113	I	30+	Male	Healed fracture, nasal bones Healed fracture, right zygomatic Healed depression fracture, right occipital Healed depression fracture, frontal
0124	I	30–50	Male	Healed depression fracture, right frontal Healed depression fracture, left frontal Healed depression fracture, superior frontal Healed fracture, nasals
1004	I	25–30	Female	None
2000	II	40–50	Male	Healed depression fracture, mid-parietal
2001	II	8–10	Subadult	None
3000	II	40–50	Male	None
3001	II	30–50	Male	Healed depression fracture, left parietal

^a Summarized from Scaffidi and Tung (2020)

were three trophy heads and four unarticulated, defleshed mandibles recovered from the northernmost burial location, Sector II, along with the skull and all four legs of a feline which received similar treatment to the human heads (Fig. 3) (Scaffidi, 2018, 2020b).

The Uraca trophies reflect a stylistically diverse and long-standing tradition of trophy head collecting, manufacturing, and curation. Five distinct styles of trophy manufacturing were documented at Uraca. These styles are techniques fully described here in prior work (Scaffidi, 2018, 2020b) but they are recapped briefly here to emphasize the variability in manufacturing techniques used in their preparation. The male individuals transformed into trophies lived and died over seven to eight centuries, from approximately 137 BCE to approximately 763 CE (Table 2), and are described here in roughly chronological order.

The first style is represented by the earliest trophy (individual 7006) from Sector I (Fig. 3a), dating to the first century BCE. It shows the perforation at bregma and occipital expansion at the foramen magnum characteristic of Wari-style heads but predates the Wari Empire by 500 years (Scaffidi, 2018, 2020b). The head is fully defleshed, although the eyes do not appear to have been cut out. The Wari may have borrowed this technique from Majes communities, or perhaps Arequipa and Wari trophy-makers derived their techniques from some other common influence in the first century BCE or earlier.

Three heads from Sector II exhibit a fully fleshed, mummified head style (Fig. 3b). Individual 7010 dates from the first century BCE to the first century CE, and two other individuals (7008 and 7009) were also crafted in this style. These heads were left fully fleshed without removal of the mandible or facial musculature—although the masseter muscles were cut, facial skin and muscles were preserved. Their perforations are on the frontal bone, and the eyes were removed and their orbits were stuffed with cotton (Scaffidi, 2018, 2020b).

The third style is represented by two individuals from Sector I (Fig. 3c). The first, individual 7001, dates to the late EIP, around the fourth or fifth century CE. Along with individual 7000, these two trophies are designated as a splanchnocranial or half-mask style (Scaffidi, 2018, 2020b), given that only the bones of the splanchnocranium (mid-facial bones) are preserved. Both are fully defleshed and show evidence of multiple re-touching episodes that suggest they were continually used over hundreds of years. They may have been worn as elements of ritual costumes which were repaired as they broke (Scaffidi, 2020b). Only one other example of this style has been documented—in a subadult from the Nasca ritual center of Cahuachi to the north (Gonzales Ruiz, 2014: 66).

The fourth style is a defleshed Nasca style face-mask (Fig. 3d) (Kellner, 2006), also called preparation style 1 by Forgey and colleagues (Forgey & Williams, 2005; Williams et al., 2001). Five individuals from Sector I (nos. 7002, 7003, 7004, 7005, and 7007) were crafted in this style. Individual 7004 dates to the sixth or seventh century CE, around the time of the transition from the EIP to the Wari era. At Uraca, this style is characterized by perforation on the frontal bone and preservation of the superior cranial vault and facial bones. Mandibles and hair are not preserved, and the heads are completely defleshed with few cutmarks. In all five individuals, the occipital was removed through a combination of chopping and burning (Scaffidi, 2018, 2020b).

The fifth style (Fig. 3e) is from Sector I, also dating to the Wari transitional period of the sixth to seventh century CE. Individual 7011 was decapitated and defleshed, as evidenced by cutmarks on the nasal bones, maxilla, and parietals (parallel with the sagittal suture). The vault and facial bones are fully preserved and unperforated. The cranium does not display any evidence of burning (Scaffidi, 2018, 2020b).

Fig. 3 Location of Uraca Sectors I and II, showing the trophy head styles: **a** Wari-style or Wari precursor style (individual 7006)—inferior view demonstrates the perforation at bregma (circled) and removal of vault bone by foramen magnum expansion; **b** mummified head (individual 7008) with cotton-stuffed eyes; **c** half face-mask style (individual 7000) with retouched perforation circled on the frontal bone; **d** Nasca-style face-mask (individual 7004) with cotton stuffed in eye orbits and sharp force injury to the right parietal circled; and **e** defleshed but unperforated style (individual 7011) (satellite imagery from QuickBird, July 12, 2011, DigitalGlobe, projected to UTM 18S relative to the WGS 1984 datum)

Violent dismemberment and the antemortem and perimortem cranial wounds documented on the trophy heads (Table 2) suggest they were taken in the context of violent intergroup raiding and warfare (Scaffidi, 2018, 2020b). All trophies show healed

trauma or perimortem trauma around the time of death (Fig. 4, Table 2). Most experienced blows to the face—five have fractures to the nasal bones (Fig. 4a), and six sustained blows to the mouth resulting in anterior tooth loss (Fig. 4b). Three individuals have blunt force trauma on the cranial vault—on the eyebrows (Fig. 4c) and around the ear (Fig. 4d). Another individual has a sharp force perimortem wound to the right parietal (Fig. 3d). In addition to this cranial trauma, the intentional dismemberment of tissues of the eyes and mouth, seen as the locus of the soul in some Andean groups (Arnold & Hastorf, 2008), suggests a violent rupture of trophy victims with their previous identity and the subsequent incorporation of those individuals into the Uraca community (Scaffidi, 2020b). Eye and mouth tissue removal may also demonstrate a recognition of the combat prowess of trophy victims and a concern with taming the spiritual powers of the enemy's head so that it could not harm the community (see discussion in Scaffidi, 2020b).

Were these violently dismembered trophies taken from the Uraca community or from external communities, and if the latter, where were Uraca's enemies from? Did they travel during childhood prior to being injured, decapitated, and interred in the Uraca burial grounds? Radiogenic isotope analysis can help us identify non-local trophy victims and compare their early-life mobility with non-trophies. Ultimately, this can clarify how trophy victim's origins and childhoods predisposed them to violent lives and deaths, and how Uracans interacted with neighboring and/or distant communities.

Radiogenic Isotopes: Identifying Locals and Non-locals in the Pre-Hispanic Peruvian Andes

Strontium Isotope Principles and Andean Expectations

Strontium isotopes have been used for decades to identify non-local individuals based on outlier $^{87}\text{Sr}/^{86}\text{Sr}$ that diverges statistically from the rest of the skeletal sample at a given site (Bentley, 2006; Ericson, 1985; Knudson et al., 2004; Price et al., 1994, 2002; Slovak & Paytan, 2011) or based on skeletal $^{87}\text{Sr}/^{86}\text{Sr}$ beyond the range of environmental baseline materials (e.g., soil, water, plants, fauna) in the vicinity of a site (Hedman et al., 2018; Hodell et al., 2004; Knudson et al., 2014; Pacheco-Forés et al., 2020; Slovak et al., 2018; Valentine et al., 2008; Willmes et al., 2018). Because strontium isotopes in skeletal tissues reflect the geological signature of food and water consumed during tissue development, outlier $^{87}\text{Sr}/^{86}\text{Sr}$ ratios have been used successfully to pinpoint non-local individuals. Because rubidium (^{87}Rb) decays into ^{87}Sr , $^{87}\text{Sr}/^{86}\text{Sr}$ is higher in older rocks with higher Rb/Sr (Bentley, 2006; Price et al., 2002; Slovak & Paytan, 2011). As bedrock weathers, its strontium is then incorporated into the mix of soils, plants, water, fauna, and atmospheric or wind-borne dust and sea-spray that comprise the human food web, known as bioavailable strontium, which varies predictably across the landscape (Bataille et al., 2018; Graustein, 1989; Lengfelder et al., 2019; Maurer et al., 2012; Montgomery et al., 2007; Valentine et al., 2008). Strontium from foods consumed and water imbibed substitutes for calcium ions in the hydroxyapatite crystals of bone and enamel without substantial

Table 2 Summary of cranial wounds and manufacturing characteristics (Maiga et al., 2018; Scaffidi, 2020b) of the 12 trophy head individuals sampled for radiogenic isotope analysis

Individual	Burial sector	Age (years)	Sex	Trophy style	Manufacturing characteristics	Cranial wound description
7000	I	20–35	Male	Defleshed splanchnocranium (half face-mask)	Primary perforation on central frontal and mastoid process Secondary perforation through the left eye orbit Mandible not preserved Maximum posterior breakage-only facial bones preserved Occular cutmarks indicate eyes were removed No burning	Healed blunt force trauma, right sphenoid
7001	I	20–40	Male	Defleshed splanchnocranium (half face-mask)	Primary perforation on central frontal Secondary perforation of the left eye orbit Mandible not preserved Maximum posterior breakage-only facial bones preserved No ocular cutmarks, cutmarks at masseter Burning at the perforation on frontal	Healed fracture, nasals and maxilla Antemortem blow, maxillary incisors
7002	I	15–22	Male	Defleshed Nasca face-mask	Perforation on left frontal Occipital cut away Mandible not preserved Skin not preserved, cutmarks at masseter Burning at occipital removal site	Healed blunt force trauma, right temporal
7003	I	20–30	Male	Defleshed Nasca face-mask	Perforation on left frontal Occipital and inferior parietals cut away Mandible not preserved Skin not preserved, cutmarks at masseter Burning at occipital removal site	Healed fracture, nasals
7004	I	20–30	Male	Defleshed Nasca face-mask	Perforation on left frontal Occipital and inferior parietals cut away Mandible not preserved Skin not preserved, cutmarks at masseter Cotton stuffed eyes Burning at occipital removal site	Perimortem sharp force injury, right parietal Healing blunt force, left maxilla and frontal Possible antemortem blow, maxillary incisors

Table 2 (continued)

Individual	Burial sector	Age (years)	Sex	Trophy style	Manufacturing characteristics	Cranial wound description
7005	I	20–40	Male	Defleshed face-mask	Perforation on left frontal Occipital and inferior parietals cut away Mandible not preserved Skin not preserved, cutmarks at masseter No burning at occipital removal site	Healed fracture, nasals Possible antemortem blow, maxillary incisors
7006	I	35–55	Male	Defleshed Wari precursor?	Perforation at bregma Occipital minimally cut-enlarged from foramen magnum Mandible not preserved No removal of eyes, but cutmarks at masseter No burning	2 healed blunt force traumas, left eyebrow Possible perimortem wound, right occipital
7007	I	18–30	Male	Defleshed Nasca face mask	Perforation on left frontal Occipital and inferior parietals cut away Mandible not preserved Cutmarks along brow ridges, cotton stuffed eye orbits Burning at occipital removal site	Antemortem blow, maxillary incisors
7008	II	20–40	Male	Mummified head	2 perforations on frontal (ectocranial and endocranial) Occipital and inferior parietals cut away Mandible preserved Eyes removed and stuffed with cotton Facial skin and musculature preserved, hair not preserved No burning	Antemortem blow, left maxillary incisors
7009	II	20–40	Male	Mummified head	Perforation on left frontal Occipital and inferior parietals cut away Mandible preserved Eyes removed and stuffed with cotton Facial skin and musculature preserved, hair preserved	Healed fracture, nasals

Table 2 (continued)

Individual	Burial sector	Age (years)	Sex	Trophy style	Manufacturing characteristics	Cranial wound description
7010	II	30–50	Male	Mummified head	No burning Perforation on central frontal Occipital and inferior parietals cut away Mandible preserved Eyes removed and stuffed with cotton Facial skin and musculature preserved, hair preserved No burning	Antemortem blow, maxillary incisors Perimortem fracture, right mandible
7011	I	35–45	Male	Defleshed, unperforated	No perforation Occipital and parietal intact Mandible not preserved Facial musculature and hair not preserved Cutmarks on maxilla, nasals, sagittal suture No burning	Fractured nasals

^a Summarized from Scaffidi (2018) and Scaffidi et al. (2020)

fractionation (Graustein, 1989; Knudson et al., 2010), so the $^{87}\text{Sr}/^{86}\text{Sr}$ value of skeletal tissues reliably reflects the geological signature of the place an individual was living while the sampled tissue was accreting (enamel) or remodeling (bone) (Bentley, 2006; Ericson, 1985; Price et al., 1994). Because bone apatite is more susceptible to the uptake of strontium and other elements from the burial environment via diagenetic contamination, tooth enamel has long been preferred as the most reliable skeletal tissue for accurate $^{87}\text{Sr}/^{86}\text{Sr}$ measurements (Bentley, 2006; Budd et al., 2000; Price et al., 1992).

The age and Rb/Sr of underlying bedrock largely determines the $^{87}\text{Sr}/^{86}\text{Sr}$ of the dietary catchment at any point in coordinate space, with the catchments overlying older geological deposits being more radiogenic (higher Rb/Sr and higher $^{87}\text{Sr}/^{86}\text{Sr}$) than those deposited more recently. The Peruvian Andes consists of two mountain ranges (Fig. 5). The eastern range (furthest from the coast and closer to the Amazon), the Cordillera Oriental, is comprised of older Precambrian-Devonian rocks, punctuated by Permian-Carboniferous, Jurassic, and Cretaceous rocks (Schenk et al., 1999). Bedrock $^{87}\text{Sr}/^{86}\text{Sr}$ along this range has not been extensively sampled but is expected to be the highest in the Andes (Knudson et al., 2014). The Cordillera Occidental (the western range, closest to the Pacific Ocean) is comprised of more recently deposited Quaternary and Tertiary sediments as well as Mesozoic-Cenozoic intrusive and Cretaceous-Tertiary volcanic rocks. Bedrock $^{87}\text{Sr}/^{86}\text{Sr}$ varies from north to south from approximately 0.7043–0.7074 along the front range (Knudson et al., 2014). Coastal areas throughout the north and south of Peru are comprised of Quaternary alluvial sediments derived from the Cordillera Occidental, which reflect the mixed geology of the corresponding highlands (Bellido et al., 1956; Gómez Tapias et al., 2019; Schenk et al., 1999). Bedrock $^{87}\text{Sr}/^{86}\text{Sr}$ is expected to be less radiogenic than corresponding highland regions (Knudson et al., 2014) but may skew higher than expected based on contributions from ocean sea spray or marine food consumption (Whipkey et al., 2000), given modern ocean $^{87}\text{Sr}/^{86}\text{Sr} = 0.7092$ (Veizer, 1989). Furthermore, the southern Andes is volcano-rich (Fig. 5), so ash from highland eruptions may shift the $^{87}\text{Sr}/^{86}\text{Sr}$ of a given dietary catchment away from bedrock-based expectations (Scott et al., 2018; Serna et al., 2020). Finally, the Amazon basin is comprised of Precambrian-Devonian sediments and alluvial contributions from the Cordillera Occidental (Bellido et al., 1956; Schenk et al., 1999). While geological models have depicted a homogenous Amazonian basin comprised of Tertiary and Quaternary sediments (Gómez Tapias et al., 2019; Schenk et al., 1999), recent studies show highly variable $^{87}\text{Sr}/^{86}\text{Sr}$ in surface waters, from 0.7056 to 0.7438, reflecting heterogeneous sedimentary input from corresponding highland geological deposits (Bouchez et al., 2010; Santos et al., 2015).

Scaffidi and colleagues' recent water strontium isoscape (2020) confirms these broad trends in environmental $^{87}\text{Sr}/^{86}\text{Sr}$, from less radiogenic along the coast and western slopes (from approximately 0.7049–0.7090) to more radiogenic in the highlands and corresponding eastern slopes of the Andes (from approximately 0.7090 to 0.7230, Fig. 6). As this research shows, variable bedrock geology in a region does not always lead to variable $^{87}\text{Sr}/^{86}\text{Sr}$ in the surface materials that comprise the dietary catchment. Based on geological models (Gómez Tapias et al., 2019; Schenk et al., 1999), the study site of Uraca is on the border of Tertiary alluvial flows

punctuated by Mesozoic-Cenozoic intrusive rocks and Cretaceous-Tertiary volcanic rocks. Environmental $^{87}\text{Sr}/^{86}\text{Sr}$ samples are expected to reflect this bedrock variation. However, water samples tested from throughout the Majes Valley show consistent $^{87}\text{Sr}/^{86}\text{Sr}$ that is relatively homogenous compared to the highly variable underlying bedrock geology. The Scaffidi et al. (2020) water isoscape predicts that $^{87}\text{Sr}/^{86}\text{Sr}$ in skeletal tissues from the Majes Valley should range from 0.7078 to 0.7082.

The range of all published archaeological human $^{87}\text{Sr}/^{86}\text{Sr}$ in the Andes (including Argentina, Bolivia, Chile, and Peru) is similar to that anticipated by the Peruvian water isoscape, ranging from 0.7038 to 0.7239 (Scaffidi & Knudson, 2020). Archaeological isoscape predictions mirror those of the water $^{87}\text{Sr}/^{86}\text{Sr}$ model, with lowest $^{87}\text{Sr}/^{86}\text{Sr}$ at the northern coast and the Nasca desert region, with progressively more radiogenic $^{87}\text{Sr}/^{86}\text{Sr}$ along the eastern slopes of the Cordillera Occidental (Scaffidi & Knudson, 2020). According to the Scaffidi and Knudson (2020) archaeological isoscape, Majes Valley sites should range in $^{87}\text{Sr}/^{86}\text{Sr}$ from 0.7077 to 0.7084, almost identical to the water model prediction. At Beringa, in the Upper Majes Valley, 58 skeletal samples have a mean $^{87}\text{Sr}/^{86}\text{Sr} = 0.7084$ and a range of 0.7078 to 0.7086—all but two individuals ($^{87}\text{Sr}/^{86}\text{Sr} = 0.7086$ and $^{87}\text{Sr}/^{86}\text{Sr} = 0.7096$) fall within the archaeological and water isoscape predictions for the valley (Knudson & Tung, 2011). Based on the cumulative prediction ranges of these prior models (confirmed by the Beringa values), $^{87}\text{Sr}/^{86}\text{Sr}$ for locally born Uraca skeletons in the Lower Majes Valley are expected to range from 0.7077 to 0.7084. However, this range is similar to that modeled by the water isoscape (Fig. 2) for latitudinally similar neighboring communities in the Sihuas and Vitor Valleys, as well as large swaths of the contiguous highlands. Price and colleagues refer to this as the problem of equifinality (Price et al., 2002)—the idea that distinct, distant regions can produce identical isotope values due to similar underlying geologies. This geological similarity in the river valleys of Arequipa necessitates the examination of additional isotopic proxies to refine the identification of non-locals based on $^{87}\text{Sr}/^{86}\text{Sr}$ alone.

Lead Isotope Principles and Andean Expectations

Lead isotopes also vary according to local geology and can be used as an additional proxy for geographic residence (Evans et al., 2018a; Jones et al., 2017; Kamenov & Gulson, 2014; Sharpe et al., 2016; Sharpe et al., 2021; Shaw et al., 2016; Smith et al., 2018; Tomczyk et al., 2019; Turner et al., 2009; Valentine et al., 2008; Wittmers et al., 2002). Lead is a radiogenic element that, like strontium, follows Ca pathways into the skeleton as Pb phosphate (Åberg et al., 1998). Like strontium, lead does not fractionate as it moves from the environment to skeletal tissues, so the lead isotope ratios of bedrock reflect that of an individual's place of residence while the sample tissue was forming (Sharpe et al., 2021). Unlike strontium isotopes which enter the body through foods ingested and water imbibed, Pb isotopes enter the body primarily through inhalation and ingestion of soils and aerosolized soil particles, dust, and anthropogenic lead sources (Åberg et al., 1998; Kamenov, 2008; Kamenov & Gulson, 2014; Sharpe et al., 2021; Turner et al., 2009). Because Pb in humans mostly reflects local soil and dust, Pb isotope ratios are not impacted by the consumption of high-calcium foods, as observed with Sr isotope ratios.

The natural Pb in soil and dust typically reflects the Pb isotopic composition of the source bedrock. In turn, the Pb isotopes in the bedrock depend on the decay of uranium (^{238}U and ^{235}U) and thorium (^{232}Th), leading to higher Pb isotope ratios in older rock with higher U/Pb and Th/Pb (Sharpe et al., 2021). The three most commonly used Pb isotope ratios in archaeology are $^{206}\text{Pb}/^{204}\text{Pb}$, $^{207}\text{Pb}/^{204}\text{Pb}$, and $^{208}\text{Pb}/^{204}\text{Pb}$: ^{208}Pb is produced by thorium (^{232}Th) decay, while ^{206}Pb and ^{207}Pb are produced by uranium decay (^{238}U and ^{235}U , respectively), all of which are reported relative to the non-radioactive ^{204}Pb (Faure & Mensing, 2005; Sharpe et al., 2021). Due to this age and decay, geologically old rocks with high U/Pb and Th/Pb will have relatively high $^{206}\text{Pb}/^{204}\text{Pb}$, $^{207}\text{Pb}/^{204}\text{Pb}$, and $^{208}\text{Pb}/^{204}\text{Pb}$ ratios. By analogy, geologically old rocks with low U/Pb and Th/Pb will have relatively low $^{206}\text{Pb}/^{204}\text{Pb}$, $^{207}\text{Pb}/^{204}\text{Pb}$, and $^{208}\text{Pb}/^{204}\text{Pb}$ ratios. Typically, it takes millions of years to develop notable changes in the natural Pb isotope ratios of a given bedrock, due to the long half-lives of both U and Th. As a result, geologically young rocks mostly reflect their initial Pb isotopic compositions at the time of formation, independent of the U/Pb and Th/Pb ratios. As a result of these combinations of age and U-Th-Pb concentrations, Pb isotopes are variable throughout geographies with distinct bedrock (Evans et al., 2018b).

However, one major complication of using Pb isotopes for tracing human origin and migration patterns is anthropogenic contamination. The Pb contamination can be from the overall environment (soil, dust, water) or can be a result of human use of objects with elevated Pb content. At present, the natural Pb isotopic composition in almost every region on Earth tends to be altered due to anthropogenic activities ultimately related to historical and/or modern mining and use of Pb ores (Kamenov & Gulson, 2014). In prehistoric people who were not exposed to high Pb environments and did not use high-lead materials, lead concentrations in bone and teeth are expected to be 10–100 times lower than in modern or historic people (Åberg et al., 1998). Pb mining began around 3000 years ago in Europe (Shotyk et al., 1998) and likely around 2000 years ago in South America (Kamenov et al., 2020). Therefore, after mining and Pb usage started, natural and anthropogenic Pb sources must be considered. For example, since Roman times, lead has been used extensively in pipes, paints, ceramic glazes, and for other common purposes (Montgomery et al., 2010). This has sometimes resulted in elevated Pb concentrations useful for identifying individuals from places with high lead usage (Åberg et al., 1998; Laffoon et al., 2020; Montgomery et al., 2010; Schroeder et al., 2013; Shaw et al., 2016).

Pb isotopes have not been utilized as much as $^{87}\text{Sr}/^{86}\text{Sr}$ for geographic provenience in the Americas due to overall low Pb concentrations and concerns about diagenetic contamination from the burial environment—particularly in bone samples that take up lead from soils as they decay (Kamenov et al., 2018; Samuelsen & Potra, 2020). A further issue with bone sampling is that because bones have distinct turnover rates, Pb isotope values in one bone are not representative of those in other skeletal elements, and different periods of lead exposure could register in different amounts across the skeleton, including tooth enamel (Montgomery et al., 2010). Nonetheless, as instrumental precision and thresholds for identifying possible diagenesis are continually refined, Pb isotopes have been increasingly used as an additional radiogenic isotope data point that can be analyzed from the same solution prepared for strontium. In some cases, these additional isotopes can help to overcome the problem of equifinality with

Fig. 4 Examples of violence-related injuries in the Uraca trophies (circled): **a** healed/healing nasal fracture (individual 7003); **b** antemortem loss of maxillary incisors (individual 7001); **c** blunt force trauma to the left frontal (individual 7006); and **d** healed blunt force trauma to the right sphenoid, right lateral view—mastoid process is inferior (individual 7000)

Sr isotopes. Price et al. (2002) define equifinality as the idea that distant regions can show the same $^{87}\text{Sr}/^{86}\text{Sr}$, making it difficult to determine whether some individuals were truly locally born or just consumed diets based on geologically based isotope ratios that are indistinguishable for consumed foods and water. Lead isotopes have been successfully used together with $^{87}\text{Sr}/^{86}\text{Sr}$ to refine the identification of non-locals in a few New World archaeological studies (Dudás et al., 2016; Jones et al., 2017; Samuelsen & Potra, 2020), but only one of these includes human skeletons from the Central Andes (Turner et al., 2009).

Generally, in the Andes, $^{206}\text{Pb}/^{204}\text{Pb}$ is lowest in the Central Andes Cordillera Occidental or western Cordillera (approximately 16.08–17.85), intermediate along the coast (17.85–18.38), and highest in the Cordillera Oriental or eastern Cordillera (above 18.38) (Mamani et al., 2008; Turner et al., 2009) (Fig. 3). The Arequipa massif shows particularly low Pb isotope values from ore and rock samples, with $^{206}\text{Pb}/^{204}\text{Pb}$ from 16.083 to 18.551 (Fig. 7a), $^{207}\text{Pb}/^{204}\text{Pb}$ from 15.435 to 15.650 (Fig. 7b), and $^{208}\text{Pb}/^{204}\text{Pb}$ from 37.625 to 38.655 (Fig. 7c) (Mamani et al., 2008: 5; Kamenov et al., 2002; Macfarlane et al., 1990). The low-radiogenic Pb isotopes in the local bedrock (including recent volcanic rocks) and ores are sourced from the Precambrian Arequipa-Antofalla metamorphic basement (Kamenov et al., 2002; Mamani et al., 2008). The basement influence on the Pb isotopes in the Central Andes extends from around 15.5° S to around 20° S (Mamani et al., 2008). At the same time, more recent volcanic rocks (< 10 My) along the volcanic arc show relatively low $^{87}\text{Sr}/^{86}\text{Sr}$, the majority between 0.706 and 0.7075 (Mamani et al., 2008). Therefore, an individual residing in the Central Andes in a region dominated by recent volcanic rocks is expected to have relatively low $^{87}\text{Sr}/^{86}\text{Sr}$ and low $^{206}\text{Pb}/^{204}\text{Pb}$, $^{207}\text{Pb}/^{204}\text{Pb}$, and $^{208}\text{Pb}/^{204}\text{Pb}$. In contrast,

an individual residing in the Central Andes in a region not dominated by recent volcanic rocks will be expected to show low $^{206}\text{Pb}/^{204}\text{Pb}$, $^{207}\text{Pb}/^{204}\text{Pb}$, and $^{208}\text{Pb}/^{204}\text{Pb}$ but elevated $^{87}\text{Sr}/^{86}\text{Sr}$ (Fig. 1).

Little comparative lead isotope data exists for Andean skeletons (but see Turner et al., 2009; Tomczyk et al., 2019) and environmental reference materials (Tomczyk et al., 2019). The only published lead isotope data from Andean human skeletons are from the Inca palace of Machu Picchu in Cusco, and these skeletons likely reflect migrants from many different surrounding areas to Cusco (Turner et al., 2009). Cusco is several days' walking distance from Arequipa, but the lower end of the $^{206}\text{Pb}/^{204}\text{Pb}$ range (18.19–19.015) from the Machu Picchu skeletons overlaps slightly with the geological range of the Arequipa massif. The same is true for $^{207}\text{Pb}/^{204}\text{Pb}$ (Machu Picchu range = 15.578–16.679) and $^{208}\text{Pb}/^{204}\text{Pb}$ (37.968–38.884). The addition of Pb isotopes to a multivariate geological provenience dataset “has the potential to be more sensitive to regional differences than Sr alone” (Samuelson & Potra, 2020: 1; Sharpe et al., 2016). Given the similar bedrock geology (Fig. 5) and predicted $^{87}\text{Sr}/^{86}\text{Sr}$ throughout the Majes Valley and nearby valleys (Fig. 7), we evaluate the utility of Pb isotopes for identifying non-local individuals who are not geologically distinct based on $^{87}\text{Sr}/^{86}\text{Sr}$ alone.

Prior Strontium Isotope Studies of Andean Trophy Heads

While there is no lead isotope data from Andean trophy heads, prior strontium isotope data from Wari and Nasca samples show contrasting patterns in the geographic origins of trophy heads recovered from those regions. At the Wari city of Conchopata, two of the five adult trophies tested displayed non-local enamel and bone $^{87}\text{Sr}/^{86}\text{Sr}$, suggesting they had lived their entire lives outside of the Ayacucho basin before being taken to the Wari heartland and decapitated in violent ritual (Tung & Knudson, 2008). Another trophy showed local enamel values but non-local bone values, suggesting he spent his adult life outside of the Ayacucho basin before his head was decapitated and used in the Conchopata ritual program (Tung & Knudson, 2008). Additionally, two of four subadult trophies tested from Conchopata show non-local, more radiogenic $^{87}\text{Sr}/^{86}\text{Sr}$, suggesting that heads were taken from locals and non-locals, both children and adults, for use in Wari rituals (Tung & Knudson, 2010). In a study of six trophies from the pre-Wari site of Nawimpukio in Ayacucho, one was interpreted as a non-local individual on the basis of a non-maize based adult diet, but strontium isotope analysis was not performed to verify the suspected non-local origins of this individual (Finucane, 2008).

Strontium isotope measurements of trophy head victims in the Nasca region (most of which pre-date the Wari Empire) suggest most were of local origins. Of the male, female, and subadults trophies from five sites around Nasca, only 2/16 (12.5%) were not within the local range, based on local small mammal $^{87}\text{Sr}/^{86}\text{Sr}$ (Knudson et al., 2009) and prior baseline studies in the region (Conlee et al., 2009). Corresponding stable carbon and oxygen isotope data do not reflect differences between the trophy and non-trophy subsamples (Knudson et al., 2009), and aDNA analysis suggests the trophy heads were taken from other people within the Nasca region (Forgey, 2006). This determination of Nasca origins does not necessarily mean heads were taken from within communities, however. Given the geological homogeneity and size of the Nasca region, it is equally possible heads were procured from neighboring or near-local

Fig. 5 The study site of Uraca in the Department of Arequipa, relative to the most recent geological model for South America (WGS 1984) (Gómez Tapias et al., 2019)—legend shows only chronostratigraphic units within Arequipa

enemy groups during local intra-ethnic conflict (Verano, 1995). In this case, trophies might show similar strontium isotope measurements, and stable isotope analysis might corroborate that they consumed isotopically similar water sources and foods.

The $^{87}\text{Sr}/^{86}\text{Sr}$ isoscape models from archaeological (Scaffidi & Knudson, 2020) and water samples (Scaffidi et al., 2020) predict homogeneous $^{87}\text{Sr}/^{86}\text{Sr}$ in many coastal to mid-elevation river valleys, like the Nasca desert and the Arequipa *yunga* (Fig. 5).

Fig. 6 Uraca's location relative to water $^{87}\text{Sr}/^{86}\text{Sr}$ isoscape predictions (reproduced from Scaffidi et al., 2020) with major river valleys referred to in the text labeled

When trophies may have been procured from nearby groups in geologically homogeneous zones (likely similar in $^{87}\text{Sr}/^{86}\text{Sr}$), it becomes critical to examine additional isotopic proxies to access more nuanced characterization of “local” geographic origins. Because no child heads were recovered at Uraca, and all were injured, young adult to middle adult males, we suspect they were procured from enemy groups within a few days’ walking distance, rather than from locals within the community.

Hypotheses About Mobility of the Uraca Trophy Heads and Non-trophy Individuals

We hypothesize that the decapitated trophy heads come from non-locally born victims, which would suggest they were from rival communities beyond Uraca. We investigate this through radiogenic isotope analysis of first molar enamel. We also hypothesize that the trophy head victims had more mobile childhoods than non-trophy individuals,

which could suggest they or their families were tied into mobility networks that structured their future violent careers, or the inverse—that locally born Uracans were exceptionally stationary compared to neighboring groups. We investigate this by assessing the change in radiogenic isotope values from first to second molar enamel, as described below.

Materials and Methods: Childhood Residential Isobiographies

Because different teeth form sequentially during juvenile growth and development, measuring radiogenic isotope values of tooth enamel in multiple teeth per individual allows us to examine residential origins and potential mobility across multiple years during infancy and early childhood. Researchers have long recognized the potential of multi-tooth or multi-tissue sampling for creating isotopic “life histories” (Eriksson & Lidén, 2013; Hrnčir & Laffoon, 2019; Laffoon et al., 2018; Marsteller et al., 2017). To complement the bioarchaeological osteobiographical approach and to avoid conflation with the ecological concept of life history, we use the term *isobiography* to describe analysis of residential movement from teeth forming in two or more discrete phases.

Tooth Enamel Samples

To reconstruct early childhood isobiographies, we sampled enamel from teeth forming from birth to around 3 years old (e.g., first molars and incisors) and from those forming from about 2.5–8 years old (e.g., premolars and second molars) (Hillson, 1986, 1996; Turner et al., 2009). Where preserved, we sampled infancy/early childhood (IEC) and middle childhood (MC)-forming tooth pairs from non-trophies ($n = 8$ individuals) and trophies ($n = 10$ individuals) to compare early childhood mobility between the two subsamples.

Elemental and Radiogenic Isotope Analyses: $^{87}\text{Sr}/^{86}\text{Sr}$, $^{206}\text{Pb}/^{204}\text{Pb}$, $^{207}\text{Pb}/^{204}\text{Pb}$, and $^{208}\text{Pb}/^{204}\text{Pb}$

Bulk sampling of tooth enamel was carried out in the Bone Chemistry Laboratory (Department of Anthropology) and a class 1000 clean lab (Department of Geological Sciences) at the University of Florida following established protocols (Kamenov et al., 2018; Kurin et al., 2016; Lofaro et al., 2019). Tooth cusps were isolated by vertical sectioning, and all enamel surfaces were mechanically cleaned of surface contamination and dentin with a high-speed NSK UM50TM diamond tip dental drill under $\times 10$ magnification. Approximately 20 mg of bulk tooth enamel was placed in acid-washed Teflon vials and digested in 8N nitric acid (HNO_3) for 24 h. After dissolution, the samples were evaporated to dryness and dissolved in 0.8 N HNO_3 , spiked with 8 ppb Rh and Re. A fraction of this solution was used for elemental analyses on an Element2 HR-ICP-MS following methods described in Kamenov et al. (2018).

The remaining solution was evaporated to dryness and Pb and Sr were extracted using ion chromatography for isotope analyses following methods described in Valentine et al. (2008). In short, Pb was first separated using columns packed with Dowex 1X-8 resin in 1N hydrobromic acid (HBr, Optima). The resultant 3ml 1N HBr wash

was collected for Sr extraction, and Pb was collected with 20% HNO₃ (Optima). Strontium was then separated using columns packed with Eichrom Sr-Spec resin and 3.5N HNO₃.

Strontium and lead isotope ratios were measured on the Nu Plasma multi-collector inductively coupled plasma mass spectrometer (MC-ICP-MS). Long-term reproducibility of NBS 987 for ⁸⁷Sr/⁸⁶Sr is 0.71024 ($2\sigma = 0.00003$), and long-term reproducibility of the NBS 981 standard for ²⁰⁶Pb/²⁰⁴Pb is 16.937 ($2\sigma = 0.004$), for ²⁰⁷Pb/²⁰⁴Pb is 15.490 ($2\sigma = 0.003$), and for ²⁰⁸Pb/²⁰⁴Pb is 36.695 ($2\sigma = 0.009$).

Diagenetic Alteration Assessment

The possibility of post-mortem contamination in the burial environment can complicate the use of chemical and isotope information recorded in archaeological skeletons. Although human enamel is more resistant to diagenetic changes than bone, elevated concentrations of certain trace elements, such as V, Mn, REE, U, and Th, can be used as evidence for post-mortem alteration (Kamenov et al., 2018). Major and trace element data for the enamel samples analyzed in this work are presented in Online Resource 1. Possible diagenetic contamination was identified where trace elemental concentrations were above the maximum threshold concentrations (MTC) proposed by Kamenov et al. (2018).

Defining Local Radiogenic Isotope Values and Statistical Comparisons of Subsamples

As described in the section on expectations above, we used environmental baseline data and predictive modeling to establish the local Lower Majes Valley range for strontium and used statistical parsing to establish the local range for each of the three lead isotope ratios. We defined the local range for each Pb isotope as the mean $\pm$ 2 SD of the entire sample, including both trophies and non-trophies (*i.e.*, we did not assume the trophies were non-locals). Even if the ⁸⁷Sr/⁸⁶Sr of a sample fell within the local range, if one of the corresponding Pb isotopes was outside of the 2σ range, it was identified as a probable non-local. We report ⁸⁷Sr/⁸⁶Sr to the fourth decimal place, since this is sufficient for discriminating between local and non-local ⁸⁷Sr/⁸⁶Sr in human tissues (Bentley, 2006; Knudson et al., 2016). We report ²⁰⁶Pb/²⁰⁴Pb, ²⁰⁷Pb/²⁰⁴Pb, and ²⁰⁸Pb/²⁰⁴Pb to three decimal places, according to the higher instrumental error and long-term reproducibility of the NBS 981 standard.

We completed statistical analysis in Minitab and R 2.3.2. We collapsed probable and secure sex estimations for statistical testing (*i.e.*, probable females were lumped together with females). When isotope values were normally distributed as determined by the Shapiro-Wilk test, we used a *T*-test to compare means between two groups. When data were non-normally distributed, we used Mann-Whitney *U* to compare medians. To compare variance between two or three subsamples or central tendencies between three subsamples, we used the parametric one-way ANOVA regardless of normality, for two reasons. First, the non-parametric alternative, Kruskal Wallis, tests ranked means rather than mean and variance, and we are interested in comparing homogeneity of means rather than their ranks (McDonald, 2009). Second, non-

Fig. 7 Lead isotope expectations reproduced by IDW interpolation of ore and rock measurements from Mamani et al. (2008) for each of the Pb isotope ratios: **a** $^{206}\text{Pb}/^{204}\text{Pb}$; **b** $^{207}\text{Pb}/^{204}\text{Pb}$; and **c** $^{208}\text{Pb}/^{204}\text{Pb}$ (triangles show measured values and shading shows IDW-interpolated predictions for those values)

parametric alternatives obscure meaningful variation in datasets where small variation would be significant to our interpretations of local or non-local (McDonald, 2009: 145–147). Furthermore, one-way ANOVA is robust against non-normality and provides reliable results, particularly with non-borderline *p*-values (McDonald, 2009).

Results: Local and Non-local Origins for the Uraca Trophy and Non-trophy Subsamples

We report 55 $^{87}\text{Sr}/^{86}\text{Sr}$ results from infancy/early childhood and middle childhood-forming tooth enamel from 37 individuals—6 females or probable females, 2 subadults whose sex could not be estimated, 13 males or probable males, and 12 trophy heads, all of which were young to middle adult males (Table 3). We also report 42 sets of $^{206}\text{Pb}/^{204}\text{Pb}$, $^{207}\text{Pb}/^{204}\text{Pb}$, and $^{208}\text{Pb}/^{204}\text{Pb}$ values for 33 of the 37 individuals tested, excluding 13 measurements as unreliable due to very low instrument voltage for Pb concentrations (Table 3).

Major and trace element data for the enamel samples analyzed in this work are presented in Online Resource 1. Almost all enamel samples show concentrations of elemental indicators for diagenetic change below the maximum threshold concentrations (MTC) proposed by Kamenov et al. (2018). Only three enamel samples show slightly elevated concentrations (Online Resource 1) indicating weak alteration. Individual 12 shows Th (0.11 ppm) above the 0.05 ppm MTC, individual 124 shows V

(0.147 ppm) and Fe (200 ppm) above the MTC (0.11 ppm and 143 ppm, respectively), and individual 2000 shows Mn (24.5 ppm) above the MTC (15.4 ppm).

The Uraca sample shows relatively constrained, but non-normally distributed $^{87}\text{Sr}/^{86}\text{Sr}$ according to Shapiro-Wilk $W(54) = .674$, $p < .001$, $n = 55$, with $\bar{x} = 0.7083 \pm 0.00032$ (1σ). Two lead isotope values are non-normally distributed: for $^{207}\text{Pb}/^{204}\text{Pb}$, Shapiro-Wilk $W(41) = .889$, $p < .001$, $n = 42$, $\bar{x} = 15.6230 \pm 0.0131$ (1σ); for $^{208}\text{Pb}/^{204}\text{Pb}$, Shapiro-Wilk $W(41) = .853$, $p < .001$, $n = 42$, and $\bar{x} = 38.5834 \pm 0.0808$ (1σ). However, $^{206}\text{Pb}/^{204}\text{Pb}$ is normally distributed according to Shapiro Wilk $W(41) = .980$, $p = .674$, $n = 42$, and $\bar{x} = 18.3830 \pm 0.0553$ (1σ).

The trophy subsample ($n = 22$) does not have a distinct median or variance from the non-trophy head subsample ($n = 33$) (Table 4). The female/subadult ($n = 11$), male, non-trophy ($n = 22$), and trophy ($n = 22$) groups do not have distinct means or variance (Table 4). High and low $^{87}\text{Sr}/^{86}\text{Sr}$ outliers are present in the male and trophy head subgroups, but not in the female and subadult subgroups (Fig. 7a).

Similarly, trophy and non-trophy central tendencies were not significantly different for the three lead isotope ratios (Fig. 8b–d, Table 4). As observed with $^{87}\text{Sr}/^{86}\text{Sr}$, variance is not significantly different between trophy and non-trophy subsamples for the three lead species. The central tendencies and variance in $^{206}\text{Pb}/^{204}\text{Pb}$ and $^{208}\text{Pb}/^{204}\text{Pb}$ of female/subadult ($n = 8$), male ($n = 17$), and trophy head ($n = 17$) subgroups are not significantly distinct, but these groups do show distinct median and variance in $^{207}\text{Pb}/^{204}\text{Pb}$ (Table 4). Lead isotope boxplots reveal three additional inter-quartile range (IQR) outlier individuals (Fig. 8b–d) who are distinct from the $^{87}\text{Sr}/^{86}\text{Sr}$ outliers (Fig. 8a).⁵

Non-local Individuals Based on $^{87}\text{Sr}/^{86}\text{Sr}$

Based on the local water and archaeological isoscape $^{87}\text{Sr}/^{86}\text{Sr}$ predictions, we identified five teeth with low-value outliers from four individuals and ten teeth with high-value outliers from seven individuals (Fig. 9). None of the outlier values are from female or subadult samples. Individual 3001, a middle adult male with one healed cranial wound, as well as trophy individuals 7000, 7001, and 7004, display low $^{87}\text{Sr}/^{86}\text{Sr}$ from 0.7071–0.7077, consistent with water isoscape predictions from *yunga* regions to the east (Sihuas Valley) and west (Ocoña Valley), coastal regions to the north at the modern-day cities of Atico and Chaparra, as well as the nearby highland Colca, Andagua, and Chuquibamba Valleys, and Lake Titicaca highlands (Fig. 6). Individual 31, a middle-adult male with one healed and one perimortem fracture (both to the right parietal), as well as trophy individuals 7002, 7003, 7005, 7009, and 7010, display high $^{87}\text{Sr}/^{86}\text{Sr}$ above 0.7084 (although individual 7010 is close to 0.7084), consistent with isoscape predictions from wide swaths of highland, coastal, and *yunga* Arequipa, as well as the distant Cusco and Lake Titicaca highlands (Fig. 6).

⁵ The IQR outliers depicted by the lead isotope ratio boxplots (Individuals 124, 2000, and 7006, Fig. 7a–d) are slightly different from the 2σ outliers depicted in the corresponding scatterplots (Individuals 124, 2000, 2001, and 7005, Fig. 9a–c) in the following section. Both the IQR and 2σ methods arbitrarily identify outliers; nonetheless, we define the lead isotope outliers as those outside of the 2σ range as depicted by the scatterplots below.

Non-local Individuals Based on $^{206}\text{Pb}/^{204}\text{Pb}$, $^{207}\text{Pb}/^{204}\text{Pb}$, and $^{208}\text{Pb}/^{204}\text{Pb}$

Local lead isotope ranges are defined as $\bar{x}_{\text{trophy and non-trophies}} \pm 2 \text{ SD}$: for $^{206}\text{Pb}/^{204}\text{Pb} = 18.272\text{--}18.494$; for $^{207}\text{Pb}/^{204}\text{Pb} = 15.597\text{--}15.649$; and for $^{208}\text{Pb}/^{204}\text{Pb} = 38.421\text{--}38.745$. Based on the 2σ range for each lead isotope, we identified three additional outliers with otherwise locally consistent $^{87}\text{Sr}/^{86}\text{Sr}$. We identified two high-value $^{206}\text{Pb}/^{204}\text{Pb}$ outliers: individual 2000, a middle adult male with one healed cranial wound, and individual 2001, an 8–10-year-old uninjured child (Fig. 10a). The same two individuals were high-value $^{207}\text{Pb}/^{204}\text{Pb}$ outliers (Fig. 10b). We identified one low-value $^{208}\text{Pb}/^{204}\text{Pb}$ outlier, individual 124, a middle adult male with four healed fractures to the cranial vault and nasal bones (Fig. 10c). The other low-value outlier has $^{206}\text{Pb}/^{204}\text{Pb}$ from the first molar (trophy individual 7005) which corroborates the non-local $^{87}\text{Sr}/^{86}\text{Sr}$ from the same tooth. It should be noted, however, that individuals 2000 and 124 show slightly elevated concentrations of REE suggesting weak diagenetic alteration, so these data should be approached cautiously.

Radiogenic Isotope Differences According to Trophy Head Style and Cranial Wound Lethality

Strontium isotope ratios of the three mummified trophy head individuals from Sector II are distinct from the eight defleshed ones from Sector I, but not for the three lead isotope ratios. The defleshed trophy samples ($n = 18$) have distinct median $^{87}\text{Sr}/^{86}\text{Sr}$ from the mummified trophy samples ($n = 4$), but similar variance (Table 4). All four teeth from the three mummified heads were high-value $^{87}\text{Sr}/^{86}\text{Sr}$ outliers (Fig. 3, Table 3). The central tendencies and variance for the mummified heads ($n = 3$) are not distinct from the defleshed heads ($n = 14$) for any of the three lead ratios (Table 4). The five teeth from the three mummified heads were tightly constrained in all three lead ratios relative to the defleshed heads, but their values were within the 2σ range for the whole sample.

The lethality of injuries is not related to isotopic variability in the 34 injured individuals ($n = 52$ samples, including trophies and non-trophies). Median $^{87}\text{Sr}/^{86}\text{Sr}$ for the lethally injured ($\bar{x} = 0.7083$, $n = 27$) and the sublethally injured ($\bar{x} = 0.7083$, $n = 25$) are not distinct according to a Mann-Whitney U $W(1) = 797.500$, $p = .161$, $n = 52$. Variance is greater for the lethally injured ($SD = 0.0004$) than for the sublethally injured ($SD = 0.0002$) but not significantly so according to a one-way ANOVA $F(1) = .250$, $p = .616$. There are no differences in mean, median, or variance between lethally and sublethally injured samples for the three lead isotope ratios.

Early Childhood Mobility of Trophies and the Lethally Injured

Finally, we calculated early childhood mobility for the 8 non-trophies and 10 trophies for which teeth from the IEC and MC phases were analyzed [mobility = absolute value (middle childhood – infancy/early childhood)]. As Fig. 11 illustrates, none of the non-trophies registered as outside of the local baseline $^{87}\text{Sr}/^{86}\text{Sr}$ in either developmental phase. However, the inclusion of $^{207}\text{Pb}/^{204}\text{Pb}$ and $^{206}\text{Pb}/^{204}\text{Pb}$ indicates that the first molar of individual 2000 (a sublethally injured non-trophy male) may have formed in a

non-local region, even though $^{87}\text{Sr}/^{86}\text{Sr}$ is consistent with local values. In this case individual 2000 may have grown up non-locally and moved into the Majes Valley or a geologically similar region by around 8–10 years old. In the alternative, the first molar enamel may have registered chemical alteration from the burial environment that does not accurately reflect the isotopic makeup of this individual's infancy/early childhood diet.

Three of the trophy heads also show locally consistent $^{87}\text{Sr}/^{86}\text{Sr}$ in both childhood phases: individual 7006 (Wari precursor style), individual 7007 (Nasca-style face-mask), and individual 7011 (defleshed, unperforated head). Four of the trophy $^{87}\text{Sr}/^{86}\text{Sr}$ remained outside of the local $^{87}\text{Sr}/^{86}\text{Sr}$ range throughout infancy to middle childhood: individuals 7003, 7004, and 7005 (Nasca-style face-masks from Sector I), and 7009 (mummified). The remaining three trophies were born outside of the local $^{87}\text{Sr}/^{86}\text{Sr}$ range but moved to the Majes Valley or a geologically similar area by the time they reached middle childhood: individuals 7000 and 7001 (the two half face-masks), and individual 7002 (a Nasca-style face-mask).

The median difference in $^{87}\text{Sr}/^{86}\text{Sr}$ from infancy to middle childhood is significantly greater for the trophies ($n = 10$) than the non-trophies ($n = 8$) (Table 4). The median difference in $^{87}\text{Sr}/^{86}\text{Sr}$ from infancy to middle childhood is also greater for lethally injured individuals ($n = 11$) than sublethally injured individuals ($n = 7$), and this difference approaches significance (Table 4).⁶

Only nine individuals had paired IEC-MC lead isotope data, none of which were suspected of diagenetic alteration. These intra-lifetime differences were normally distributed according to Shapiro Wilk for $^{206}\text{Pb}/^{204}\text{Pb}$, $W(8) = .929$, $p = .509$; for $^{207}\text{Pb}/^{204}\text{Pb}$, $W(8) = .934$, $p = .570$; and for $^{208}\text{Pb}/^{204}\text{Pb}$, $W(8) = .982$, $p = .996$. The mean change over the IEC-MC phases is greater for the trophies ($n = 4$) than non-trophies ($n = 4$) for all three lead species, but none of those differences were significant (Table 4). Similarly, the lethally injured ($n = 6$) had greater early life ranges for all three lead species compared to the sublethally injured ($n = 3$), but those differences were not significant (Table 4).

Discussion: The Circulation of Non-local Enemy Heads as Prestige Items

War and Raiding for Trophies from Nearby or Distant Enemy Communities

The overwhelming evidence that Uracans participated in persistent intergroup violence (Scaffidi & Tung, 2020), combined with the violent injuries and violent dismemberment of the trophies (Scaffidi, 2020b) and the evidence of their mostly non-local radiogenic isotope ratios presented here, suggest the trophies were taken from enemy combatants during battles or raids with neighboring or distant communities. The bioarchaeological and radiogenic isotope data does not support the alternative that Uraca's trophies were taken from local, revered ancestors or social substitutes from

⁶ This is not surprising since the trophy head and lethally injured subsets almost entirely overlap. Non-trophy individual 10 is lethally injured, and all trophy heads are presumed lethally injured—therefore, the two subsamples only differ by the addition of non-trophy individual 10.

other communities such as women and children who were not engaged in fighting. All but three trophies (individuals 7006, 7007, and 7011) are non-local relative to the established $^{87}\text{Sr}/^{86}\text{Sr}$ baseline and the 2σ range of $^{206}\text{Pb}/^{204}\text{Pb}$, $^{207}\text{Pb}/^{204}\text{Pb}$, and $^{208}\text{Pb}/^{204}\text{Pb}$ —nine of the 12 trophy individuals grew up outside of the Majes Valley or had non-local mothers. The additional five non-trophies with non-local IEC $^{87}\text{Sr}/^{86}\text{Sr}$ indicate the presence of non-local, first-generation migrants to Uraca who were not violently dismembered like the trophy victims. These non-locals likely originated in communities in coastal or highland portions of Arequipa, or even as far away as the southern portions of the Cusco and Puno regions. Importantly, none of the $^{87}\text{Sr}/^{86}\text{Sr}$ is consistent with origins in Nasca, the Wari heartland in Ayacucho, or northern parts of Cusco and Puno (see summary of values by region in Scaffidi & Knudson, 2020).

The fact that 20% (5/25) of the non-trophies tested were non-local is not surprising given Uraca's location near *Toro Muerto* and the nexus of *yunga*-elevation trails connecting Arequipa to points north and south. These four individuals (males 31, 2000, and 2001 and subadult 124) may have travelled to Uraca and *Toro Muerto* as a religious pilgrimage, to trade, to move llama caravans from the highlands to the coast, or *en route* to another location—before settling there for an unknown duration prior to death and burial. Or, given that the first molar reflects a proportion of its maternal Sr signal geographic residence due to *in utero* development and post-natal nursing contributions (Slovak & Paytan, 2011), it is possible that the mothers of individuals 31, 2001, and 124 relocated to Uraca before or shortly after childbirth. The fact that the three adult non-local males sustained healed cranial injuries (individual 31 also sustained a lethal wound) and that injured male individual 2000 had moved to the Majes Valley by middle childhood suggest a few other possibilities. These males may have had valuable combat or raiding experience in their own communities and may have moved (or been moved) to Uraca to fight for them. In the alternative, these injured males might have been taken by Uracan combatants as captives from outside groups. Just as in other Native American groups, these captives may have lived on for some period of time before being killed (Robb, 2008) or may have been integrated as subservient community members (Alt, 2008; Berryman, 2007; Burdick, 2016; Helmke, 2020; Inomata & Triadan, 2009; Martin, 2008; Santos-Granero, 2010).

Trophy head individuals 7006, 7007, and 7011 displayed Sr and Pb isotope values consistent with local Majes Valley values in both the IEC and MC phases. It is possible these males were local Uracans killed in distant combat and decapitated in lieu of transporting the entire body home, as Lozada and colleagues argue (2018). However, individual 7006 lived approximately 500 years before individual 7011 (and individual 7007 is undated), so the social context surrounding his decapitation may have been quite different from individual 7011, who lived in the Middle Horizon. Given the violent defleshing of individuals 7006, 7007, and 7011 (Scaffidi, 2018, 2020b), it is more likely that these trophy heads were taken from enemy combatants that grew up in other communities with similar strontium and lead isotope values. It is also possible that these individuals grew up in the Majes, but in enemy communities in the distant highland or coastal portions of the Majes-Camaná drainage. Importantly, the near-local $^{87}\text{Sr}/^{86}\text{Sr}$ for IEC-MC phases from the Wari-style head are distinct from Ayacucho basin values, which range from 0.7055 to 0.7061 (Tung & Knudson, 2011). This, combined with the fact that the head predates the Wari Empire by 500 years (Scaffidi,

Table 3 Measurements of $^{87}\text{Sr}/^{86}\text{Sr}$ ($n = 55$), and $^{206}\text{Pb}/^{204}\text{Pb}$, $^{207}\text{Pb}/^{204}\text{Pb}$, and $^{208}\text{Pb}/^{204}\text{Pb}$ ($n = 42$) for 37 individuals

Individual-PAU export #	BCL#	Burial sector	Age (years)	Sex and Trophy Category	Tooth	Developmental phase	$^{87}\text{Sr}/^{86}\text{Sr}$	$^{208}\text{Pb}/^{204}\text{Pb}$	$^{207}\text{Pb}/^{204}\text{Pb}$	$^{206}\text{Pb}/^{204}\text{Pb}$
0004-190	3740	I	15–18	Probable Male	RXM1	Infancy-early childhood	0.7083	38.5415	15.6247	18.3757
0008-197	3744	I	27–45	Female	RXM1	Infancy-early childhood	0.7083	38.5593	15.6343	18.4185
0009-193	3741	I	25–40	Male	RXM2	Middle childhood	0.7083	38.4662	15.6167	18.3157
0010-162	4108	I	20–30	Male	LXM2	Middle childhood	0.7083	38.6705	15.6333	18.2789
0010-163	3742	I	20–30	Male	RXM1	Infancy-early childhood	0.7083	38.5529	15.6168	18.3156
0012-200	4109	I	35+	Probable Female	RXM2	Middle childhood	0.7084	NA	NA	NA
0012-201	3743	I	35+	Probable Female	LX11	Infancy-early childhood	0.7083	38.4835	15.6251	18.4028
0031-154	3745	I	30–50	Male	LXM1	Infancy-early childhood	0.7086	NA	NA	NA
0035-160	3746	I	25–35	Male	RXM1	Infancy-early childhood	0.7083	38.6177	15.6282	18.4446
0036-169	3747	I	15–20	Female	LXM1	Infancy-early childhood	0.7083	38.5754	15.6170	18.3804
0037-152	3748	I	30–50	Male	RXM2	Middle childhood	0.7083	38.6073	15.6143	18.3044
0038-166	3749	I	15–18	Probable Female	RXM1	Infancy-early childhood	0.7083	38.5764	15.6217	18.3935
0048-087	3750	I	25–55	Male	RXM1	Infancy-early childhood	0.7083	38.5939	15.6207	18.3848
0048-086	3789	I	25–55	Male	RXM2	Middle childhood	0.7083	NA	NA	NA
0051-067	3751	I	25–35	Male	LXM1	Infancy-early childhood	0.7083	38.5938	15.6179	18.3467
0053-083	3766	I	30–40	Male	RXM1	Infancy-early childhood	0.7081	NA	NA	NA
0060-046	3767	I	18–30	Female	RXM1	Infancy-early childhood	0.7083	38.6195	15.6434	18.4496
0061-089	3788	I	30–40	Male	RXM2	Middle childhood	0.7084	38.6145	15.6193	18.3651
0061-090	3768	I	30–40	Male	RXM1	Infancy-early childhood	0.7083	38.646	15.6241	18.3361
0086-096	3769	I	30–40	Female	LXM1	Infancy-early childhood	0.7083	38.6435	15.6311	18.3984
0086-097	3787	I	30–40	Female	LXM2	Middle childhood	0.7083	NA	NA	NA
0090-110	3770	I	30–55	Male	RXM1	Infancy-early childhood	0.7083	NA	NA	NA
0106-005	3771	I	1–4	Subadult	rxm2	In utero-early infancy	0.7083	38.617	15.6248	18.3789

Table 3 (continued)

Individual-PAU export #	BCL#	Burial sector	Age (years)	Sex and Trophy Category	Tooth	Developmental phase	$^{87}\text{Sr}/^{86}\text{Sr}$	$^{208}\text{Pb}/^{204}\text{Pb}$	$^{207}\text{Pb}/^{204}\text{Pb}$	$^{206}\text{Pb}/^{204}\text{Pb}$
0113-135	3772	I	30+	Male	RXM1	Infancy-early childhood	0.7083	38.6192	15.6221	18.3982
0113-136	4110	I	30+	Male	RXM2	Middle childhood	0.7084	38.5181	15.6222	18.384
0124-139	3773	I	30-50	Male	LXM1	Infancy-early childhood	0.7084	38.2263	15.6021	18.4512
1004-210	3774	I	25-30	Female	LXM2	Middle childhood	0.7082	NA	NA	NA
2000-219	3775	II	40-50	Male	LXM1	Infancy-early childhood	0.7083	38.7112	15.6621	18.5117
2000-220	4111	II	40-50	Male	RXM2	Middle childhood	0.7083	NA	NA	NA
2001-216	3776	II	8-10	Subadult	LXM1	Infancy-early childhood	0.7084	38.7135	15.6632	18.5008
3000-238	4112	II	40-50	Male	LXM1	Infancy-early childhood	0.7084	38.5994	15.612	18.3736
3000-239	3777	II	40-50	Male	LXM1	Infancy-early childhood	0.7083	38.6088	15.6201	18.3878
3001-242	3778	II	30-50	Male	LXM1	Infancy-early childhood	0.7072	38.5952	15.6259	18.3707
7000-284	3752	I	20-35	Male Trophy	RXM1	Infancy-early childhood	0.7077	38.6232	15.6246	18.4141
7000-283	3779	I	20-35	Male Trophy	RXM2	Middle childhood	0.7083	NA	NA	NA
7001-289	3753	I	20-40	Male Trophy	LXM1	Infancy-early childhood	0.7074	38.4941	15.6015	18.4616
7001-288	3780	I	20-40	Male Trophy	LXM2	Middle childhood	0.7084	NA	NA	NA
7002-316	3754	I	15-22	Male Trophy	LXM1	Infancy-early childhood	0.7085	38.5705	15.6196	18.4091
7002-315	3781	I	15-22	Male Trophy	LXM2	Middle childhood	0.7084	NA	NA	NA
7003-293	3782	I	20-30	Male Trophy	LXM2	Middle childhood	0.7086	38.6709	15.6398	18.3792
7003-294	3755	I	20-30	Male Trophy	LXM1	Infancy-early childhood	0.7085	38.5959	15.6225	18.3639
7004-250	3756	I	20-30	Male Trophy	RXM1	Infancy-early childhood	0.7074	38.5016	15.6079	18.4717
7004-249	3783	I	20-30	Male Trophy	RXM2	Middle childhood	0.7070	NA	NA	NA
7005-253	3784	I	20-40	Male Trophy	LXM2	Middle childhood	0.7085	38.564	15.6069	18.2996
7005-254	3757	I	20-40	Male Trophy	RXM1	Infancy-early childhood	0.7086	38.6169	15.6161	18.2480
7006-245	3758	I	35-55	Male Trophy	LXM2	Middle childhood	0.7083	38.6941	15.6455	18.3971

Table 3 (continued)

Individual-PAU export #	BCL#	Burial sector	Age (years)	Sex and Trophy Category	Tooth	Developmental phase	$^{87}\text{Sr}/^{86}\text{Sr}$	$^{208}\text{Pb}/^{204}\text{Pb}$	$^{207}\text{Pb}/^{204}\text{Pb}$	$^{206}\text{Pb}/^{204}\text{Pb}$
7006-246	3759	I	35–55	Male Trophy	LXM1	Infancy-early childhood	0.7083	38.6431	15.6250	18.3563
7007-271	3760	I	18–30	Male Trophy	RXM2	Middle childhood	0.7079	38.5012	15.6142	18.3641
7007-272	3761	I	18–30	Male Trophy	RXM1	Infancy-early childhood	0.7080	38.5775	15.6120	18.3326
7008-275	3762	II	20–40	Male Trophy	LDM2	Middle childhood	0.7084	38.5798	15.6158	18.4033
7009-307	3763	II	20–40	Male Trophy	LXM2	Middle childhood	0.7086	38.5552	15.6208	18.4169
7009-308	3785	II	20–40	Male Trophy	RXM1	Infancy-early childhood	0.7086	NA	NA	NA
7010-311	3764	II	30–50	Male Trophy	RDP1	Middle childhood	0.7084	38.5936	15.6200	18.3931
7011-127	3786	I	35–45	Male Trophy	LXM2	Middle childhood	0.7084	38.5335	15.6081	18.3304
7011-128	3765	I	35–45	Male Trophy	LXM1	Infancy-early childhood	0.7083	38.6162	15.6237	18.3782

Table 4 Statistical comparisons of trophy and non-trophy subgroups. Significant *p* values are in bold

Isotope	Central Tendency		Variance					
	Subgroups (<i>n</i>)	Test	Test statistic (DF)	<i>p</i> Value	Subgroups (<i>n</i>)	Test	Test statistic (DF)	<i>p</i> Value
⁸⁷ Sr/ ⁸⁶ Sr	Trophy (22), $\bar{x}$ = 0.7083	Mann-Whitney <i>U</i>	<i>W</i> (1) = 823.0	.084	Trophy (22), σ = .0005	One-way ANOVA	<i>F</i> (1) = .830	.368
	Non-trophy (33), $\bar{x}$ = 0.7082				Non-trophy (33), σ = .0002			
	Female/subadult (11), $\bar{x}$ = 0.7083	One-way ANOVA	<i>F</i> (2) = .043	.651	Female/subadult (11), σ = 0.0001	One-way ANOVA	<i>F</i> (1) = .043	.651
	Male (22), $\bar{x}$ = 0.7083				Male (22), σ = 0.0003			
	Trophy (22), $\bar{x}$ = 0.7082	Mann-Whitney <i>U</i>	<i>W</i> (1) = 182.0	.037	Trophy (22), σ = 0.0004	One-way ANOVA	<i>F</i> (1) = 2.46	.133
	Defleshed trophy (18), $\bar{x}$ = 0.7083				Defleshed trophy (18), σ = .0005			
	Mummified trophy (4), $\bar{x}$ = 0.7085	Mann-Whitney <i>U</i>	<i>W</i> (1) = 50.0	.023	Mummified trophy (33), σ = .0001	NA		
	Δ IEC-MC ^a Trophy (10), $\bar{x}$ = 0.0009							
Δ IEC-MC ^a Non-trophy (8), $\bar{x}$ = 0.0002	Mann-Whitney <i>U</i>	<i>W</i> (1) = 125.0	.069	NA	NA			
Δ IEC-MC ^a Lethal (11), $\bar{x}$ = 0.0008								
²⁰⁶ Pb/ ²⁰⁴ Pb	Δ IEC-MC ^a Sublethal (7), $\bar{x}$ = 0.0002	<i>T</i> -test	<i>T</i> (34) = .520	.606	Trophy (17), σ = 0.055	One-way ANOVA	<i>F</i> (1) = .270	.606
	Trophy (17), $\bar{x}$ = 18.378				Non-trophy (25), σ = 0.056			
	Non-trophy (25), $\bar{x}$ = 18.387	One-way ANOVA	<i>F</i> (2) = 1.780	.182	Female/subadult (11), σ = 0.041	One-way ANOVA	<i>F</i> (2) = 1.780	.182
	Female/subadult (8), $\bar{x}$ = 18.415				Male (22), σ = 0.058			
	Male (17), $\bar{x}$ = 18.373	<i>T</i> -test	<i>T</i> (14) = -1.88	.081	Trophy (22), σ = 0.055	One-way ANOVA	<i>F</i> (1) = .85	.372
	Trophy (17), $\bar{x}$ = 18.378				Defleshed trophy (14), σ = 0.056			
	Defleshed trophy (14), $\bar{x}$ = 18.372	<i>T</i> -test	<i>T</i> (5) = -3.40	.750	Mummified trophy (3), σ = 0.012	One-way ANOVA	<i>F</i> (1) = .274	.105
	Mummified trophy (3), $\bar{x}$ = 18.404				NA			
Δ IEC-MC ^a Trophy (5), $\bar{x}$ = 0.059	<i>T</i> -test	<i>T</i> (2) = .050	.965	NA	One-way ANOVA	<i>F</i> (1) = .274	.105	
Δ IEC-MC ^a Non-trophy (4), $\bar{x}$ = 0.049				NA				
²⁰⁷ Pb/ ²⁰⁴ Pb	Δ IEC-MC ^a Lethal (6), $\bar{x}$ = .0551	Mann-Whitney <i>U</i>	<i>W</i> (1) = 125.0	0.606	Trophy (17), σ = 0.011	One-way ANOVA	<i>F</i> (1) = .274	.105
	Δ IEC-MC ^a Sublethal (3), $\bar{x}$ = 0.053				NA			
	Trophy (17), $\bar{x}$ = 15.620							

Table 4 (continued)

Isotope	Central Tendency		Variance			Test	Test statistic (DF)	p Value	Subgroups (n)	Test	Test statistic (DF)	p Value
	Subgroups (n)	Test	ANOVA	Test statistic (DF)	p Value							
²⁰⁸ Pb/ ²⁰⁴ Pb	Non-trophy (25), $\bar{x} = 15.622$								Non-trophy (25), $\sigma = 0.014$			
	Female/subadult (8), $\bar{x} = 15.633$	One-way ANOVA	$F(2) = 3.260$	.049					Female/subadult (8), $\sigma = 0.015$	One-way ANOVA	$F(2) = 3.260$	.049
	Male (17), $\bar{x} = 15.622$								Male (17), $\sigma = 0.012$			
	Trophy (17), $\bar{x} = 15.619$								Trophy (17), $\sigma = 0.011$			
	Defleshed trophy (14), $\bar{x} = 15.615$	Mann-Whitney U	$W(1) = 93.0$	.126					Defleshed trophy (14), $\sigma = 0.003$	One-way ANOVA	$F(1) = .001$	.975
	Mummified trophy (3), $\bar{x} = 15.621$	T-test	$T(5) = -1.12$	.304					Mummified trophy (3), $\sigma = 0.012$			
	Δ IEC-MC ^a Trophy (5), $\bar{x} = 0.0234$								NA			
	Δ IEC-MC ^a Non-trophy (4), $\bar{x} = 0.0153$								NA			
	Δ IEC-MC ^a Lethal (6), $\bar{x} = 0.022$	T-test	$T(5) = .970$	.378					NA			
	Δ IEC-MC ^a Sublethal (3), $\bar{x} = 0.015$								NA			
²⁰⁸ Pb/ ²⁰⁴ Pb	Trophy (17), $\bar{x} = 38.580$	Mann-Whitney U	$W(1) = 560.0$	.573					Trophy (17), $\sigma = 0.057$	One-way ANOVA	$F(1) = .001$	.958
	Non-trophy (25), $\bar{x} = 38.599$								Non-trophy (25), $\sigma = 0.095$			
	Female/subadult (8), $\bar{x} = 38.599$	One-way ANOVA	$F(2) = .021$	.808					Female/subadult (8), $\sigma = 0.068$	One-way ANOVA	$F(2) = .021$	.808
	Male (17), $\bar{x} = 38.5750$								Male (17), $\sigma = 0.106$			
	Trophy (17), $\bar{x} = 38.584$								Trophy (17), $\sigma = .057$			
	Defleshed trophy (14), $\bar{x} = 38.594$	Mann-Whitney U	$W(1) = 97.0$	.268					Defleshed trophy (14), $\sigma = .063$	One-way ANOVA	$F(1) = .070$	.800
	Mummified trophy (3), $\bar{x} = 38.574$	T-test	$T(5) = -1.24$	.262					Mummified trophy (3), $\sigma = .120$			
	Δ IEC-MC ^a Trophy (5), $\bar{x} = 0.105$								NA			
	Δ IEC-MC ^a Non-trophy (4), $\bar{x} = 0.066$								NA			
	Δ IEC-MC ^a Lethal (6), $\bar{x} = 0.107$	T-test	$T(5) = 2.20$	.079					NA			
	Δ IEC-MC ^a Sublethal (3), $\bar{x} = 0.049$								NA			

^a The change (Δ) in IEC-MC is the absolute value of the difference between the IEC (infancy-early childhood) and MC (middle childhood) teeth

2018, 2020b) is strong evidence that the Wari trophy manufacturing style was indigenous to the Majes Valley rather than the Wari heartland. Or, perhaps this style was indigenous to Ayacucho, but Majes trophy-makers in the first century BCE (when the head was taken) were familiar with the foreign style and appropriated it for their own purposes on a near-local head. A final possibility is that this male hailed from the Majes Valley or nearby but was taken captive by Ayacucho natives, and then the head was repatriated by Uracan combatants. However, the latter two explanations are unlikely since there is no archaeological evidence of Arequipa-Ayacucho contact at this early date.

Other patterns in the trophy manufacturing styles provide insights into residential histories of victims. Trophy head individuals 7008, 7009, and 7010 (the three mummified heads from Sector II) all show similar Sr and Pb isotope measurements and are more similar to each other than the defleshed heads, which show much more variability in isotopic values and in processing techniques. These three heads may have been taken during one or many violent attacks against the same enemy community. Or, Uracans may have collected these similarly manufactured heads of similar origins in one raiding event from an enemy community that originally captured and produced these three heads. Likewise, the similar isotopic values of the two horizontal half-masks (individuals 7000 and 7001) as low-value outliers suggest they were taken in the same event or produced by the same community. In this case, the manufacturing process might reflect stylistic decisions made by other groups and not by Uracans. Another tantalizing possibility, however, is that the Uraca trophies were all produced locally, but the trophy victims' distinct proveniences dictated their head preparation and the styles chosen for them by trophy-makers.

Highly-Mobile Childhoods for Trophy Victims

Paired IEC-MC enamel measurements suggest that trophied individuals lived a childhood in relative geographic flux compared to the non-trophied individuals—the boys destined for violent killing and dismemberment were more mobile from infancy through middle childhood than the locally born boys and girls who were not ultimately transformed into trophies. Prior research has shown that intra-lifetime mobility can be established when $^{87}\text{Sr}/^{86}\text{Sr}$ differs to the third or fourth decimal place (Knudson et al., 2016) or by > 0.001 (Knipper et al., 2014; Kootker et al., 2016; Slater et al., 2014; see discussion in Hrnčir & Laffoon, 2019). However, particularly where environmental baselines are well-established and intra-individual offsets are miniscule for most individuals, smaller offsets into the fifth decimal place can indicate intra-lifetime mobility (Hrnčir & Laffoon, 2019; Knipper et al., 2018). Even by the most conservative measure of 0.001, the $^{87}\text{Sr}/^{86}\text{Sr}$ of individuals 7000 and 7001 (the two half-masks) (Fig. 10) show that they moved within their early childhoods or their mothers nursed them as infants in different places from their middle childhood residence locations. Both of these trophies moved from less radiogenic regions like the nearby Arequipa coast or highlands to Uraca or geologically similar regions by the time they were 8–10 years old. By the less conservative metric of four decimal places, individuals 7002, 7004, 7005, and 7007 (all Nasca-style masks) also moved during their childhoods. Individual 7002 moved from a more radiogenic location such as other parts of the Arequipa *yunga* to Uraca or geologically similar regions. Individuals 7004 and 7005 moved but stayed

Fig. 8 Boxplot of variability between female, male, subadult, and trophy subsamples for **a** $^{87}\text{Sr}/^{86}\text{Sr}$; **b** $^{206}\text{Pb}/^{204}\text{Pb}$; **c** $^{207}\text{Pb}/^{204}\text{Pb}$; and **d** $^{208}\text{Pb}/^{204}\text{Pb}$ (labeled value is the mean and stars indicate IQR outliers)

outside of Uraca. Individual 7007 moved during childhood, but entirely within Uraca or a geologically similar region (Fig. 10).

The six childhood migrants who were eventually killed and dismembered likely traveled with their highly mobile families. This may represent a normal amount of childhood mobility for communities outside of Uraca at this time. Perhaps these communities needed to establish relationships with other places in order to increase access to food, water, marital partners, or other resources during the challenging environmental and cultural changes of the mid-first millennium CE. In the alternative (and since children do not generally move on their own), this high level of childhood mobility for the trophy victims could show that they or their families held special social positions that enabled them or forced them to move frequently. As another possibility, perhaps the boys who grew to become combatants and trophy victims experienced distinct childhoods, even for children that grew up outside of Uraca. Perhaps these boys were groomed from birth for special roles as fighters and raiders—the Spanish chronicler Guamán Poma de Ayala's Colonial accounts (1613) tell us that by middle childhood, boys began to travel beyond the home to participate in hunting parties and took on more adult roles (see discussions in Toyne, 2018; Lozada, 2019). Similarly, perhaps boys destined for specialized roles as combatants left their homes and traveled to other places to train for combat or to assist with hunts, raiding parties, or other male-dominated duties.

In contrast, the eight non-trophies did not move during childhood (Fig. 10), and this is consistent with prior interpretations about the nature of mobility at Uraca. The grave goods and tomb construction techniques at Uraca are local, with very little evidence for long-distance trading (Scaffidi, 2018; Scaffidi & Tung, 2020). Uraca is situated at the widest, most agriculturally productive portion of the Majes Valley, with a steady supply

Fig. 9 $^{87}\text{Sr}/^{86}\text{Sr}$ for the entire sample (Y-axis reference lines indicate local archaeological and water isoscape predicted $^{87}\text{Sr}/^{86}\text{Sr}$ range for the Lower Majes Valley)

of river water year-round (Scaffidi, 2018). This geographic positioning may have supplied Uracans coveted food and water security during a time of alternating floods and droughts around the mid-first millennium CE (Shimada et al., 1991; Thompson & Davis, 2014). Possibly because of this self-sufficiency, Uracans' external interactions seem to have been limited to violent combat, raids, and trophy-taking excursions with nearby or distant communities (Scaffidi & Tung, 2020). Indeed, as discussed above, four of the five non-locally born non-trophies were injured adult males who could have been forced to migrate from another community, enemy combatants captured alive, near-local fighters sent to aid Uraca in combat, or migrants motivated by some other factor not related to violence.

Non-local Enemy Heads as Prestigious Exotica in Regional Exchange Networks

The broad variation in the geographic origins and manufacturing techniques of the trophies suggests a few different possible scenarios. First, each trophy could represent a combatant killed by Uracans, decapitated after battle, and taken home for extensive processing. Second, some of the trophies may have already been processed and curated in caches maintained by enemy communities, and Uraca stole them during raids. A third possibility is that some of the trophies were traded in to Uraca through non-violent exchange relationships, although the intensity of cranial trauma described for the non-trophies by Scaffidi and Tung (2020) and for the trophy heads by Scaffidi (2020b) makes this unlikely. In the latter two scenarios, trophy heads may not represent direct enemies of Uraca, but rather, enemy heads previously taken by Uraca's enemies.

The collection, manufacturing, use, and re-use of trophies with diverse geographic origins at Uraca suggest that this violent practice was an important catalyst for inter-regional mobility. The stylistic variation could be explained by Uracans raiding or trading trophies from distant places with distinct communal manufacturing techniques from

Fig. 10 Scatterplots of paired strontium and lead isotope data for trophies and non-trophies: **a** $^{87}\text{Sr}/^{86}\text{Sr}$ by $^{206}\text{Pb}/^{204}\text{Pb}$; **b** $^{87}\text{Sr}/^{86}\text{Sr}$ by $^{207}\text{Pb}/^{204}\text{Pb}$; and **c** $^{87}\text{Sr}/^{86}\text{Sr}$ by $^{208}\text{Pb}/^{204}\text{Pb}$ (X-axis reference lines indicate local expected ratios determined by archaeological and water isoscape predictions; Y-axis reference lines indicate local expected ratios determined by $\bar{x}_{\text{trophy}}$ and non-trophies ± 2 SD)

Uracá or by different trophy-takers or trophy-makers using their own idiosyncratic methods (Scaffidi, 2020b). The variation in strontium and lead isotope values of the trophies suggests Uracá collected heads from throughout Arequipa—perhaps even from contiguous highland or coastal regions—but because enamel bulk sampling averages bioavailable Sr over years, based on data from this study, it is impossible to say whether how far or how frequently the non-trophy Uracáns traveled to collect trophies. It is also possible that combatants from many different geological zones traveled to Uracá to attack them and were instead taken as trophies in those encounters. In either case, the accumulation of heads from non-local individuals transformed in drastically different ways throughout their use lives demonstrates that dominating the bodies of geographic outsiders was critical to Uracá's ritual and sociopolitical life.

The exchange of powerful objects from foreign locales has important implications for reconstructing the ordering of social and spatial relationships in the past. Restricting the exchange of exotic objects was one mechanism for the accumulation of social power in elites in ancient non-state societies (Earle, 1997; Goldstein, 2000; Junker, 1993). Objects from exotic or foreign locations were particularly powerful—as Helms argues (Helms, 1993, 2014), foreign, unknown geographies, and people carry a kind of danger, such that people who encounter foreign people and places accumulated social prestige and even magico-spiritual power by developing specialized knowledge over the outside world. In many parts of the pre-Hispanic Andes, the circulation and exchange of high-status objects over long distances via complex webs of camelid caravans was a critical factor in the emergence of social status hierarchies and socio-political complexity (Browman, 1980; Goldstein, 2000; Nielsen, 2001, 2013; Nielsen et al., 2019; Núñez & Dillehay, 1979; Vaughn, 2006). Elsewhere, Scaffidi (2020a)

Fig. 11 $^{87}\text{Sr}/^{86}\text{Sr}$ for IEC-MC pairs ($n = 36$ results from 18 individuals) (Y-axis reference lines indicate expected local values based on the archaeological and water isoscape predictions for the Lower Majes Valley; non-trophies are labeled on the X-axis for estimated biological sex and injury type as either peri (perimortem) or ANTM (antemortem))

argues that exchanging blows in violent combat against neighboring communities was another critical way of establishing social hierarchies between and within Arequipa *yunga* communities. It follows that the accumulation of exotic heads, taken through violent war and raids from neighboring or distant communities, would have generated prestige and even spiritual power in those who subjugated external enemies and their heads (Scaffidi, 2020b).

By destroying and transforming non-local heads, trophy artisans would have challenged and reinforced relationships between Uraca and other groups, profoundly shaping the social identities of the trophy victim, trophy-makers, and the community or communities who observed trophy head displays and trophy head rituals. The exchange of crafts between communities can be read as a type of “social project” that reinforces intergroup relationships and communal identities (DeMarrais, 2013). As Spielmann echoes (Spielmann, 2002: 197), prehistoric crafting and exchange served to “fulfill ritual obligations and create and sustain social relations.” The violent (or perhaps non-violent) exchange and meticulous crafting of non-local trophies linked Uraca into a network of interactions comprised of intergroup violence and head taking (Scaffidi, 2020a), through which individual and communal identities were continuously re(negotiated) and narratives of dominance may have been told, retold, and reframed.

Conclusions: Local Isotope Values and Regional Mobility in Arequipa

This study demonstrated through radiogenic isotope analysis that most of the Uraca trophy victims lived their infancy and childhood beyond the Lower Majes Valley, while the remainder originated in geologically similar regions. Wherever they grew up, the individuals who were eventually transformed into trophy heads experienced more residential mobility in childhood than the non-trophy individuals tested here. The addition of lead isotope data enabled us to pinpoint two probable non-locals that had geologically local strontium ratios—one was already categorized as non-local based on strontium, but the other was previously classified as local based on strontium alone. Two other trophy individuals (with elevated REE data) are interpreted as probable non-locals based on lead isotope data. Together with the previously reported evidence of endemic violence at Uraca and the wide variability in trophy manufacturing techniques, we conclude that this community was engaged in violent combat and the taking of adult male human trophies from communities and individuals deemed as social outsiders. Comparing the data reported here to the local bioavailable Sr baseline, it seems these enemies originated in neighboring valleys or contiguous coastal or highland zones. The greater early-life mobility for those who would become trophies suggests that some movement was a feature of much of these male combatants’ lives and may have predisposed them in some way for the risks and rewards of the violence they would eventually perform and experience.

Finally, the fact that 20% of the non-trophy individuals sampled originated outside the Lower Majes demonstrates that migration (whether forced, voluntary, or something in-between) was not uncommon, but further analysis is needed to understand why those individuals migrated, when, from where, and how often they moved. Paired isotopic data on additional trophy and non-trophy individuals, including females, uninjured individuals, and subadults, will further clarify what proportion of individuals from each category are local and their respective degrees of childhood mobility. Additional

samples from adolescence (third molars) and the years before death (bone) will extend Uraca residential isobiographies throughout their lifetimes and help us understand their geographic residence location prior to death and burial at Uraca. Data from these additional life course phases will shed further light on the social contexts of violence at Uraca and the impact of endemic violence at Uraca on mobility (and vice-versa). This will help us pinpoint some of the reasons why migration into Uraca and around occurred and where and how far Majes Valley mobility networks extended—providing important insights into intergroup interactions during the EIP and Middle Horizon in southern Peru and nearby regions.

Important limitations on this study include the absence of environmental lead baseline data and the absence of comparative data—contemporaneous skeletons from unlooted tombs—from Arequipa. The only other published $^{87}\text{Sr}/^{86}\text{Sr}$ data from Arequipa are from human skeletons from the village of Beringa in the Upper Majes Valley (Knudson & Tung, 2011), which are largely similar with the Uraca findings reported here. Excavations of unlooted tombs and AMS dating of their burials are imperative for documenting corroborative evidence of geographic outsider identity, such as non-local cranial modification styles, architectural styles, grave offerings, clothing, and stable isotope data evincing the consumption of non-local foods. Additional isotopic measurements from Uraca as well as comparative analyses from skeletal samples throughout the region will continue to shed light on the variation in archaeological skeletal remains. Furthermore, ongoing baseline studies of $^{87}\text{Sr}/^{86}\text{Sr}$ in water, plants, faunal remains, and soils by the Andean Paleomobility Unification (APU) project (Scaffidi et al., 2020; Scaffidi & Knudson, 2020) will further refine expectations and models of local $^{87}\text{Sr}/^{86}\text{Sr}$, which are particularly critical for identifying people who were not local during distinct developmental phases throughout their lives. Finally, comparative Pb isotope data from the Andes are greatly needed from human skeletons and environmental reference materials to characterize the geographic variability expected from various geological catchments. Multi-tissue, multi-tooth, and inter-laboratory error studies are also needed to understand what degree of Pb isotope variability would reflect intra-lifetime mobility vs. laboratory error.

Determining that the Uraca trophies were mostly taken in the context of violent intergroup raids against external groups is fundamental for understanding the motivations and consequences of violence and how violent behaviors shaped individual and communal identities. This study does not discount the possibility that some of the Uraca heads were taken from local individuals, or that the trophies were simultaneously imbued with other complex religious and social meanings not emphasized here. However, our findings demonstrate that, at least in the Majes Valley of the Arequipa *yunga*, the killing, decapitation, transformation, and ritual use of non-local adult male heads—or trading or raiding for already-transformed heads—was instrumental in linking communities together through violent exchanges that profoundly structured relationships between and within these communities and the region for generations.

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Code Availability No software applications or custom code were used in this study.

Author Contribution Scaffidi developed the concept, excavated and completed bioarchaeological analysis of Uraca skeletons, and wrote the manuscript. Sharpe, Scaffidi, Kamenov, and Krigbaum completed isotopic analysis of Uraca teeth. Scaffidi analyzed isotopic and spatial data. Scaffidi wrote the manuscript, with pre-submission revisions by Kamenov, Sharpe, and Krigbaum.

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Data Availability All data are available in the tables of the manuscript and Online Resource 1.

Declarations

Conflict of Interest The authors declare no competing interests.

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Affiliations

Beth K. Scaffidi¹ · George D. Kamenov² · Ashley E. Sharpe³ · John Krigbaum⁴

✉ Beth K. Scaffidi
cscaffidi@ucmerced.edu

¹ Department of Anthropology and Heritage Studies, University of California Merced, 5200 Lake Road, Merced, CA 95343, USA

² Department of Geological Sciences, University of Florida, Gainesville, FL 32611, USA

³ Center for Tropical Paleoecology and Archaeology, Smithsonian Tropical Research Institute, Balboa-Ancon, Republic of Panama

⁴ Department of Anthropology, University of Florida, 1112 Turlington Hall, Gainesville, FL 32611, USA