Archaeometry **62**, Suppl. 1 (2020) 19–34 doi: 10.1111/arcm.12521

STABLE ISOTOPE ANALYSIS OF THE INCA MUMMY FROM NEVADO DE CHUSCHA (SALTA, ARGENTINA)**

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*This paper presents the carbon ($^{13}C/^{12}C$), nitrogen ($^{15}N/^{14}N$), oxygen ($^{18}O/^{16}O$), hydrogen ($^{2}H/^{1}H$) and sulfur ($^{34}S/^{32}S$) stable isotope values measured in the hair of a female individual from northwestern Argentina. The analysis of segments of this tissue allows for the recording of the diet and migratory changes with a short time resolution. The sample is from a mummified young female individual discovered in Chuscha mount, Salta province. It was found at more than 5000 masl, in a mountain sanctuary of the Inca expansion (*capacochas*). The paper discusses the paleodiet and mobility patterns of this individual in the period before her death, focusing on the isotopic variations in a limited time scale. The results indicate that the individual moved from a different region to the place where she was sacrificed. Furthermore, in the last year the individual was alive, a shift in the isotopic composition of the food consumed is detected: a variation in the importance of C_4 over C_3 resources is evident. The results are compared with the isotopic estimations for other children and young people recovered in archaeological contexts associated with *capacochas *to infer variability in the geographical trajectories covered during their last months of life.*

KEYWORDS: STABLE ISOTOPE, PALEODIET, MOBILITY, *CAPACOCHA*, HAIR

INTRODUCTION

Sacrifices of children and adolescents in mountain sanctuaries was an extended practice during the Inca Empire, as testified in European chronicles and also several archaeological excavations

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throughout the Andes (e.g., Rostorowski 2003; Ceruti 2004; Wilson *et al*. 2007; Faux 2012). This practice, known as *capacocha*, aimed to sooth weather conditions that were adverse for agricultural practices, asking for fertility and the prosperity of crops. They may even have responded to different interests of the sovereign, such as to guarantee a successful warlike conflict or an architectonic work (Rostorowski 2003), or to accompany him in his death. For instance, Betanzos (1987) described an important *capacocha* performed for Pachacutec Inca Yupanqui's burial. In addition, in the chronicles related by Cristobal de Molina (1959), this practice was argued to have been invented during this last reign and implied the sacrifice of children from the four corners of the empire: Kollasuyu, Chinchasuyu, Antisuyu and Contisuyu. The ceremony was interpreted as a way to consolidate Inca power over occupied regions. Several authors (García and Juárez 2008; Vitry 2008; Moyano 2009) revealed its particular importance in the Kollasuyu, the southern point of the empire, as it intended to mitigate the serious economic and political crisis of such a region by expiation (Duviols 1976).

The ritual basically implied the movement of people and goods from occupied locations to Cusco, as well as the circulation of objects and people from the imperial centre to the periphery. In this way, a distributive strategy was reinforced, strengthening the links with local authorities (Ceruti 2015). The individuals offered for sacrifice—mainly females—responded to three kinds of situations: virgin maidens devoted to the sovereign and sent to Cusco as his entourage; children voluntarily entrusted by their own parents as a tribute of the occupied province; or sons and daughters of local chiefs who offered them as a service (Cobo 1990 [1653]; Andrushko *et al*. 2011; Ceruti 2015). In the case of young ladies—the *acllas* or chosen women—they were acquired by the empire and conducted to Cusco to the *acllas huasi*, an institution where they learnt to prepare *chicha*, a drink made of fermented maize (De Molina 1959). However, there are also records of young men being sacrificed, perhaps prisoners captured during warlike conflicts. This could have been the case of the 'boy' from the Cerro El Toro, in San Juan, Argentina (Schobinger 1966). Summing up, the children and young people sacrificed were born in the four corners of the empire and later directed, together with their entourage and relatives, to different locations to be buried alive.

Bioarchaeological studies of isotopes and ancient DNA have enquired into the ethnicity and geographical origin of the children and adolescents sacrificed in mountain sanctuaries (Fernández *et al*. 1999; White *et al*. 2002, 2007; Knudson *et al*. 2006; Wilson *et al*. 2007; Price *et al*. 2007; Tung and Knudson 2010; Andrushko *et al*. 2011). Consequently, the child from the Aconcagua was inferred to have been born on the plateau (Previgliano *et al*. 2003; Faux 2012) and an extra-Andean environment was suggested for the Maiden of the Llullaillaco, while the two accompanying children had connections with the Cusco area—although a genetic correlation with the Mapuche peoples from southern Argentina and Chile was also proposed for one of them (Reinhard and Ceruti 2005; Faux 2012). The non-local origin of some of the children was also evident in Juanita, a mummy from Ampato, south of Peru, whose DNA did not indicate any relation to local populations (Reinhard 1998). Carbon ($^{13}C/^{12}C$), nitrogen ($^{15}N/^{14}N$), oxygen ($^{18}O/^{16}O$), deuterium ($^{2}H/^{1}H$) and sulfur ($^{34}S/^{32}S$) stable isotopes in hair segments were useful in order to assess shifts in both the kind of resources consumed and the origin of the water drunk. Hence, seasonal changes in the diet ingested by the Maiden of the Llullaillaco and Sarita from the Sara Sara (Faux 2012) were proposed, together with a shift from a marine to a terrestrial diet in the case of the boy from the Aconcagua (Fernández *et al*. 1999).

One of the best-studied *capacocha* examples in Argentina is the mummy from Chuscha mount (Panarello *et al*. 2003; Schobinger 2003). It is a naturally mummified female of an estimated age of eight to nine years from Chuscha mount, Salta province, some 5000 masl (Fig. 1). The Nevado de Chuscha is located in the northern border of Sierra del Cajón, some 5468 masl, to the south-

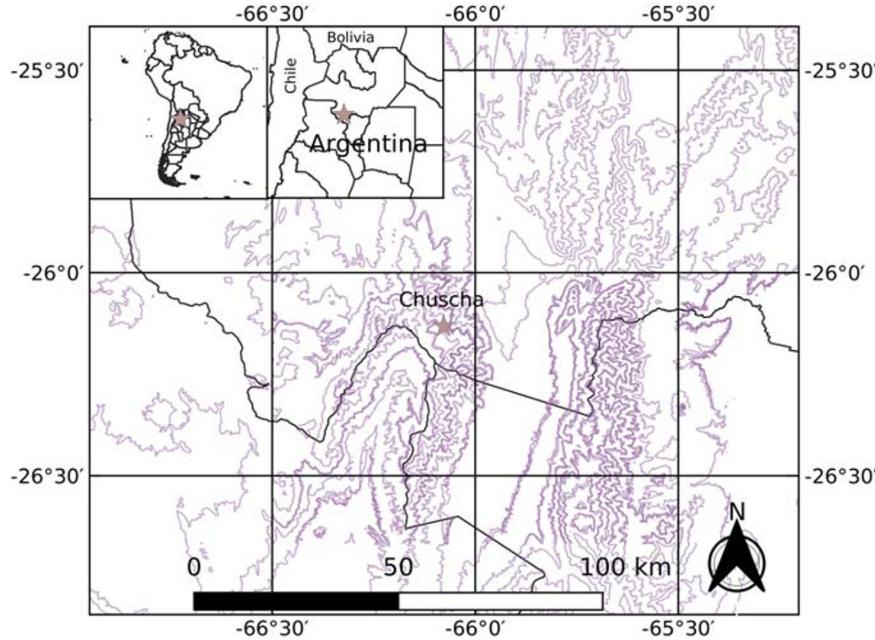

Figure 1 *North-west Argentina, with the Nevado de Chuscha site.*

east of Salta province, in the Cafayate archaeological area. This region presents a large number of imperial constructions and evidence of the Inca royal trail (Schobinger 2001–03). On top of this mount, a circular dry-stone walled structure was detected, which may have contained the so-called 'mummy of the Quilmes' or 'Queen of the Mount', one of the most significant pieces of evidence for imperial expansion in the region. The recovery of this female subadult body at the beginning of the 1920s did not follow any professional protocol, and it was transported and exhibited in different sites in Argentina over more than 50 years. However, there was minor damage to the individual, despite having suffered many variations in temperature and location over time (Schobinger 2001–03).

This is an outstanding case as it was dressed in a tunic, a male piece of clothing in Inca society (Ceruti 2004). The way it died was also different from the common procedure in this kind of sacrifice, because it was killed with a bladed weapon. The other modalities, such as suffocation or live burial, did not involve bleeding (Schobinger 2003). The individual is presumed to have participated in one of the hundreds of rituals celebrated on mountain altars during the Inca expansion, probably as part of the Inca's *acllas* entourage (Ceruti 2004). Many of its clothing items and additional offerings were lost. According to the documents, its hair was arranged in thin braids and it was wearing a brown *unku* made of two parts—one of them with a checkered design—a headband with geometric embroidery supporting a crest of colour feathers and a wool sash decorated with designs of Inca influence (Schobinger 2004). Among the materials missing, there were a necklace of beads made of different minerals, a *chuspa* with coca leaves and the remains of combs made of teasel spines, and a *topu*s. As regards the associated grave goods, there are records of the missing gold and silver necklaces and bracelets, *pucos*, and metal and clay toys. Among the elements present, *pucos* of Inca style were identified, as well as small shells that may have formed a necklace. Furthermore, there was a piece that could have been introduced later into the assemblage: a heavy metal disc where the mummy was supposed to be sitting when found (Schobinger 2004).

To reconstruct the last 10 months before the death of the mummy from Chuscha mount, the isotopic values ($\delta^{13}C$, $\delta^{15}N$, $\delta^{34}S$, $\delta^{18}O$ and $\delta^{2}H$) measured in its hair are presented herein. The purpose is to provide a paleodiet and mobility study of the period before its death, focusing on the isotopic variations relative to the shift in the kind of food and water consumed. The segmented analysis of this tissue allows the recording of dietary and migratory changes with a short time resolution because hair does not present metabolic activity once keratin is synthesized. Additionally, we compare the results with the conclusions published for the rest of mummified individuals involved in *capacochas*. Our interest rests on showing how similar or different the life histories of the children and adolescents involved in these imperial sacrifices were, at least regarding the ethnohistorical expectation of a compulsory visit to Cusco before starting the pilgrimage to the sacred mounts selected for the sacrifice. This information, inferred from the isotopic measurements understood as palaeodietary and geographical markers, is used to discuss the way power relations were created between the centre of the empire and its periphery, as these rites could have been performed without a compulsory visit to the imperial capital and, consequently, without a direct link with the Inca.

Theoretical–methodological principles

To determine if there is a shift in the kind of resources consumed, carbon ($^{13}C/^{12}C$), nitrogen ($^{15}N/^{14}N$) and sulfur ($^{34}S/^{32}S$) stable isotopes are analysed. The analysis of carbon stable isotope defines the dominant photosynthetic pattern in the diet, because this element is incorporated in the ecosystem via plant photosynthesis. Different photosynthetic patterns exist: C_3, C_4 and crassulacean acid metabolism (CAM), all with different ranges of isotopic distribution. In the case of the Andean plant resources for human consumption, in the first photosynthetic pattern we can mention all the tubers as well as quinoa (*Chenopodium quinoa*), beans (*Phaseolus vulgaris*), calabash (*Curcubita* sp.), and gathered resources such as carob tree (*Prosopis* sp.) and *chañar* (*Geoffroea decorticans*). C_4 plants include maize (*Zea mays*) and, with a less certain economic relevance, amaranth (*Amaranthus caudatus*) (Gheggi and Williams 2013; Killian Galván *et al*. 2016). It is difficult to evaluate the economic importance of CAM vegetables in the past, even if they are consumed by modern populations (Killian Galván *et al*. 2015). The distribution of these pathways varies depending on an altitudinal gradient, as the C_3 pattern results more efficient in lower temperatures and higher humidity, gaining importance as altitude increases (Tieszen *et al*. 1979). Animals for human consumption may be found in any of the photosynthetic pathways, depending on the amount of pasture with either a C_3 or C_4 photosynthetic pattern. North-western Argentina records a strong variation depending on altitude, with a C_3 photosynthetic pattern in higher altitudinal sectors (Samec *et al*. 2017).

$\delta^{15}N$ values are used in the reconstruction of trophic chains and, in the case of humans, as indicators of eating vegetal or animal protein, as much as to distinguish terrestrial from marine diets. $\delta^{15}N$ values of terrestrial plants depend on different factors related to weather, the nitrogen source available in the soil (e.g., NO_3^-, NH_4^+), and their metabolism (Handley and Raven 1992). A crucial factor is water availability, where a lower level of precipitations corresponds to higher $\delta^{15}N$ values. This mechanism is explained by a more open nitrogen cycle in ecosystems with a higher loss of this element (Austin and Vitousek 1998). North-western Argentina records a strong variation depending on altitude, with low isotopic values in higher altitudinal sectors (Samec *et al*. 2017). In agricultural and herding contexts, manure is also indicated as a source enriching the heavier isotope in plants (Finucane *et al*. 2006; Szpak 2014).

The isotopic composition of sulfur ($\delta^{34}S$) in human tissues has proved useful for paleodiet reconstruction (Richards *et al*. 2003; Nehlich 2015). Isotopic values in human and faunal tissues generally reflect the $\delta^{34}S$ values of the resources consumed. Furthermore, the isotopic values found on the base of the trophic chains depend on local mineralogy and geology, atmospheric gases and the microbial processes active in the soil (Rossmann *et al*. 1998; Richards *et al*. 2003). Specifically, it has been used to separate marine from terrestrial diets (Richards *et al*. 2003) due to the characteristic high values and homogeneous isotopic composition of the oceans (Nehlich 2015). However, the high values associated with marine contexts may not reflect the consumption of these resources due to the sea-spray effect, which generates $\delta^{34}S$ values in coastal soils similar to oceanic parameters (Wadleigh *et al*. 1994). Macko *et al*.'s (1999) study of mummies from coastal environments in South America indicates $\delta^{34}S$ values near 15‰. Further research in the area presents measurements on human remains (hair and nail) and animal fibres (camelids) in Argentina Puna (Araníbar *et al*. 2007). Analysis in Peru also demonstrates different areas with specific isotopic ranges depending on the closeness to the coast and volcanic activity (Bishop 2017).

Hydrogen and oxygen isotopic values measured in hair have been widely used in studies of residential mobility in different fields of anthropology (Ehleringer *et al*. 2008; Bowen *et al*. 2009). Its reliability depends on the predictable variation in the isotopic composition of water across space (Craig 1961; Dupras and Schwarcz 2001. Two main processes explain this spatial variation: on the one hand, the molecules with the lightest isotope are more quickly evaporated; and, on the other, the heaviest isotope condenses and precipitates more easily than the lightest. Thus, the values of meteorological water (rain, snow, hail, drizzle) vary depending on the altitude, latitude, humidity, temperature and distance to the coast (Craig 1961).

The isotopic values recorded in animal tissues are the result of hydrogen and oxygen absorption from different sources, such as atmospheric oxygen, food and the physiological processes involved in water consumption (Podlesak *et al*. 2008). From controlled studies it is known that although the water drunk is responsible for the highest percentage of body hydrogen and oxygen, the water in the food also contributes to body content (Longinelli 1984; Luz *et al*. 1984; Luz and Kolodny 1985; Podlesak *et al*. 2008). A procedure to model the incorporation of hydrogen and oxygen stable isotopes in human tissue implies considering all these sources as well as the fractioning associated with the synthesis of tissues and losses (e.g., expired CO_2 or exhaled water vapour). These models consider the isotopic values of the appropriate sources and physiological parameters to predict the isotopic values of the water drunk from the isotopic measurements of tissues, or vice versa (Ehleringer *et al*. 2008; Bowen *et al*. 2009; O'Grady *et al*. 2012). Hence, they are useful models to approach the geographical origin of people by measuring the stable isotopes in their tissues, particularly in hair. It should be remembered that the water drunk might have been previously treated by evaporation in different ways, which conditions its isotopic signal. This process is crucial in the typical feeding practices of the Andes, because the boiling process needed for *chicha* production may result in more positive $\delta^{18}O$ values due to the evaporation of ^{16}O (Wright and Schwarcz 1998).

METHODS

A lock of hair of approximately 10 cm was segmented every 10 mm. It was cleaned in an ultrasonic bath of deionized water and a mixture of methanol–chloroform (2:1 v/v) and later dried in an oven at 40°C. The measurement of $\delta^{13}C$ and $\delta^{15}N$ values was performed in INGEIS using a Carlo Erba Elemental Analyzer, coupled to a Finnigan MAT Delta V continuous-flow isotope ratio mass spectrometer, through a Thermo ConFlo IV interface. δ^{18}O, δ^{2}H and δ^{34}S values were processed in The University of New Mexico Center for Stable Isotope. The first two were analysed in a Costech 4010 Elemental Analyzer and a High Temperature Elemental Analyzer (TCEA) connected to a Thermo Scientific Delta V mass spectrometer through a Thermo ConFlo IV interface. For δ^{34}S a Thermo Delta Plus XL mass spectrometer was used.

The model proposed by Bowen *et al*. (2009) was applied to predict the isotopic values of water sources that would generate the δ^{18}O and δ^{2}H values in human hair. The purpose was to compare possible residence areas with the stable isotope values of the water from relevant regions, such as Chuscha mount and Cusco, the imperial centre visited by the children to be sacrificed, according to Andean chronicles. These monthly and annual water values were calculated using the model available in the Online Isotopes in Precipitation Calculator (Bowen and Revenaugh 2003; Bowen *et al*. 2005; IAEA/WMO 2015; Bowen 2019). These data are based in basic predictions that consider both latitude and altitude, while interpolating 'residual values' or differences between prediction and measurement. These first-order predictions, however, lack the needed precision to predict certain places correctly—valleys, in particular—due to the intense recycling of water by evaporation (Rohrmann *et al*. 2014; Bershaw *et al*. 2016), especially in samples of surface water. Consequently, it should be noted that the values for the model of consumed water are an approximation rather than the exact representation.

RESULTS

Table 1 summarizes the isotopic values analysed. As appreciated, the isotopic systems considered in most of the hair segments resulted in satisfactory C/N relations (3.0–3.8; O'Connell and Hedges 1999). In the case of carbon and nitrogen isotopic values, 11 measurements were calculated, eight for deuterium and oxygen and six for sulfur.

According to the results, the individual presents a δ^{13}C value of −18.2‰ in the distal portion of the hair, whereas the proximal part yields a δ^{13}C value of −10.9‰ (Fig. 2, a). Consequently, it indicates a drastic shift in the dominant photosynthetic pattern of the individual's diet, from C_3 to C_4. Additionally, in nitrogen values (Fig. 2, b) a cyclic pattern is observed, as the δ^{15}N value in the sample is +8.4‰ in the distal portion of the hair, while in the proximal part it is +9.1‰, with

Table 1 *Stable isotopes in the hair of the Chuscha girl*

AIE (Laboratory Code)	*Sample*	*δ^{13}C (‰)*	*δ^{15}N (‰)*	*δ^{2}H (‰)*	*δ^{18}O (‰)*	*δ^{34}S (‰)*	*%C*	*%N*	*C/N ratio*
27648	CH1	−10.9	9.1	−79.3	10.1	n.a.	43.6	14.2	3.6
27649	CH2	−10.4	9.4	−76.3	10.8	6.1	42.0	13.6	3.6
27650	CH3	−11.3	10	−89.5	11.1	5.8	44.2	14.3	3.6
27651	CH4	−11.7	9.9	−93.6	10.7	6.4	43.5	14.1	3.6
27652	CH5	−14.1	11.0	−113.8	8.3	7.5	34.8	11.8	3.4
27653	CH6	−14.8	10.0	−120.5	9.3	8	42.9	13.8	3.6
27654	CH7	−15.0	9.8	−122.7	9.4	n.a.	36.4	11.5	3.7
27655	CH8	−15.3	9.4	−126.9	9.3	8.1	41.6	13.4	3.6
27656	CH9	−16.8	8.9	n.a.	n.a.	n.a.	42.7	13.8	3.6
27657	CH10	−17.9	8.6	n.a.	n.a.	n.a.	38.7	12.4	3.6
27658	CH11	−18.3	8.4	n.a.	n.a.	n.a.	40.3	13.0	3.6

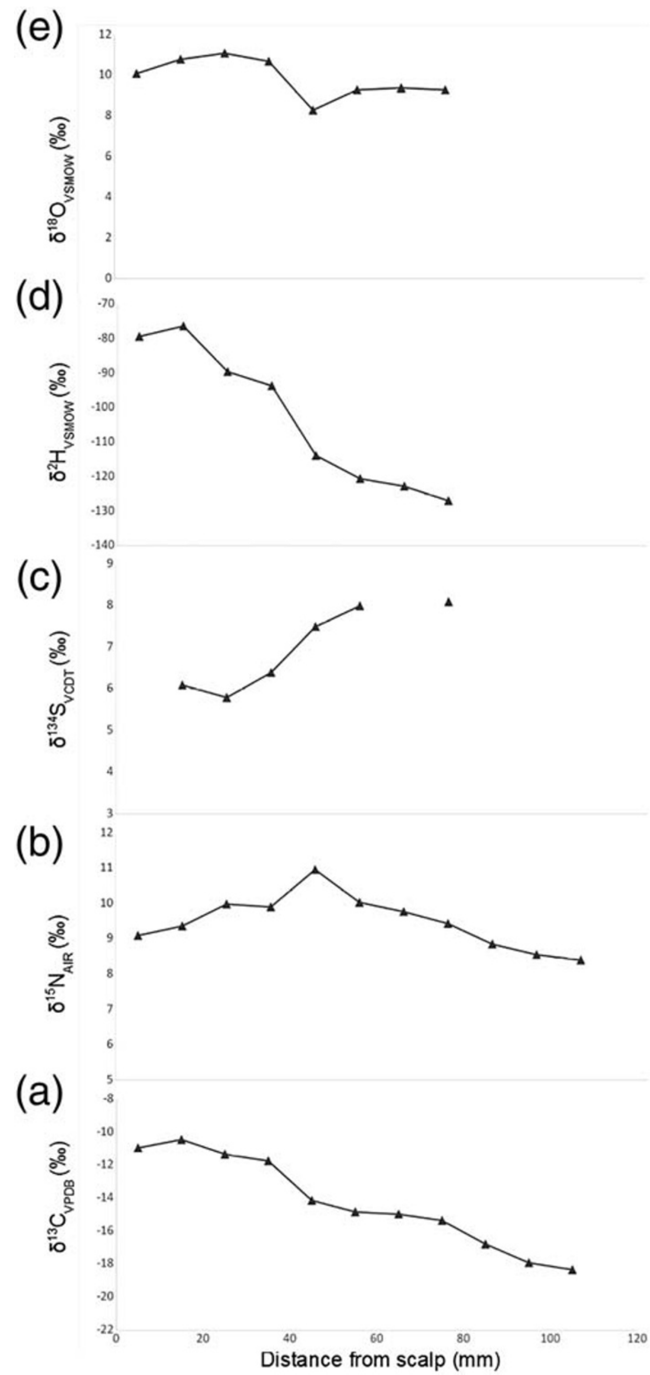

Figure 2 *Serial isotopic data from scalp hair taken from the Chuscha girl: (a)* $\delta^{13}C_{VPDB}$*; (b)* $\delta^{15}N_{AIR}$*; (c)* $\delta^{34}S_{VCDT}$*; (d)* $\delta^{2}H_{VSMOW}$ *and (e)* $\delta^{18}O_{VSMOW}$*.*

the most positive value (+10.3‰) in the middle of the hair segment analysed. Hence, the individual progressively incorporated a higher component of C_4 plants in its diet, while the amount of animal protein seems to have remained virtually constant with an isotopic variation during the last 10 months of life of approximately 2‰, that is, less than a trophic level (about 3–5‰). However, this variation may be explained by environmental changes related to aridity. In the case of the isotopic values of sulfur (Fig. 2, c), the tendency results in more positive values (δ^{34}S +8.1‰) at later moments and lower ones in earlier times (δ^{34}S +6.1‰). That is, although there is a shift in the values, they may be due to isotopic differences in the geological substrate, always considering a terrestrial environment and discarding the inclusion of marine or coastal resources.

Estimated δ^2H values present a similar trend to that found in carbon: lower values (δ^2H = –126.9‰) at the beginning of the chronological segment studied and more positive ones (δ^2H = –79.3‰) towards the end (Fig. 2, d). However, this does not happen in the case of oxygen, which indicates a smaller variation among them between +9.3‰ and +10.1‰ (Fig. 2, e).

DISCUSSION

The analysis of different isotopic systems, such as the ones presented herein, approaches several aspects related to the diet and mobility during the year before death of any individual. From the measurements on the hair of the mummy from Chuscha, who was probably part of an Inca *capacocha*, we record drastic changes in its last months of life. In this way, the analysis allows one to tackle the study of this Inca ritual because the shifts detected may be coherent with the pilgrimage described in the chronicles of the Spanish conquest and occupation period in the Andean area.

In the first place, we detect a progressive increase of C_4 photosynthetic resources, such as maize (or amaranth), replacing C_3 plants such as tubers or quinoa. This gradual shift in diet composition is coherent with the expected situation. On the one hand, it may be associated with a progressive substitution of resources inside the C_3 photosynthetic pattern by a C_4 resource, represented by maize, the main foodstuff in all the Inca festivities, which used to be consumed in different preparations such as flour or fermented beverages. Furthermore, this gradual shift in the dominant photosynthetic pattern may also result from the movement between isotopically different places. These alternative explanations are not mutually exclusive, since the routes followed by the children would be assisted by *tambos* with provisions of this cereal, securing its consumption.

From δ^{15}N behaviour, no major modification in the kind of protein consumed is noted. The values recorded are related to paleodiets with a high participation of animal resources typical of altitudes < 3500 masl. In Puna environments in north-western Argentina, relatively more positive isotopic values have been identified (Killian Galván 2015, 2018), even if we consider that hair presents richer values of the heaviest isotopes (1.4‰ in δ^{13}C and 0.86‰ in δ^{15}N) compared with bone collagen (O'Connell *et al*. 2001). Similarly to δ^{15}N, δ^{34}S values reflect the consumption of terrestrial resources rather than marine species, which dismisses an origin and/or transit near the coast in the last 10 months.

Interpreting δ^2H and δ^{18}O results is more complex due to several possible sources, such as diet and drinking water (Sharp *et al*. 2003). In the case of δ^{18}O, two regions or areas of possible isotopic equilibrium can be differentiated that may be connected with the individual's residence in a specific geographical location. The earliest region, identified between 80 and 50 mm (segments 8 to 6) from the root, is characterized by an average δ^{18}O value of $+9.3 \pm 0.06$‰. The later or more recent region may be defined between 40 and 10 mm (segments 4 to 2) and its δ^{18}O average is

+10.9 ± 0.2‰. It is difficult to trace similar regions for δ^2H values as there are no clear areas of isotopic equilibrium, but rather a linear increase in time, making the definition of residence areas less probable. The comparison between both values (Fig. 3) has a weak correlation ($R^2 = 0.57$). Nevertheless, it is possible to detect that in some areas the shift is highly progressive and the difference between consecutive segments is quite low (≤ 4‰). One of these regions coincides with the δ^{18}O equilibrium region in segments 8 to 6: it has an average δ^2H of −123.4 ± 3.3‰. For more recent values, there are also two slightly different regions: segments 3 and 4, with an average of −91.6‰ (a difference of 4‰) and segments 1 and 2, where the average is −77.8‰ (a difference of 3‰).

Using the model proposed by Bowen *et al.* (2009) and assuming that 100% of the food was local, the predictions of δ^{18}O and δ^2H values for the water drunk in the most distal or early region of the hair (segments 8 to 6) are −12.3‰ and −91.0‰, respectively, while in the most proximal area or earliest portion, the δ^{18}O prediction is −10.5‰. As regards the predicted δ^2H values for the two recent regions, they are −59‰ and −45‰.

Predictions about the earliest residence area correspond to a region with more negative values and even consumption of water sources which are not strongly deviated from the corresponding global meteoric water line (GMWL) equation (Craig 1961); that is, precipitation values are not altered by evaporation. For the more recent area, the predictions suggest water sources at a lower altitude and latitude located in places near the coast or affected by evaporation. This phenomenon may be attributed to the effect of diet on hydrogen, as well as the consumption of a water source with an excessive level of deuterium (25), probably due to evaporation or evapoperspiration. As mentioned above, the water drunk may have been previously treated by evaporation using different methods, which have consequences for its isotopic signal. An example can be the case of *chicha* consumption due to the boiling process needed for its production (Wright and Schwarcz 1998).

Table 2 presents the monthly and annual predictions of stable isotope values for water in the Chuscha and Cusco regions. It can be deduced that both sites suffer significant seasonal variations, but in a similar order. The values for Chuscha tend to be lower for most of the year than those for Cusco, which has a smaller amplitude. Because δ^{18}O values are not as strongly affected by the diet as δ^2H, the comparison is restricted to this marker. Thus, it can be seen that the δ^{18}O values in both locations coincide with the two regions observed in the hair: distal (−12.3‰) and proximal (−10.5‰). Therefore, it is difficult to attribute these values to any residence area or even postulate a transit between them.

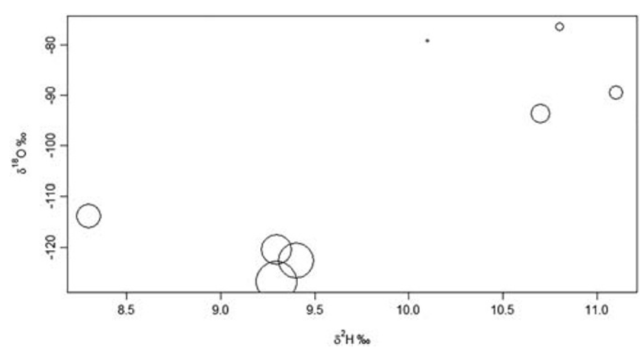

Figure 3 *Isotope values of deuterium and oxygen measured in the hair of the Chuscha girl forming two groups: the measurements in the oldest segments are represented with the largest circles and the most recent with the smallest ones.*

Table 2 *Environmental water isotope ratios estimated using the online isotopes in precipitation calculator v. 2.1 (http://waterisotopes.org) for the Chuscha and Cusco regions*

Water		*January*	*February*	*March*	*April*	*May*	*June*	*July*	*August*	*September*	*October*	*November*	*December*	*Annual*
Chuscha	δ^2H (‰)	−96.0	−114.0	−101.0	−95.0	−92.0	−79.0	−79.0	−53.0	−64.0	−71.0	−92.0	−95.0	−98.0 ± 20.0
	$\delta^{18}O$ (‰)	−14.3	−16.8	−15.3	−15.0	−14.4	−12.5	−12.4	−9.2	−10.6	−11.5	−13.6	−14.2	−15.5 ± 1.8
Cusco	δ^2H (‰)	−119.0	−126.0	−126.0	−104.0	−95.0	−69.0	−60.0	−39.0	−46.0	−62.0	−74.0	−82.0	−122.0 ± 14.0
	$\delta^{18}O$ (‰)	−16.9	−17.7	−18.6	−15.0	−13.4	−10.7	−9.3	−7.1	−7.8	−9.9	−11.5	−12.5	−17.3 ± 1.2

It is significant that oxygen and deuterium isotopic values and their variations in the hair could at least be generated by seasonal changes without moving residence. However, the high correlation of δ^2H values with δ^{13}C ones ($R^2 = 0.96$) suggests that modifications in δ^2H are associated with a shift in the diet of this individual, when it changed from a C_3 to a C_4 photosynthetic pathway (Fogel and Cifuentes 1993). Furthermore, the high correlation of carbon and deuterium isotopic values with sulfur ones ($R^2 = 0.90$ and 0.94, respectively) may be the result of change in the geographical space. Considering that the last element is conditioned by local geology, these correlations can be explained by the transit of the individual between different locations that presented differing base isotopic signals. This possibility is further reinforced by the bulk deuterium and oxygen isotopic values in two different groupings, reflected in the measurements in the oldest hair segments and the most recent ones (Fig. 3).

When considering the time of the 'events' or characteristics of the isotopic profile in this hair sample, it is significant that the greatest shift or isotopic difference between consecutive segments is identified in the same place for all the elements, except for nitrogen: the passage from the fifth (40–50 mm) to the fourth (30–40 mm) segment. It corresponds to five to six months before death, considering a growth rate of 0.8–1.3 cm/month (Sachs 1995; Robbins 2012; Lehn *et al*. 2018) and an average of a month for the isotopic signal to be evident in the hair fibre (Hüelsemann *et al*. 2009; Petzke and Lemke 2009). In the case of δ^{18}O and δ^2H values, the transition is drastic, with differences of 2.4‰ and 20‰, respectively. It is also interesting that segment 5 corresponds to the maximum δ^{15}N value and minimum δ^{18}O result. This fifth segment may be assigned to a short trip or a shift in the water consumed towards values low enough for a 1‰ displacement of δ^{18}O values in the hair. Although this segment would represent water consumption with a maximum of −13.4‰ δ^{18}O values and probably correspond to higher altitude or latitude sites, δ^2H values differed in this characterization.

Regional comparison

An aspect to be explored is the comparison of the isotopic evidence among the children and young women who participated in the *capacochas*. We wondered if there are coincidences in feeding changes such as the transit through the isotopic areas visited in the last months of their lives due to the long pilgrimage. This has previously been suggested elsewhere, arguing a possible route which would include Cusco, taking into account the Spanish chronicles and relations about the state sacrifices described (Wilson *et al*. 2007). Comparable cases with relevant information are numbered five: Sarita, recovered from Sara Sara mount in Peru; the boy from the Aconcagua, Argentina; and the three children from Llullaillaco in Salta, Argentina (Schobinger 1966; Reinhard 1998; Reinhard and Ceruti 2000; Wilson *et al*. 2007).

The observation of δ^{13}C values (Fig. 4, a) indicates that the only clear coincidence that could represent a shift in the feeding pattern is found between the adolescent sacrificed in Llullaillaco —the Maiden—and the girl from Chuscha. This result suggests that the food consumed during the pilgrimage coincides at least in these two cases. That is, there is a progressive increase in the C_4 photosynthetic pattern. In the case of the Lighting Girl—who was also found on Llullaillaco—there is a progressive and positive shift in the isotopic signal of carbon, but it remains inside the range of C_3 photosynthetic pattern resources. In the rest of the cases, there is either a small variation in the isotopic composition (the boy from Llullaillaco) or the modification is that expected for seasonal changes (the boy from Aconcagua and Sarita). In terms of δ^{15}N values (Fig. 4, b), they become progressively more positive in all individuals from Llullaillaco, although the Maiden exhibits a more dramatic shift, with a difference of about 6‰ in its last year of life. It

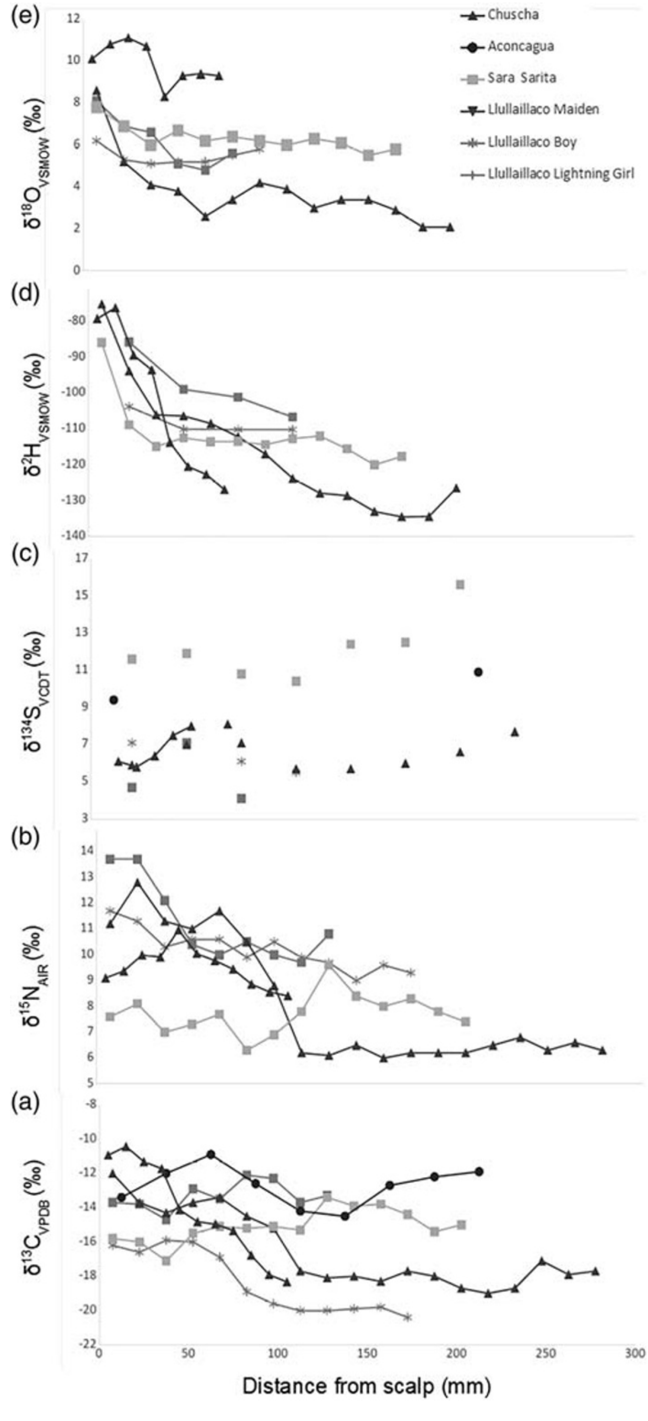

Figure 4 *Serial isotopic data from scalp hair taken from each child: Chuscha girl, Aconcagua boy, Sarita girl, Llullaillaco Maiden, Llullaillaco Boy and Llullaillaco Lightning Girl: (a)* $\delta^{13}C_{VPDB}$*; (b)* $\delta^{15}N_{AIR}$*; (c)* $\delta^{34}S_{VCDT}$*; (d)* $\delta^{2}H_{VSMOW}$ *and (e)* $\delta^{18}O_{VSMOW}$.

is not the case for Sarita or the Chuscha mummy, who showed a cyclic pattern. However, we can confirm that, except for Sarita and the boy from Aconcagua, all the individuals sacrificed consumed food with the same isotopic signal six months before dying.

As regards the truly spatial markers, we consider the δ^{34}S values (Fig. 4, c) of the two females from Llullaillaco and the girl from Chuscha (between about 7 and 8‰), corresponding to approximately six months before death. The boy from the former mount reports a lower value. The girl from Chuscha and the Maiden, in time, have coinciding values for the weeks before death. On the other hand, the values for the boy from Aconcagua and Sarita differ from those identified in this subgroup because they are considerably higher. Some elements seem to confirm that the route followed by the latter two individuals was quite different. It should be remembered that the Nevado de Sara Sara was an important sanctuary in the Cuntisuyu, the western province of the Inca Empire (Albornoz 1967), whereas the remaining cases correspond to the southern region of the empire. In terms of δ^{2}H values (Fig. 4, d), the isotopic signal tends to increase in all cases, except for the Lighting Girl from Llullaillaco. Grater similitude is found again between the individual sacrificed in Chuscha and the Maiden due to the progressive shift towards increasingly more positive values, although this coincidence is not found in δ^{18}O values (Fig. 4, e).

The data obtained explain the different life histories of the individuals sacrificed. Despite the relative importance the chronicles assign to maize as a valued resource present in Inca festivities, it does not seem to have been the dominant resource in the diet of all the individuals selected for sacrifice. Furthermore, it is not clear that there was a compulsory transit joining common geographical spaces, such as Cusco, at least during the last year before death of the children analysed. This scenario coincides with diversity in the form *capacochas* were performed. As Vitry (2008) has described, they followed less regular patterns than expected for a state religious institution.

CONCLUSIONS

The analysis of stable isotope on hair segments enhances our knowledge about the life history of the individuals who participated in fundamental events for the expansion of the Inca Empire. The ritual sacrifice of children in mountain sanctuaries has been pointed as one of the most powerful imperial strategies to build alliances and perpetuate Inca power in occupied regions. Isotopic information gains particular relevance as it explores the changes suffered by individuals in their last year of life in particularly relevant aspects for such a ritual: changes in paleodiet and long-distance mobility. In three of the five isotopic relations studied in this paper, a significant and progressive shift is detected in the values measured at the beginning and end of the sequence. These shifts would indicate different feeding patterns during the year previous to the sacrifice. However, the bulk analysis of all the isotopic systems suggests, in time, a residential change for the individual recovered from Nevado de Chuscha during the months before to death. This kind of research indicates, from a comparative perspective, that the life histories of the children and adolescents involved in the *capacochas* were different, at least regarding the ethnohistorical expectation of a compulsory visit to Cusco before starting the pilgrimage towards the sacred mounts selected for the sacrifice. This variability is indicative of the different forms power relations adopted between the centre of the empire and its periphery, since these rites may have been performed without a direct link to the Inca. However, the transit routes followed by some of these children may have coincided, such as the one presented here and the Maiden of the Llullaillaco. The study of a larger number of individuals, as well as further information in order to draw better isotope maps, would help understand the political implications of this pre-Hispanic practice.

ACKNOWLEDGEMENTS

The authors thank to Estela Ducós and Nazareno Piperizza for their collaboration in the laboratory work at INGEIS. Special thanks to Aixa Vidal for translating this paper as well as Andrés Duhour for collaboration in the elaboration of the map. This research was supported by CONICET and ANPCyT (grant number PICT 2016-3075).

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