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# The timing and mode of southern Andean human migrations

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## Abstract

While recent genomic and isotopic information show that migration has been pervasive along human history, southern Andean archaeology has largely overlooked its importance in shaping human trajectories of sociocultural change. Building on previous isotopic research that identified the presence of migrant farmers in the Uspallata Valley (Mendoza, Argentina), we present chronological and bioarchaeological results that help to characterize the timing and mode of human migrations in the southern Andes. The burials with migrants show the representation of the different age classes, including a high abundance of children, as well as both men and women, suggesting that family groups were likely involved. The Bayesian modeling of 16 direct dates for migrants indicates that these migrations started between 1210–1275 CE (median 1255 CE) and finished at 1320–1425 CE (median 1360 CE), indicating that there is nearly no overlap between the commencement of this migration phase and the southwards expansion of the Inka Empire. The model defines a diachronic process that lasted between 55 and 195 years, implying that migration to Uspallata was a multi-generational process that involved between two and eight generations (median of four generations). Our contextual, bioarchaeological and chronological evidence indicates that the conditions fostering migration to Uspallata were sustained through time, inviting to explore persisting push-pull dynamics acting during this period. <sup>87</sup>Sr/<sup>86</sup>Sr results show that migration occurred across the daily territories of these groups and may have involved movement across social or ethnic frontiers.

## Introduction

Migration is understood as the long-term or permanent movement of human beings across space and over time, occurring beyond the scale of traditionally occupied territories (Anthony 1990; Snow 2009; Tsuda et al. 2015). Despite the wealth of studies in the south central Andes, particularly—but not exclusively—in relation with the diasporic Tiwanaku societies (Knudson et al. 2004; Knudson et al. 2014; Torres-Rouff and Knudson 2017; Tessone et al. 2023), human migration still is a neglected process in the archaeology of the southern Andes. Due to a lack of analytical resolution, and also probably as part of the “retreat from migrationism” that followed the dominant approaches developed up to the 1960s (Adams et al. 1978; Hakenbeck 2008), migration is still not viewed as a significant variable

in shaping the socio-demographic trajectories of southern Andean societies (although see Gambier 2000; Marsh 2023; Menéndez et al. 2014). Recently, however, the development of a macro-regional isoscape of bioavailable strontium isotopes ( $^{87}\text{Sr}/^{86}\text{Sr}$ ) across the southern Andes of Argentina and Chile has allowed identifying the remains of southern Andean migrants with confidence (Barberena et al. 2017, 2023). By applying this isoscape in a region characterized by striking east-west variation in rock age and composition, we have identified a pulse of human immigration of intensive maize farmers in the Uspallata Valley (Mendoza, Argentina, Figure 1). This is recorded by means of non-local  $^{87}\text{Sr}/^{86}\text{Sr}$  values for human bone and teeth remains from three nearby archaeological sites (Barberena et al. 2020; Barberena et al. 2021a). To understand the social dynamics of a migratory process it is paramount to establish its *timing* and, through the integration of multiple proxies, the *mode(s)* of migration in terms of the socio-demographic composition of the migrant groups, their geographic source, the presence of human groups in the receiving area, and the differences and similitudes between local and migrant groups (Cabana and Clark 2011; Cameron 2013; Snow 2009).

Using radiocarbon dates on humans identified as migrants from the three archaeological sites containing migrant groups at Uspallata Valley, we employed Bayesian modeling to determine the likely *timing* and *duration* of the migration event/s. By combining this temporal dimension with an analysis of the demographic profiles and mortuary practices that formed these sites, we assess the *modes* of past migration. Ultimately, we aspire to obtain new insights into social dynamics in the southern Andes.

## Study area and contextual background

The Uspallata Valley is located in northwestern Mendoza Province, Argentina, flanked by the towering mountain ranges of Precordillera to the east and the Andes to the west, with striking topographical and ecological variation ( $-32.594^{\circ}\text{S}$ ,  $-69.359^{\circ}\text{W}$ ). Connected to the north with the Calingasta and Iglesia Valleys, the region makes up a longitudinal biogeographic corridor extending east of the Andes for over 350 km. In addition, the main paths crossing the Andes range that provide access to the western shed can be accessed along this natural corridor. During the last 3000 years, the southern Andes were characterized by a diverse array of socioecological niches variously combining hunting-gathering, horticulture, intensive agriculture, and camelid pastoralism across space and time (Barberena et al. 2022; Durán et al. 2018a; Gambier 2000; Gil et al. 2014). This social landscape set the conditions for multiple forms of interaction ranging from cooperation to conflict, particularly during the last 2000 years, when all the available regions had been incorporated into human territories.

Due to the high diversity of bedrock age and composition, the geology of Uspallata and surrounding areas is especially suited to track local residence and immigration, since Uspallata is flanked by the Paleozoic Precordillera to the east and by the younger Frontal and Principal Cordillera to the west (Figure 1). Biologically available strontium from each geological unit was characterized by the analysis of modern and archaeological rodents (with restricted home ranges) and plant samples (Barberena et al. 2017, 2021b). These are appropriate for building a baseline as a frame of reference for human samples (Copeland et al. 2010; Hoppe et al. 1999; Price et al. 2002; Scaffidi and Knudson 2020; Washburn et al. 2021). We analyzed 65 rodent samples and 26 plant samples from the main geological units along a 250-km transect from the Pacific coast (Chile) to the lowlands east of the Andes (Argentina). The results show that these samples closely track the geological regions, and that the Uspallata Valley is characterized by values averaging the highly radiogenic sediments from the Paleozoic Precordillera to the east, composed of the oldest Andean formations of  $\sim 500\text{--}350$  my, and the less radiogenic sediments from the younger Frontal Cordillera (Ramos and Folguera 2009).

We have recorded non-local  $^{87}\text{Sr}/^{86}\text{Sr}$  values for 62 samples from three archaeological sites: Potrero Las Colonias (from now onwards “PLC”; 57 samples, 40 individuals), Túmulo III (three samples, three individuals), and Usina Sur 2 (two samples, two individuals). This makes up for 45 individuals isotopically confirmed as migrants in Uspallata, summing up 29.2% of the minimal number of individuals reconstructed for these three sites ( $N = 154$ ). Importantly, only one individual from PLC and one from Túmulo III produced a local  $^{87}\text{Sr}/^{86}\text{Sr}$  signal. Available  $\delta^{13}\text{C}_{\text{coll}}$ ,  $\delta^{13}\text{C}_{\text{ap}}$ , and  $\delta^{15}\text{N}$  shows



**Figure 1.** Study area of the Uspallata and other Andean valleys in Argentina: red dot, location of the sites with migrants; green dots, location of rodent samples utilized to build the strontium isoscape; white dots, location of modern plant samples utilized to build the strontium isoscape.

that these individuals had largely C<sub>4</sub>-based diets, implying a subsistence most likely focused on intensive maize agriculture (Barberena et al. 2020) and excludes radiocarbon reservoir offsets.

## Methods

### *Bioarchaeology*

The comingled characteristics of the sites PLC and Túmulo III, comprising the largest part of our sample, combined with outdated recovery techniques applied in the 1930s original excavations by Carlos Rusconi (Rusconi 1961, 1962a), lead to mixed assemblages where the integrity of the specimens for each individual has been largely lost. For the quantification of these remains, we began by separating specimens from adults and subadults to accurately estimate the Minimal Number of Individuals (MNI) (Grayson 1984; Gifford-Gonzalez 2018). Then, we followed an additional step proposed for comingled human remains aimed at calculating the “Most Likely Number of Individuals” (MLNI), which estimates the original number of deposited individuals instead of the individuals recovered—as done by the MNI—based on the pairing of well-preserved homologous elements (Adams and Konigsberg 2004). The analysis was adjusted by considering additional variables such as the morphology, size, robusticity and presence of distinctive morphologic features in the remains (Grayson 1984; Buikstra and Ubelaker 1994).

For the estimation of age and sex we considered diagnostic elements with good preservation; crania in adults and femora in subadults, while sex determinations were conducted only for adults utilizing dysmorphic features of the *os coxae* and the skulls. To reconstruct the age at death profile, we divided the samples into Subadults (prenatal stage to the fusion of the epiphyses of the post-cranial skeleton, ca. 20 years) and Adults (>20 years) (Buikstra and Ubelaker 1994; Scheuer and Black 2000). The age at death in subadults was estimated by means of the longitudinal size of the femora using a digital caliper and an osteometric table, following the age categories defined by Buikstra and Ubelaker (1994): fetal (before birth–40 weeks); infant (0–4.9 years); child (5–14.9 years); adolescent (15–19.9 years). To estimate age at death in adults we used the cranium given its better preservation and associated sex information (Meindl and Lovejoy 1985), applying the following categories: young adult (YA: 20–34 years), middle adult (MA: 35–49 years), old adult (OA: >50 years) (Buikstra and Ubelaker 1994).

### *Chronology*

Radiocarbon measurements were obtained for 16 individuals of the three sites with migrants in Uspallata: nine from PLC, six from Túmulo III and one from Usina Sur 2. Five of these were previously reported (Gil et al. 2009; Barberena et al. 2020). Of the 14 dates produced by us, 10 were dated at DirectAMS (United States) and four at CIRAM Lab (France). The two remaining dates were analyzed at the University of Arizona AMS Laboratory (United States) (Gil et al. 2009). Bone collagen pre-treatment methods are described in SI. Calibration and Bayesian modelling were undertaken using the SHCal calibration curve (Hogg et al. 2020, Aug 12) in OxCal 4.4 (Bronk Ramsey 2009). All Bayesian models created are single-phase and uniform. The primary model includes the 16 radiocarbon measurements representing the three archaeological sites, whilst two other models are site-specific sequences for PLC and Túmulo III. Given that Usina Sur 2 is only represented by one date, no model was made. Within OxCal, the ‘Difference’ function was used to determine the coevality of specific temporal distributions. All age estimates are here noted at 95.4% credible/confidence intervals (CI) and rounded to 5 years. OxCal code can be found in SI.

## Results

### *Bioarchaeology and mortuary practices*

As mentioned, two of the sites with migrants were excavated by the pioneer archaeologist Carlos Rusconi in the 1930’s (Rusconi 1947, 1962b). PLC site is a multiple burial excavated in 1939 from

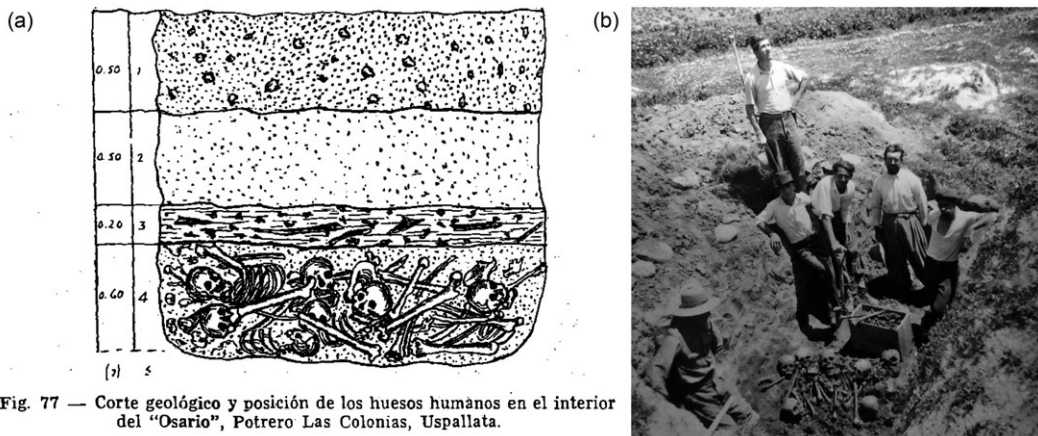


Fig. 77 — Corte geológico y posición de los huesos humanos en el interior del “Osario”, Potrero Las Colonias, Uspallata.

**Figure 2.** PLC site: (a) Section of the excavation drawn by Rusconi signaling layers 3 and 4 (Rusconi 1962a); Figure 77); (b) Photograph of the excavation taken on February 10th, 1939 (Image facilitated by Estela Rusconi).

which most of the available isotopic information for migrants comes from. Rusconi describes the burial as an “ossuary” containing partly disarticulated bones deposited in a small pit of  $\sim 2.5 \times 2$  m (Rusconi 1962a, 370) (Figure 2). While Rusconi does not record the precise limits of the burial pit (layer 4), he indicates that the remains were directly overlain by a 20 cm-thick layer containing ash, charcoal and some burnt undetermined bone remains (layer 3). Based on this, Rusconi suggests that the mortuary practices involved the ignition of fires above the deposit containing the remains (Rusconi 1947). While this suggestion cannot be assessed in absence of precise contextual information, only two bones showed evidence of burning, thus discarding a significant role of the practice of cremation.

As a result of the bioarchaeological analysis, we quantified 875 diagnostic bone specimens from cranial and post-cranial anatomical elements (Table 1). The quantitative analysis allows determining an MNI of 124, of which 70 are adults and 54 are subadults. Due to a complex conservation history of these remains during the last 90 years, it is likely that part of the excavated remains has been lost and that the original number of deposited individuals was considerably higher (Guevara et al. 2022). Indeed, the MLNI (Adams and Konigsberg 2004) reconstructed is of 76 adults and 74 subadults for a total of 150 individuals. Sex determinations conducted on the preserved crania from adults show the presence of 8 females (38%) and 13 males (62%). As for the coxae, the sample is composed of 30 females (43%), 24 males (34%) and 16 undetermined (23%).

Rusconi postulates two alternative hypotheses to explain the formation of this cemetery site: inter-group conflict followed by violent deaths or an epidemic that decimated a large part of these groups (Rusconi 1961, 214–215). Both scenarios would have involved the speedy interment of the deceased in a communal burial with little to no associated cultural remains (Rusconi 1947; Guevara et al. 2022). Preliminary taphonomic analysis does not show traces of trauma and violent deaths. Importantly for the timing and mode of site formation, Rusconi suggests that the site represents a unique depositional event due to a catastrophic event.

Túmulo III site corresponds to another multiple burial poorly described by Rusconi as containing incomplete and comingled remains from several individuals including subadults of different ages (Rusconi 1962a, 190). The author does not record any association with cultural materials on this site. Shortly, and while contextual information is limited, it appears to share some contextual characteristics with PLC: mixed remains from multiple individuals in a context that does not include mortuary goods. The bioarchaeological study of the remains shows an MNI of 26 individuals composed by 12 adults (46%) and 14 subadults (54%) (Table 1). There is a high representation of subadults compared to adults in the categories of <40 weeks, 0–3.9 years and 4–14.9 years.

**Table 1.** Anatomical representation and MNI for the sites with migrants from Uspallata

Site	Potrero Las Colonias			Túmulo III		
	Adults	Subadults	Total	Adults	Subadults	Total
Tibia	82	42	124	9	10	19
Coxae	94	29	123	8	1	9
Humerus	87	56	143	12	13	25
Femur	96	68	164	10	24	34
Cubitus	77	37	114	15	12	27
Radius	81	25	106	11	6	17
Cranium	21	28	49	—	2	2
Total	538 (65.4%)	285 (34.6%)	823	65 (48.9%)	68 (51.1%)	133

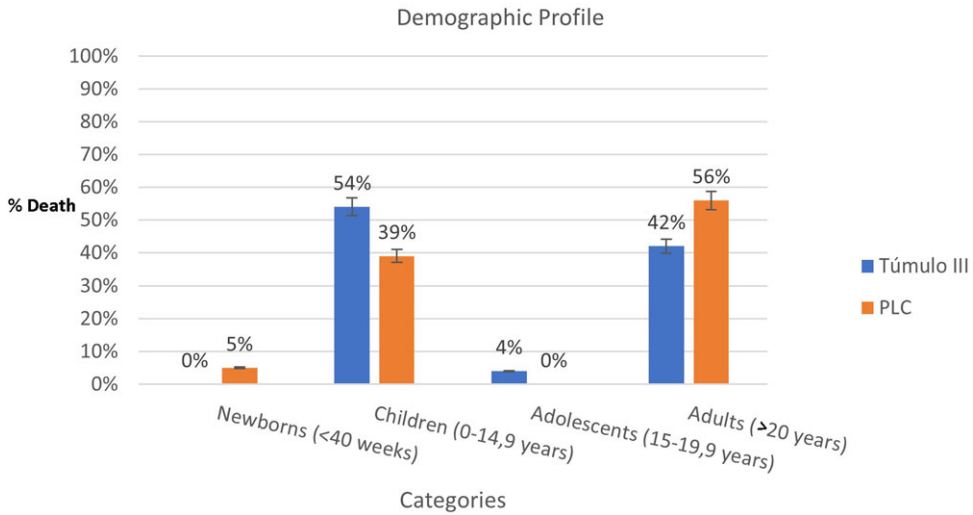
Element	Pairs	Left	Right	MNI (L+R-P)	Pairs	Left	Right	MNI (L+R-P)
MNI in adults								
Tibia	29	45	39	55	—	2	4	6
Coxae	24	44	50	70	—	4	4	8
Humerus	27	41	46	60	—	6	6	12
Femur	31	48	48	65	—	4	2	6
Cubitus	16	40	37	61	2	7	6	11
Radius	23	44	37	58	—	5	5	10
Combined	150	262	257	70				12
MNI in subadults								
Tibia	6	14	28	36	2	5	7	10
Coxae	9	16	13	20	—	1	—	1
Humerus	7	26	30	49	1	5	8	12
Femur	14	33	35	54	4	9	9	14
Cubitus	1	23	14	36	1	7	3	9
Radius	2	15	10	23	—	3	3	6
Combined	39	127	130	54	8	30	30	14
Total MNI per site				124				26

Finally, Usina Sur 2 is the third site where we recorded a non-local  $^{87}\text{Sr}/^{86}\text{Sr}$  signal which is isotopically like those from PLC and Túmulo III. This context was excavated by our team in 2017 in the context of a rescue of the remains that eroding in the front of a receding ravine. We recovered the partial remains of two adult individuals of undetermined sex (Barberena et al. 2020).

While the recovery conditions of the sites PLC and Túmulo III prevent an accurate paleodemographic reconstruction, there are some significant inferences to be made regarding the composition of the migrant groups (Baitzel and Goldstein 2016). Firstly, nearly all the subadult and adult age categories are represented. Indeed, the interval of individuals between 0 and 14.9 years (children) is very high in PLC (39%) and Túmulo III (54%) (Figure 3). Rusconi himself remarked the high abundance of newborns and young individuals during the excavations (Rusconi 1962a): 190). Since both differential preservation and recovery techniques would tend to under-represent the smaller and more fragile subadult remains, we suggest that there is a fidelity in terms of age composition between the available sample and the individuals originally deposited.

### Bayesian modeling

The chronological results are presented in Table 2. Bayesian modeling results estimate the start and end of the migrant phase in Uspallata to 1210–1275 CE (median 1255 CE) and 1320–1425 CE (median



**Figure 3.** Age at death profiles at PLC and Túmulo III.

1360 CE), respectively, with a likely duration of between 55 to 195 years (median 105 years) (Figure 4). These start and end estimates are comparable to those produced by the site-specific models for PLC (Figure S1) and Túmulo III (Figure S2; Figure S3). The individual date for Usina Sur 2 also falls within this period. As such, migration likely began coevally at these archaeological sites and represents a regional process. Modeling also indicates that the commencement of this migratory phase precedes the start of Inka occupation in the region—as calculated in (Marsh et al. 2017)—by 90–210 years. As a note, real/potential offsets introduced by collagen turnover in bone (including intraskeletal variation) (Hedges et al. 2007; Jørkov et al. 2009; Sealy et al. 1995) as well as targeted vs. dated event (death of the individual vs. time of migration) should fall within the dating uncertainty (around a century for calibrated ages in this period), particularly for subadults. Therefore, these factors are unlikely to significantly alter the results.

## Discussion

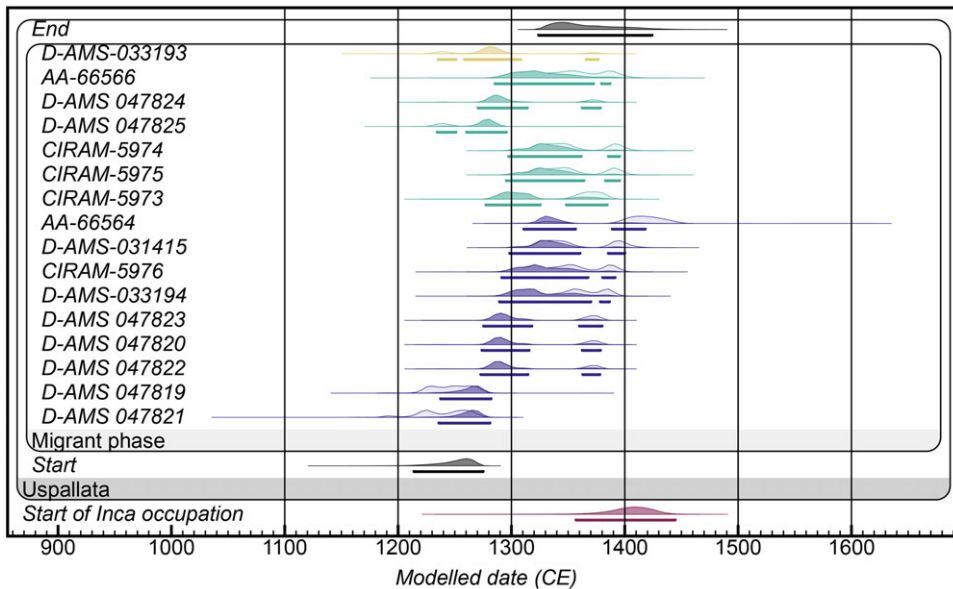
The integration of the mortuary and demographic results with the Bayesian modeling of the radiocarbon dates allows characterizing the timing and mode of the process of human migration in the southern Andes. The migrant groups show a high representation of children—between 0 and 14.9 years old—at PLC (39%) and Túmulo III (54%) burial sites. These sites were excavated in the 1930's with techniques that likely produced partial recovery of the remains. However, since this bias would preferentially affect the smaller and more fragile subadult bones, we are confident that their high representation is a primary feature of these cemeteries. Considering that, in addition to the representation of the different age classes, both men and women are present, we tentatively infer that family groups were involved (Chamberlain 2006). These two sites are the only in Uspallata and nearby regions in which large numbers of individuals of different age and sex are deposited without any grave goods (Barberena et al. 2020; Da Peña Aldao et al. 2016; Durán et al. 2018b; Rusconi 1947; Schobinger 1974).

The Bayesian modeling of the 16 dates for the sites with migrants indicates that this was likely a diachronic process lasting between 55 and 195 years (Figure 4). If the span of one human generation is taken to be ~25 years (Timpson et al. 2021; Wang et al. 2023), the results suggest that migration to Uspallata was a multi-generational process that involved at least two and up to eight generations with a median estimation of four generations. Independently of the precise number, the Bayesian model suggests that the socioecological conditions fostering migration to Uspallata were sustained through

**Table 2.** Radiocarbon dates for the sites with migrants in the Uspallata Valley

Site	Latitude	Longitude	Individual	Sample	Lab code	pMC	$\delta^{13}\text{C}$ (‰)	$^{14}\text{C}$ date	1 $\sigma$ error	Source
Potrero Las Colonias	-32.605006°	-69.364833°	810a	Mandible	D-AMS 047821	89.96 ± 0.24		850	21	This paper
Potrero Las Colonias			300	Atlas	D-AMS 047819	90.14 ± 0.22		834	19	This paper
Potrero Las Colonias			307	Mandible	D-AMS 047822	91.12 ± 0.22		747	19	This paper
Potrero Las Colonias			301	Cranium	D-AMS 047820	91.15 ± 0.22		744	19	This paper
Potrero Las Colonias			471a	Petrous bone	D-AMS 047823	91.21 ± 0.22		739	19	This paper
Potrero Las Colonias			811a	Tarsal	D-AMS- 033194	91.86 ± 0.29	-6.6	682	25	(Barberena et al. 2020)
Potrero Las Colonias			387	Petrous bone	CIRAM-5976	92.04 ± 0.31	-11.45	667	27	This paper
Potrero Las Colonias			Sample #152	Tarsal	D-AMS- 031415	92.41 ± 0.32	-11.1	634	28	(Barberena et al. 2020)
Potrero Las Colonias			MMy-284	Bone	AA-66564			568	38	(Gil et al. 2009)
Túmulo III			-32.587191°	-69.360288°	3	Petrous bone	CIRAM-5973	91.47 ± 0.31	-10.32	716
Túmulo III	1	Petrous bone			CIRAM-5975	92.22 ± 0.31	-10.27	651	27	This paper
Túmulo III	5	Petrous bone			CIRAM-5974	92.28 ± 0.31	-9.16	645	27	This paper
Túmulo III	#146	Metatarsal			D-AMS 047825	90.7 ± 0.21		784	19	This paper
Túmulo III	#145	Metatarsal			D-AMS 047824	91.05 ± 0.22		753	20	This paper
Túmulo III	Mmy-1097	ND			AA-66566			671	40	(Gil et al. 2009)
Usina Sur 2	-32.634250°	-69.374458°			1	Rib	D-AMS- 033193	90.84 ± 0.28	-6.2	772





**Figure 4.** Bayesian model for the migrant phase at Uspallata, including radiocarbon measurements from PLC (blue), Túmulo III (green) and Usina Sur 2 (yellow). Bars underneath each distribution denote 95.4% CI. “CE” denotes Common Era (calibrated). The start of Inka occupation in the region (as calculated in Durán et al. 2018b; Marsh et al. 2017), is included at the bottom in red. The interval between this and the commencement of the migrant phase at Uspallata is estimated to 95–220 years.

time. Importantly, the  $^{87}\text{Sr}/^{86}\text{Sr}$  values for migrants are very homogeneous pointing towards a very similar—though still undetermined—source area (Barberena et al. 2020, 2021a).

Finally, the dates suggest that there is nearly no overlap between the migration and the southwards expansion of the Inka Empire (Bárcena 2007; Troncoso 2018), with an earliest estimation for its arrival in Uspallata around 1400 CE (Cornejo 2014; Marsh et al. 2017; cf. García et al. 2023). Considering that in this earliest estimation there is a minimal overlap near the end of the modelled interval, we suggest the Inka expansion is largely unrelated to the dynamics of the migratory process recorded. However, since the estimation for the end of this interval encompasses between 1320–1425 CE, it is possible that there was a minimal overlap between the end of the migration phase and the Inka arrival. In any case, as was previously suggested (Alconini and Covey 2018; Pavlovic et al. 2019; Troncoso 2018), our results suggest that there likely was a multicultural social setting when the Inka arrived.

## Conclusions and perspectives

We have presented contextual, bioarchaeological and chronological evidence supporting an inter-generational migration pulse shortly preceding the Inka arrival in the southern Andes of Argentina. This process involved groups composed by the different age classes and sexes, probably representing families, which were deposited in multiple burials with no significant grave goods. Importantly, the  $^{87}\text{Sr}/^{86}\text{Sr}$  signature suggests that these individuals come from the same—still undetermined—geological region. This research raises new questions for which we have no clear answers yet. Combined, these issues make up an exciting research program for years to come. Firstly, the multi-generational character of the migratory pulse invites to explore possible “push” factors (Anthony 1990; Ingram and Schollmeyer 2021), or what Tsuda et al. (2015) define as disruptions, that may have triggered the abandonment of the migrants’ homeland. We will consider climate change, conflict and/or diseases, among other possible factors. In parallel, the results suggest that the Uspallata Valley exerted a strong

pull influence on the migrants. While the reasons for this may be manifold, the existence of previous social links between the source and destination areas may have been significant. In any case, migration occurred beyond the territories of these groups as measured by  $^{87}\text{Sr}/^{86}\text{Sr}$  and may have involved movement across social or ethnic frontiers (Feuer 2016; Parker 2006).

The migrants from the different sites show strikingly similar non-local  $^{87}\text{Sr}/^{86}\text{Sr}$  values, raising the scenario that they died not long after arriving at Uspallata, since otherwise the differential incorporation of local strontium would produce more diverse isotopic values. We need to investigate the socio-ecological scenarios that may have led to this dramatic outcome.

We are currently working on several dimensions that will help us move forward in answering these questions. Firstly, we are combining studies of human paleogenomics and cranio-facial geometric morphometrics to assess biological distances between locals and migrants, as well as group sizes and possible source areas. Geometric morphometrics will also inform on aspects of cultural identities through the study of cranial modifications (Menéndez 2015; Torres-Rouff and Knudson 2017). Paleogenomic studies will also target pathogen DNA which, combined with the paleopathological study of the remains, may shed light on the health and nutrition background of the migrant groups (Nelson et al. 2020). Finally, we will seek to understand the social disruptions produced by the migrations in the local groups and how these affected the ensuing interactions that were brought by the Inka shortly after.

**Supplementary material.** To view supplementary material for this article, please visit <https://doi.org/10.1017/RDC.2024.50>

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