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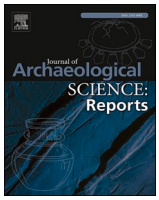

First Swiss alpine agropastoral societies: Contribution of isotope analysis to the study of their diet and mobility☆

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ABSTRACT

The aim of this study is to add new data to the knowledge of the first alpine agro-pastoral societies by studying their dietary practices and mobility. Using the principles of isotopic biogeochemistry, the stable isotope ratios of carbon (δ^{13}C), nitrogen (δ^{15}N) and sulphur (δ^{34}S) on bone collagen and strontium isotopes ($^{87}Sr/^{86}Sr$) on dental enamel were measured to discuss the diet and residence history of 49 individuals from the Middle Neolithic necropolises of Collombey-Muraz – Barmaz I and II (Valais, Switzerland). Individuals from both burial assemblages have collagen isotope values indicating a diet based on terrestrial resources with a very high consumption of animal proteins. However, the individuals from Barmaz II have consumed a nitrogen-15 enriched resource. The strontium results show that only a few individuals buried in Barmaz I show non-local values, whereas all individuals buried in Barmaz II have values similar to the environment in which they were buried. Whether in terms of diet, access to resources or mobility, no differences were observed between male and female individuals, neither in their isotopic values nor in the variability of these values. Taken all together, the results suggest the existence of a possible reserved area in the burial zone, even if coming from 'elsewhere' did not seem to have any influence on access to food resources. However, if being male or female did not seem to play an important social role in this population, it seems that it is the location of their burial that gives more information about their status. Finally, these new data, combined with previous knowledge, raise the question of whether the individuals buried at Barmaz II belonged to a group that was socially distinct from the rest of the Barmaz population.

1. Introduction

The dietary practices and mobility of human populations have always been shaped by the climatic and environmental constraints of their environment, requiring them to adapt constantly. The diversity of responses adopted by ancient populations to adapt to their environment is a direct reflection of socio-cultural processes and choices. Similarly, the way in which human populations interact with each other or within themselves is the result of social phenomena that archaeologists have long been trying to read. Isotope geochemistry has proved to be a relevant and developed tool for understanding the lifestyles and livelihoods of past populations. The routine introduction of certain isotope analyses in the 1970s led to the development of research in these areas. While most regions of Europe are now well documented, Switzerland has only recently been investigated (Moghaddam et al., 2016; Knipper et al., 2017; Varalli et al., 2021), and relatively little for the neolithic (Chiaradia et al., 2003; Desideri, 2009; Siebke et al., 2020). The combination of several isotopes makes it possible to obtain a cross-sectional view of the environment, whether for the study of diet or mobility. The information obtained from isotopic biogeochemistry can be compared with that obtained from archaeobotany and archaeozoology and allows the position of individuals in the food chain and the biotope to be determined. Finally, this study provides the first isotopic data linking diet and mobility for the Neolithic of western Switzerland. The main aim is to

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discuss the dietary habits and mobility patterns as a first step towards identifying the social and economic functioning of the first alpine agro-pastoral societies.

The Valais region is original in its environmental diversity. Situated in the heart of the Alps, it lies in the southwest of Switzerland (Fig. 1, in dark grey). With a vertical drop of 4,262 m, this mountainous region has a variety of ecosystems ranging from hilly to nival (Baudais et al., 1990). After the retreat of the glaciers more than 14′000 years ago, large alluvial fans were formed in the Rhone plain by torrents flowing down from the peaks. These accumulations form elevated areas suitable for human settlement, both in the Neolithic period and today, where many towns are still located (Corboud et al., 2008).

The Neolithic period is documented in Valais as early as 5500 BCE (Corboud et al., 2008), when the area was still very enclosed and undeveloped (Gallay, 1986; Rachoud-Schneider and Praz, 2002). Settlement sites from this period have yielded remains such as cereals, sickles, millstones, and domestic fauna, showing that the first Neolithic settlers in Valais had already mastered all the innovations associated with this period (Nicod, 2008; Besse and Von Tobel, 2011). The study of ceramics has also revealed links with the Isolino group from Varese in northern Italy (Gallay, 1986; Müller, 1995). The Neolithic therefore took hold in Valais with the arrival of pastoral farmers from northern Italy (Steuri et al., 2023), who settled particularly in the Sion region (Gallay and Corboud, 1983; Gallay et al., 2008). From 5000 BCE onwards, the large deciduous forests were gradually cleared to allow the establishment of villages and the cultivation of cereals such as barley and various types of wheat (Pignat and Crotti, 2002; Gallay et al., 2008). In addition to growing crops and raising livestock, communities continue to hunt and gather wild species, albeit on a more marginal scale (Gallay et al., 2008). There is currently little evidence of fishing in Valais.

Neolithic populations were already practicing and mastering animal husbandry when they arrived north of the Alps. In all the faunal assemblages from Neolithic archaeological sites in Valais, domestic species dominate in terms of the number of remains (Chaix, 1976; Chiquet, 2011). Livestock farming seems to have been used to satisfy dietary needs for animal protein and to provide secondary materials such as hides and bones for processing (Reynaud-Savioz, 2013). Of all the Middle Neolithic sites in Valais, domestic sheep and goats are the most represented species, accounting for 70 % of the remains attributed to them (Chaix, 2008). On a smaller scale, these communities also raise cattle and pigs (Chiquet, 2011; Honegger, 2011). Valais is unique by its economy who is dominated by production. While in the upper Rhone Valley, livestock farming dominates, this is not the case in the Swiss Plateau, where hunting is still very common, although not the majority (Reynaud-Savioz, 2013). In Valais, hunting seems to be more anecdotal and used as an opportunistic means of subsistence. Indeed, wild fauna accounts for a small proportion of the animal remains found and is represented by deer, roe deer and wild boar (Chaix, 1977; Chenal-Velarde and Chenevoix, 2011). The plant economy seems to have been based mainly on cereal production. Studies carried out at various archaeological sites in the region show that different types of wheat were cultivated on a relatively large scale. But other crops, such as barley, peas, and poppies, were also cultivated, albeit in smaller quantities. While the consumption of cultivated plants (and especially cereals) was by far the majority, gathering was still practiced (Martin and Lundström-Baudais, 2013; Martin, 2015).

For this study, two contemporary burial sites 200 m apart were selected: the Collombey-Muraz – Barmaz necropolises (Fig. 2). Known since the beginning of the 20th century and excavated in the 1950s and again in the 1990s, these two necropolises have continued to attract the interest of researchers. In fact, these two funerary areas are not only contemporary, but also close to each other. These characteristics have led researchers to try to specify the links that unite or differentiate these two human populations (Simon and Kramar, 1986; Eades, 1996; Desideri and Eades, 2002; Desideri, 2005; Abegg, 2019). These links have already been the subject of several studies, and this one completes them. Located about fifteen kilometers from Leman Lake and about one km from the Rhone River, the site rises to an altitude of 470 m on the

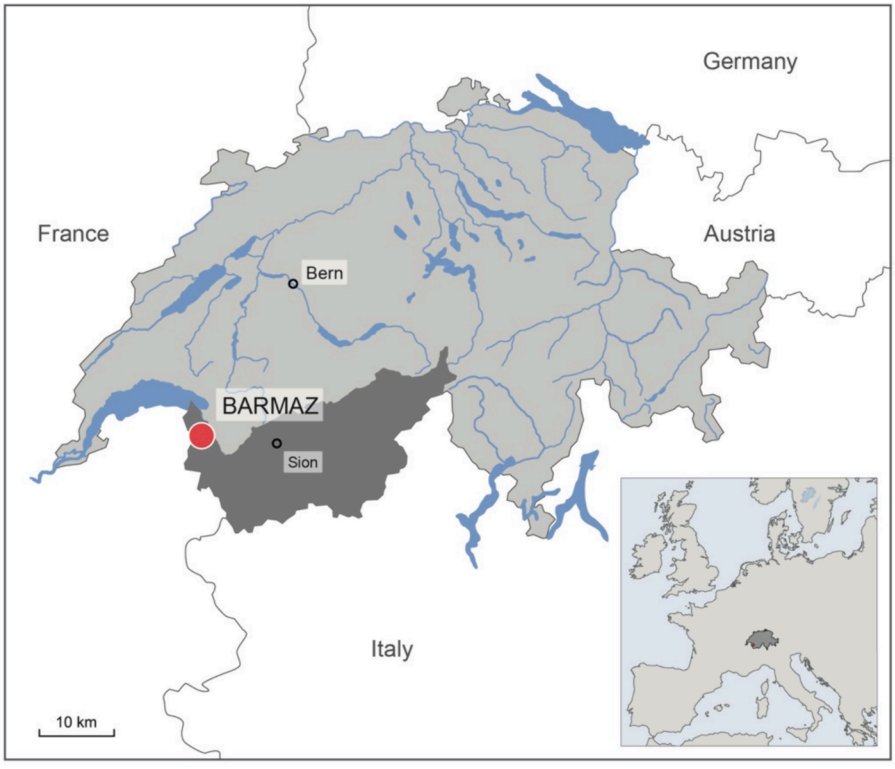

Fig. 1. Map of Switzerland with location of the Collombey-Muraz – Barmaz site situated at the entry of Alps in Valais canton (in dark grey) (Switzerland) (www.atlas-monde.net and Federal Office of Topography, modified).

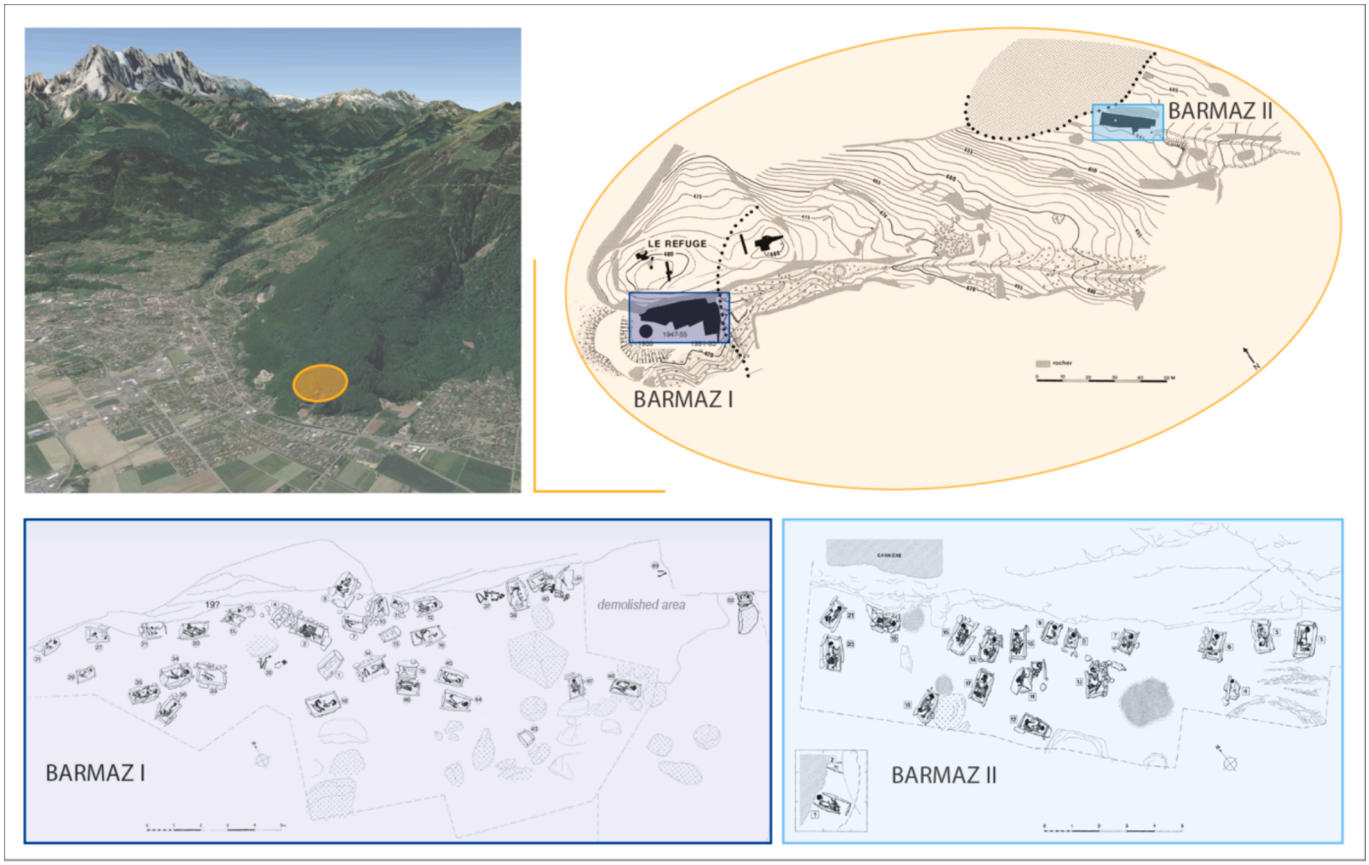

Fig. 2. In orange, the location of the site of Barmaz, looking south. It is located on the plain, at the foot of the Chablais massif, which rises to an altitude of 2500 m. The site is divided into two contemporary burial areas named Barmaz I (dark blue) and Barmaz II (light blue) (Honegger and Desideri 2003, modified).

south-western slopes of the upper Rhone valley (Fig. 2). The two areas together contain 60 graves dating from the Middle Neolithic I (Table 1).

2. Material and methods

In this research, the most used isotopic ratios to discuss the diet and mobility of ancient populations have been mobilized, i.e. measurements of $\delta^{13}C$, $\delta^{15}N$, $\delta^{34}S$ and $^{87}Sr/^{86}Sr$. The difference in isotopic composition between each link in the food chain (trophic shift) is related to the fractionation in favor of the heavy isotope and is not identical for all of them (0–1 ‰ for carbon, 3–5 ‰ for nitrogen and less than 1 ‰ for sulphur; Deniro and Epstein, 1981; Schoeninger and Deniro, 1984; Bocherens and Drucker, 2003). Analysis of carbon isotope composition ($\delta^{13}C$) provides information on the environment (e.g. marine/terrestrial, temperate/arid, closed/open) and the type of plants consumed. C_3 plants (wheat, barley, oats, etc.) are generally found in more temperate areas (Farquhar et al., 1989; Lee-Thorp, 2008). C_4 plants (maize, millet, sugar cane, etc.) are more characteristic of hot or arid environments and have more positive values than C_3 plants (O'Leary 1988; Lee-Thorp, 2008). The study of nitrogen isotopic compositions ($\delta^{15}N$) allows to discuss the trophic position of individuals and to place them in the food chain of their environment. They also reveal the consumption of marine and aquatic resources (Schoeninger and DeNiro, 1984; France, 1994). Sulphur is an environmental marker and is assimilated by plants in the form of sulphate. Terrestrial plants obtain sulphate from the soil through precipitation, whereas aquatic plants obtain it from the water. It is this difference in origin that makes $\delta^{34}S$ values highly variable in the environment (Richards et al., 2003; Nehlich, 2015). As such, this isotope is often used to differentiate between marine and terrestrial and/or freshwater resources and to highlight fish consumption. Strontium serves as a geochemical signature of the environment in which an individual lives. The isotopic signature of the rocks in an environment is reflected in the soil, in the water and thus also throughout the food chain, and finally in the skeleton, where it is recorded in the mineral fractions of bones and teeth (Hobson, 1999; Bentley, 2006). Unlike certain other isotopes, strontium is not fractionated over time or by biological processes and can be considered as a direct indicator of the local environment (Price et al., 1994).

Isotopic results and their interpretation differ depending on the part of the skeleton analyzed. Teeth are formed between birth and the end of adolescence and do not change once they have finished growing. Each tooth develops at a different rate. For example, studying the first permanent molar provides information about the first years of life, while the second and third molars relate to childhood and adolescence respectively. Bone is renewed throughout life. The rate of turnover is difficult to determine because it depends on an individual's age, sex and state of health. Furthermore, bone tissue is constantly being renewed in the same individual, but the rate can vary in each bone, depending on its

Table 1
Summary table of radiocarbon dates for the Collombey-Muraz – Barmaz necropolises, calibrated using Oxcal v4.4.4, Bronk Ramsey (2021) (after Honegger, 1995).

	Lab ID	Individual	Material	^{14}C BP	Cal ^{14}C BCE
Barmaz I	CRG763	R40	Human bone	5150 ± 80BP	4230–3714 BCE
Barmaz I	CRG750	R19	Human bone	5255 ± 120BP	4341–3798 BCE
Barmaz I	ARC411	R33	Human bone	5595 ± 60BP	4547–4337 BCE
Barmaz II	ARC409	R03	Human bone	5430 ± 110BP	4491–3989 BCE

composition – a bone with a high proportion of trabecular bone will have a higher turnover than one with a high proportion of cortical bone (Hedges et al., 2007; Schini et al., 2023). For example, the epiphyses of long bones can be completely renewed about every 6 months, whereas the diaphysis renews itself much more slowly (Marieb, 1999). The isotopic results obtained from bone are therefore considered to be an indicator of a specific moment in the last years of a person's life.

2.1. Sample studied

Before studying human values, it is essential to establish a frame of reference of local values that will help to understand the paleoeconomy and subsistence strategies of the community, as well as the environment in which the human population lived. By analyzing wild and domesticated species, it is possible to understand the environmental characteristics (altitude, arid/temperate, closed/open environment) as well as farming practices, which can strongly influence the isotopic values of domesticated animals. The isotopic data of local animals can also be used to understand the contribution of meat and dairy products to the human diet. The reference frame of this study consists of 12 faunal remains (bones and teeth) from Middle Neolithic layers contemporary with the burials, including goats, cattle, suids and deer.

The human samples comprise 32 individuals from Barmaz I and 17 from Barmaz II, whose age at death, sex and stature have been re-evaluated using recent methods (Desideri and Rosselet-Christ, forthcoming). For Barmaz I, 22 adults (8 females, 6 males and 8 undetermined sex) and 10 immatures were included, and for Barmaz II, 14 adults (9 females and 5 males) and 3 immatures were included. Given the number of individuals, and to avoid statistical bias, we have considered for discussion only an "immature" group comprising individuals aged 5 to 14 years and an "adult" group, represented by individuals aged 15 to over 60 years. Immature individuals aged less than 5 years were excluded from the sampling to avoid lactation signals. For each selected individual, a bone fragment and a tooth were sampled (Fig. 3). To study the diet, the isotope ratios $\delta^{13}C$, $\delta^{15}N$ and $\delta^{34}S$ were measured on the bone collagen, recording the protein intake of the diet during the last years of life. Where possible, the same bone was selected to avoid comparing values from bones with different turnover (see above). So, the analyses were mainly carried out on the humerus, which was the most represented and best-preserved bone. In its absence, the radius was sampled (n = 3), but on two occasions it was done on another bone: a femur (BAIR14a) and an unidentified long bone (BAIR15) (Table 2). To investigate mobility, analyses were performed on the hydroxyapatite from second molar enamel whenever possible. Where this was not possible, two samples from a canine (BAIR19 and BAIIR10) and one from a first incisor (BAIR17) were selected (Table 2). For the second molars, samples were taken from the best-preserved cusp corresponding to development between 2.5 and 5.5 years of age (AlQahtani et al., 2010). For the canine samples, this period is between 1 and 4 years and for first incisor between 3.5 and 5.5 years (AlQahtani et al., 2010). Strontium values will be indicative of the childhood, which will allow the identification of individuals who spent the first years of their lives in the environment in which they were buried.

2.2. Laboratory procedure

2.2.1. Bone collagen extraction procedure

Collagen extractions from all human and animal remains were carried out at LAMPEA (UMR 7269, Aix-en-Provence, France) and isotope ratios measured by EA-IRMS analysis at the Iso-Analytical Limited Laboratory (Cheshire, UK). Collagen was extracted using Longin (1971) method (see supplementary material §2.2).

2.2.2. Enamel preparation for strontium analyses

Sample preparation for the strontium study was carried out at the University of Geneva (see supplementary material §2.2). Strontium ratios were measured using a Thermo-ionization Mass Spectrometer (TIMS) at the Department of Geosciences, University of North Carolina (USA).

3. Results

3.1. Reliability of results

Collagen preservation was monitored by assessing collagen extraction yield (≥10 mg/g = 1 %), C, N and S percentages (%C ≥ 30 %, %N ≥ 10 % and %S ≥ 0.15 %), and C:N, C:S and N:S atomic ratios (2.9 < C:N < 3.6, C:S = 600 ± 300 and N:S = 200 ± 100) (Ambrose, 1990; DeNiro, 1985; Nehlich and Richards, 2009; van Klinken, 1999) (see supplementary material Tab. 1, Fig. 1). All the samples met the required quality criteria, apart from one goat (BAI AA), which had been selected to measure the values of the local environment. As it did not meet the required minimum yield, this sample was excluded from the reference group.

In order to verify that the isotopic variations observed were not related to a diagenetic effect, the data were subjected to correlation tests (Pearson linear correlation with Bonferroni corrections) and no correlation was observed between extraction yield and isotopic abundances or between carbon and nitrogen percentages and isotopic abundances (see supplementary material Tabs. 2–3 and Figs. 2-3). The data obtained do not show variations due to diagenetic effects of the burial conditions and can therefore be used for the study.

3.2. Dietary study

3.2.1. Environmental background

The local reference for the study of diet consists of 2 cattle, 2 suids, 1 deer and 1 goat (Table 3).

The fauna isotopic ratios $\delta^{13}C$ range from −21.6 ‰ to −20.6 ‰ with slightly more negative values for omnivores than for herbivores. Values of $\delta^{15}N$ range from 3.8 ‰ to 5.9 ‰ with higher values for omnivores. Values of $\delta^{34}S$, meanwhile, are scattered between −1.1 ‰ and 6.1 ‰ with no difference between groups.

3.2.2. Human data

The isotopic data show an average $\delta^{13}C$ of −20.7 ± 0.4 ‰ (values between −21.6 ‰ and −19.8 ‰), an average $\delta^{15}N$ of 8.7 ± 0.7 ‰ (values between 6.9 ‰ and 10.4 ‰) and an average $\delta^{34}S$ of 1.1 ± 2 ‰

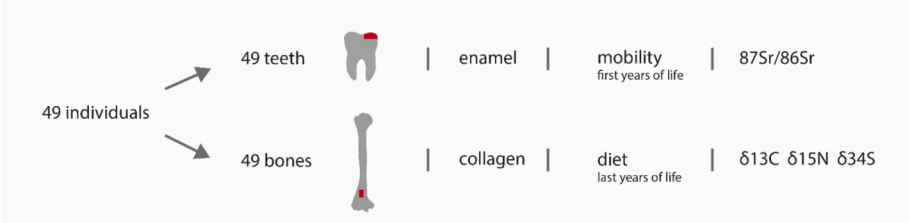

Fig. 3. Summary of human samples, tissue types and isotopes selected.

Table 2
Human remains analyzed with their biological identities (abbreviations: n.d. = not determinable, M = molar, I = incisor, C = canine, R = right, L = left).

Sample	Sex	Age (y. o.)	Age group	Bone sampled	Tooth sampled
BAI R02	male	> 40	adult	humerus R	M_2 R
BAI R04	n.d.	10–12	immature	humerus R	M_2 L
BAI R07A	n.d.	12–14	immature	humerus R	M_2 L
BAI R08A	n.d.	15–17	adult	humerus L	M_2 L
BAI R12A	male trend	< 60	adult	humerus R	M_2 L
BAI R14A	n.d.	n.d.	adult	femur R	M_2 L
BAI R15	n.d.	4–7	immature	long bone	M^2 L
BAI R16A	female	20–29	adult	humerus R	M_2 L
BAI R17B	n.d.	4–6	immature	humerus L	I_1 L
BAI R18	male	> 30	adult	humerus R	M_2 L
BAI R19	n.d.	14–17	adult	radius R	C_R
BAI R20	n.d.	> 40	adult	humerus L	M_2 L
BAI R21	n.d.	6–10	immature	humerus R	M_2 L
BAI R27	n.d.	7–10	immature	radius n.d.	M_2 L
BAI R29A	n.d.	7–9	immature	humerus R	M_2 L
BAI R31	n.d.	5.5–7.5	immature	humerus L	M_2 L
BAI R32	n.d.	n.d.	adult	humerus R	M_2 L
BAI R33A	n.d.	n.d.	adult	radius L	M_2 L
BAI R34A	female trend	n.d.	adult	humerus R	M_2 R
BAI R35	female trend	n.d.	adult	humerus L	M_2 L
BAI R36	female	< 60	adult	humerus L	M_2 L
BAI R37A	female	< 60	adult	humerus R	M^2 R
BAI R38A	female	> 60	adult	humerus L	M_2 R
BAI R38B	n.d.	6–8	immature	humerus L	M_2 R
BAI R40A	male	> 40	adult	humerus R	M_2 L
BAI R41	n.d.	n.d.	adult	humerus n. d.	M_2 L
BAI R44A	female	n.d.	adult	humerus R	M_2 L
BAI R45A	male trend	30–60	adult	humerus L	M_2 L
BAI R46	female trend	> 50	adult	humerus L	M_2 L
BAI R47	n.d.	7–9	immature	humerus L	M_2 L
BAI R48A	male trend	> 40	adult	humerus L	M_2 R
BAI R49	n.d.	n.d.	adult	humerus L	M_2 R
BAII R01A	female	20–39	adult	humerus L	M_2 L
BAII R03	female	> 26	adult	humerus L	M_2 L
BAII R05	female	> 30	adult	humerus L	M^2 R
BAII R06	n.d.	10–14	immature	humerus R	M_2 L
BAII R07	n.d.	7–9	immature	humerus L	M_2 L
BAII R09	n.d.	5.5–7.5	immature	humerus R	M_2 L
BAII R10	female	> 30	adult	humerus R	C_L
BAII R11A	male	> 40	adult	humerus L	M_2 L
BAII R12	female	15–20	adult	humerus L	M_2 L
BAII R13A	female	> 40	adult	humerus L	M_2 L
BAII R14	female	18–26	adult	humerus L	M_2 L
BAII R15	female	< 60	adult	humerus R	M_2 R
BAII R17	male	20–29	adult	humerus L	M_2 L
BAII R18	male	20–29	adult	humerus R	M_2 L
BAII R19	male	26–39	adult	humerus L	M_2 L
BAII R20	male	30–60	adult	humerus R	M_2 L
BAII R21	female	< 60	adult	humerus R	M_2 L

(values between −3.1 ‰ and 4.9 ‰) (Table 4). The values of $\delta^{13}C$, $\delta^{15}N$ and $\delta^{34}S$ show a difference between the lowest and the highest (Δ) of 1.8 ‰, 3.5 ‰ and 8 ‰ respectively. The values of $\delta^{13}C$ and $\delta^{15}N$ are positively correlated and thus mark the trophic level of the individuals. The $\delta^{15}N$ and $\delta^{34}S$ are also positively correlated. The higher the $\delta^{15}N$ values, the higher the $\delta^{34}S$ values. A significant enrichment in ^{13}C, ^{15}N and a significant depletion in ^{34}S are observed between omnivore and human values (Mann-Whitney; $p = 0.0117$; 0.0001 and 0.046). The values show, an average increase in $\delta^{13}C$ of 0.3 ‰ between herbivores and humans and 0.8 ‰ between omnivores and humans. The increase in $\delta^{15}N$ is 4.5 ‰ between herbivores and humans and 3 ‰ between omnivores and humans. The $\delta^{34}S$, on the other hand, shows a decrease of 1.2 ‰ between herbivores and humans and of 3.5 ‰ between omnivores and humans (Table 5).

3.3. Mobility study

3.3.1. Environmental background

The 5 faunal samples have $^{87}Sr/^{86}Sr$ values ranging from 0.708193 to 0.709711 with an average of 0.708938 ± 0.0007 (Table 6). The values show a high degree of homogeneity, with no differences between the sampled species. It is therefore possible to define a range of local values that could correspond to a limited geographical area around the site. This local variation, calculated from the mean of the values obtained and the mean of the standard deviations (Kjällquist and Price, 2019), is between 0.708218 and 0.709658 (Fig. 4).

3.3.2. Human data

A fragment of dental enamel was taken from each individual (n = 49), which made it possible to obtain information from childhood. The approach is to compare the data from the local framework with the values obtained from the second molars of the population to determine the local or exogenous origin of the human population of Barmaz (Fig. 5).

The strontium isotope signatures of all the Barmaz individuals range from 0.708080 to 0.713098, with 0.708228 and 0.713098 respectively for Barmaz I and 0.708080 to 0.709513 for Barmaz II (Table 7). However, most of the values for the two areas are between 0.708000 and 0.70950, which are values defined as local (based on the faunal reference). A comparison of the medians of the two areas shows a significant difference between their $^{87}Sr/^{86}Sr$ values (Mann-Whitney, $p = 0.031$). This result can also be seen graphically. Only a few individuals buried in Barmaz I show non-local values, whereas all individuals buried in Barmaz II have similar values to the environment in which they were buried (Fig. 5). The seven individuals whose isotopic signatures are clearly out of range (BAIR16a, BAIR19, BAIR35, BAIR38a, BAIR40a, BAIR41 and BAIR45) are aged between 15 and 60 years old, with no young children showing non-local values.

4. Discussion

4.1. Environment and resources

The $\delta^{13}C$ values are homogeneous and representative of mammals from a terrestrial, open, and temperate environment with C_3 photosynthetic plants, typical of these regions. The suids $\delta^{13}C$ values are low and closer to those expected for wild fauna evolving in more closed environments (Farquhar et al., 1989). However, these values remain within known standards for adjacent regions where the climate can be relatively cold (Goude and Fontugne, 2016). The $\delta^{15}N$ data are more scattered and, as expected, two groups of trophic levels stand out. The first, herbivores, show the lowest $\delta^{15}N$ values, as expected for consumers of exclusively plant proteins. The second group, omnivores, is represented by suids and shows higher nitrogen values suggesting the consumption of both plant and animal proteins. The isotopic results for the fauna show a relatively high interspecific dispersion and significant

Table 3
Isotope ratios $\delta^{13}C$, $\delta^{15}N$, $\delta^{34}S$ of animal bone collagen.

Sample	Species	Age group	Trophic level	C (%)	$\delta^{13}C$ (‰)	N (%)	$\delta^{15}N$ (‰)	S (%)	$\delta^{34}S$ (‰)
BAI A	*Bos taurus*	adult	herbivore	42.1	−21.2	15.6	4.6	0.18	5.2
BAI B	*Bos taurus*	adult	herbivore	41.8	−21.0	15.5	3.9	0.18	−1.1
BAI C	*Cervus elaphus*	adult	herbivore	36.7	−21.0	13.5	3.8	0.16	3.1
BAI D	*O. aries/C. hircus*	adult	herbivore	42.7	−20.6	15.0	4.3	0.18	2.2
BAI E	*Sus domesticus*	adult	omnivore	39.4	−21.6	14.7	5.9	0.18	6.1
BAI F	*Sus domesticus*	adult	omnivore	42.4	−21.4	15.6	5.4	0.20	3.1

Table 4
$\delta^{13}C$, $\delta^{15}N$ and $\delta^{34}S$ values of human bone collagen from Barmaz I and II burials.

Sample	Sex	Age (y.o.)	Age group	C (%)	$\Delta^{13}C$ (‰)	N (%)	$\Delta^{15}N$ (‰)	S (%)	$\Delta^{34}S$ (‰)
BAI R02	male	> 40	adult	42.6	−21.2	15.0	8.7	0.22	2.4
BAI R04	n.d.	10–12	immature	40.5	−20.6	15.0	8.1	0.21	4.6
BAI R07A	n.d.	12–14	immature	39.0	−21.1	14.5	7.9	0.19	0.6
BAI R08A	n.d.	15–17	adult	43.6	−20.4	16.3	8.0	0.19	−0.3
BAI R12A	male trend	< 60	adult	38.9	−20.2	14.6	8.9	0.17	1.2
BAI R14A	n.d.	n.d.	adult	34.7	−21.0	12.7	8.5	0.19	1.2
BAI R15	n.d.	4–7	immature	42.5	−21.0	15.7	8.0	0.23	−0.1
BAI R16A	female	20–29	adult	43.5	−20.6	16.0	8.6	0.25	1.1
BAI R17B	n.d.	4–6	immature	42.2	−21.4	15.6	8.9	0.22	1.5
BAI R18	male	> 30	adult	43.7	−20.4	16.2	8.4	0.21	−0.8
BAI R19	n.d.	14–17	adult	42.9	−20.9	15.8	8.5	0.22	1.9
BAI R20	n.d.	> 40	adult	41.0	−20.9	15.4	8.3	0.18	2.0
BAI R21	n.d.	6–10	immature	43.1	−20.6	16.0	8.5	0.21	0.1
BAI R27	n.d.	7–10	immature	40.5	−21.1	15.0	7.6	0.20	0.2
BAI R29A	n.d.	7–9	immature	42.9	−20.6	15.8	7.8	0.22	0.7
BAI R31	n.d.	5.5–7.5	immature	43.0	−21.1	15.9	6.9	0.21	−1.7
BAI R32	n.d.	n.d.	adult	42.7	−20.6	15.8	8.8	0.20	4.1
BAI R33A	n.d.	n.d.	adult	42.0	−20.9	15.3	10.1	0.22	3.4
BAI R34A	female trend	n.d.	adult	42.4	−20.9	15.6	8.7	0.20	2.0
BAI R35	female trend	n.d.	adult	39.4	−20.6	14.7	9.2	0.19	2.8
BAI R36	female	< 60	adult	41.8	−20.8	15.5	8.6	0.20	0.6
BAI R37A	female	< 60	adult	42.2	−20.6	15.6	9.0	0.20	0.8
BAI R38A	female	> 60	adult	41.0	−20.9	14.7	8.1	0.19	−2.6
BAI R38B	n.d.	6–8	immature	43.6	−20.9	16.1	8.2	0.21	−2.9
BAI R40A	male	> 40	adult	42.0	−20.9	14.4	8.1	0.25	−1.9
BAI R41	n.d.	n.d.	adult	41.1	−20.3	15.2	9.1	0.21	0.5
BAI R44A	female	n.d.	adult	43.0	−20.6	16.0	8.4	0.21	−0.7
BAI R45A	male trend	30–60	adult	43.1	−20.3	16.0	9.3	0.21	−1.1
BAI R46	female trend	> 50	adult	34.4	−20.6	12.4	8.5	0.16	1.3
BAI R47	n.d.	7–9	immature	39.1	−21.4	13.8	8.4	0.19	1.8
BAI R48A	male trend	> 40	adult	41.4	−20.5	15.0	9.1	0.17	1.3
BAI R49	n.d.	n.d.	adult	42.3	−20.7	15.7	8.9	0.19	−1.2
BAII R01A	female	20–39	adult	42.6	−21.3	15.9	8.7	0.22	2.5
BAII R03	female	> 26	adult	38.3	−20.7	13.9	9.2	0.27	1.7
BAII R05	female	> 30	adult	35.3	−19.9	13.2	8.6	0.16	1.5
BAII R06	n.d.	10–14	immature	36.9	−20.3	13.4	9.7	0.19	2.1
BAII R07	n.d.	7–9	immature	37.0	−21.6	13.7	9.3	0.23	4.9
BAII R09	n.d.	5.5–7.5	immature	42.1	−20.7	15.7	8.4	0.20	3.4
BAII R10	female	> 30	adult	40.5	−20.4	15.1	8.8	0.17	4.1
BAII R11A	male	> 40	adult	43.4	−20.4	16.1	8.8	0.19	3.2
BAII R12	female	15–20	adult	33.7	−21.2	12.5	9.2	0.18	3.8
BAII R13A	female	> 40	adult	38.0	−20.7	13.8	8.7	0.19	0.8
BAII R14	female	18–26	adult	40.2	−19.8	15.0	10.4	0.18	−0.1
BAII R15	female	< 60	adult	41.8	−20.0	15.6	8.8	0.20	−3.1
BAII R17	male	20–29	adult	42.6	−20.3	15.8	10.4	0.21	2.6
BAII R18	male	20–29	adult	40.7	−20.7	15.2	9.5	0.21	4.5
BAII R19	male	26–39	adult	41.1	−19.9	15.2	9.5	0.21	−0.1
BAII R20	male	30–60	adult	33.0	−20.3	12.3	9.3	0.16	2.9
BAII R21	female	< 60	adult	42.4	−20.2	15.8	9.2	0.20	−1.6

heterogeneity in $\delta^{15}N$ and $\delta^{34}S$ values ($\Delta^{15}N = 2.1$ ‰, $\Delta^{13}C = 1$ ‰ and $\Delta^{34}S = 7.2$ ‰). The small numbers of each animal species make it impossible to define their diet, but it is possible to identify some elements, particularly a rather homogeneous diet based on C_3 plants for herbivores, whereas the diet of suids seems to be more heterogeneous. Although suids are omnivores, their diet was relatively rich in plants, but with a proportion of a nitrogen-15 enriched resource. These higher $\delta^{15}N$ values may be related to the feeding method, given that these are domestic animals. For example, the use of manure on crops, particularly for forage, can lead to a significant enrichment in ^{15}N and thus confuse signals in the rest of the food chain (Bogaard et al., 2007). The use of manure in Neolithic agricultural activities is already well documented in other border regions and is often mobilized for very specific plant species or in a restricted space (Bogaard et al., 2013; Goude and Fontugne, 2016). However, one does not exclude the other, these high levels of $\delta^{15}N$ could also result from the consumption of food scraps (rather animal in this case) from the table of humans, suggesting a certain proximity between the village and the territory of domestic suids. In both

Table 5
Statistical parameters for $\delta^{13}C$, $\delta^{15}N$ and $\delta^{34}S$ values of human, herbivores, and omnivores bone collagen (abbreviations: n = number of individuals, min = minimal value, max = maximal value, sd = 2σ standard deviation, med = median).

	n	$\delta^{13}C$ min	$\delta^{13}C$ max	$\delta^{13}C$ mean ± sd	$\delta^{13}C$ med.	$\delta^{15}N$ min	$\delta^{15}N$ max	$\delta^{15}N$ mean ± sd	$\delta^{15}N$ med	$\delta^{34}S$ min	$\delta^{34}S$ max	$\delta^{34}S$ mean ± sd	$\delta^{34}S$ med
Humans	49	−21.6	−19.8	−20.7 ± 0.4	−20.6	6.9	10.4	8.7 ± 0.7	8.7	−3.1	4.9	1.1 ± 2	1.2
female	17	−21.3	−19.8	−20.6 ± 0.4	−20.6	8.1	10.4	8.9 ± 0.5	8.7	−3.1	4.1	0.9 ± 4.1	4.1
male	11	−21.2	−19.9	−20.5 ± 0.4	−20.4	8.1	10.4	9.1 ± 0.6	9.1	−1.9	4.5	1.3 ± 2	1.3
immature	13	−21.6	−20.3	−21 ± 0.4	−21	6.9	9.7	8.3 ± 0.7	8.2	−2.9	4.9	1.2 ± 2.3	0.7
Herbivores	4	−21.2	−20.6	−21 ± 0.3		3.8	4.6	4.2 ± 0.4		−1.1	5.2	2.3 ± 2.6	
Omnivores	2	−21.6	−21.4	−21.5 ± 0.1		5.4	5.9	5.7 ± 0.3		3.1	6.1	4.6 ± 2.1	

Table 6
Isotope ratios $^{87}Sr/^{86}Sr$ from the dental enamel of the fauna selected for the local frame of reference (abbreviation: sd = 2σ standard deviation).

Sample	Species	Age group	$^{87}Sr/^{86}Sr$	± sd
BAI G	*Ovis aries/Capra hircus*	adult	0.708579	0.0007
BAI H	*Ovis aries/Capra hircus*	adult	0.708689	0.0007
BAI I	*Bos taurus*	adult	0.708193	0.0006
BAI J	*Ovis aries/Capra hircus*	adult	0.709711	0.0009
BAI K	*Cervus elaphus*	adult	0.709515	0.0007

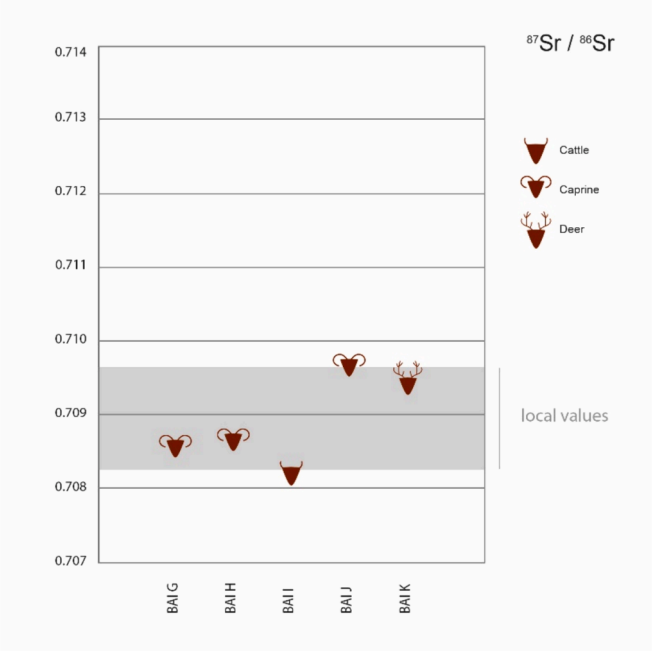

Fig. 4. Distribution of $^{87}Sr/^{86}Sr$ values for the local environment frame of reference, with local boundaries in grey.

cases, they benefited from a different feeding/farming strategy from the other domestic species.

While the difference in $\delta^{15}N$ between suids and the rest of the fauna may be due to a different diet, the difference in sulphur (which is not linked to a species) suggests that the fauna evolved in different environments, in particular more or less close to water (Nehlich, 2015). The small sample size makes it difficult to investigate this hypothesis further, but the difference in environment does not seem to be linked to the farming conditions of a particular species. Siebke et al. (2020) have shown that $\delta^{34}S$ values may vary a lot across Switzerland, with high values in the north (Jura region), intermediate values on the Plateau (north of the Alps) and low values in the Alps. We suggest that the answer may lie in the fact that these animals belonged to small human populations living in slightly different environments, probably around the region of Barmaz.

4.2. Human dietary patterns

4.2.1. What they ate

The differences between the $\delta^{13}C$ values of fauna and humans are characteristic of the expected trophic shift (+0 ‰ to +1 ‰) within a similar photosynthetic C_3-type environment (DeNiro and Epstein, 1978). Similarly, the average herbivore-human and omnivore-human trophic shifts are in the expected range, between 3 ‰ and 5 ‰ (Fig. 6) (DeNiro and Epstein, 1981). Thus, they appear to derive their total protein intake from the environment (broadly defined) in which they evolved.

In the Valais, archaeological studies of Middle Neolithic sites have shown the predominance of the consumption of domestic species, mainly goats and cattle, as well as *suidae*, although to a lesser extent (Chaix, 1976; Chiquet, 2011; Chiquet and Reynaud Savioz 2019). The isotopic results largely show that the diet of the Barmaz population was based on a high proportion of animal proteins. This was particularly true for proteins from herbivores. However, the data also indicate that proteins from omnivores, such as *suidae*, appear to be a resource that should not be underestimated. Although the isotopic data are consistent with the archaeological data, it is difficult to estimate the proportion consumed of each species, and individuals with the highest nitrogen values may be consuming an unidentified resource. Depending on the environment and archaeological knowledge, two hypotheses are possible: either the consumption of freshwater products from the river or the lake, or the consumption of meat from young animals with enriched values and therefore a higher trophic level than adults of the same species (shift due to suckling juveniles) (e.g. Balasse et al., 2000).

The main challenge is the characterization of the consumption of freshwater resources, since the isotopic variability can be very high, making it necessary to have an isotopic reference geochronologically close to the population studied. Unfortunately, few ichthyofaunal remains and no archaeological remains related to fishing have been discovered in this region. However, although freshwater resources are rarely the main source of protein, numerous isotopic studies carried out on Neolithic populations have revealed values that could indicate the consumption of this resource, particularly in the south and north of France (Goude et al., 2013; Rey et al., 2017), as well as in Belgium (Bocherens et al., 2007) and Germany (Dürrwächter et al., 2006). Recent work by Cheung et al. (2021) even suggests that it could be introduced as early as infancy, in the weaning diet. More locally, the work of Siebke et al. (2020) shows that protein intake from freshwater resources has been suggested for Neolithic populations in northern Switzerland. In the region of Barmaz, where the proximity of Lake Leman and the Rhone River ensures the availability of freshwater resources, its consumption may reflect a more 'personal' choice, or a more opportunistic means of obtaining the resources needed for survival. However, in line with previous archaeological studies, it does not appear that the Middle Neolithic populations of this region often resorted to hunting practices.

The other resource that can increase nitrogen isotopic compositions could be the consumption of unweaned animals, which generally have higher $\delta^{13}C$ and $\delta^{15}N$ values than their mothers (e.g. Balasse et al., 2000). This hypothesis leads to the consumption of a resource before it has reached its maximum yield, which implies different herd

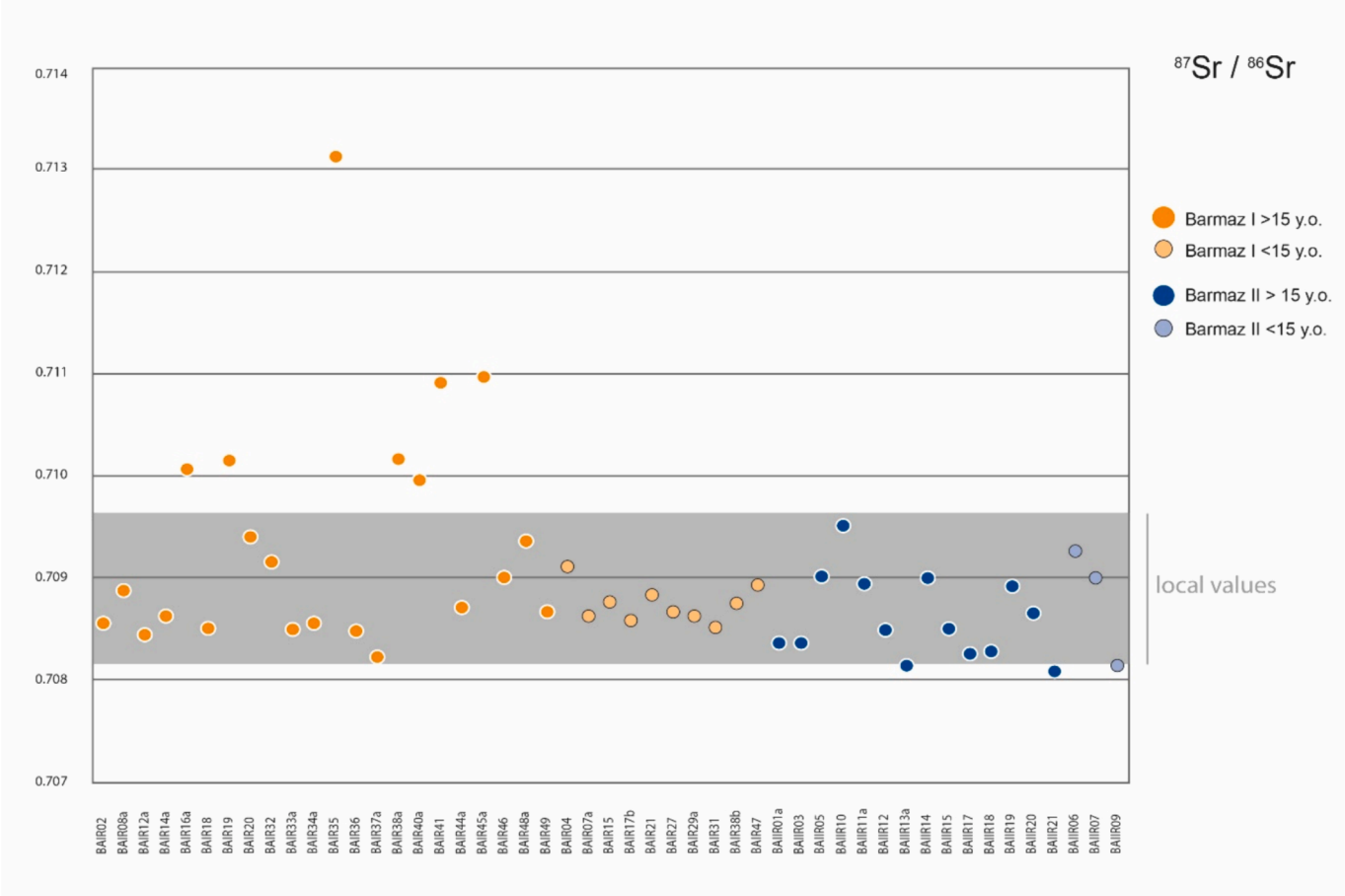

Fig. 5. Graphical representation of the $^{87}Sr/^{86}Sr$ values of the dental enamel of individuals of Barmaz I and II. In grey, the values considered as local.

management and an impact on the individuals dependent on the herd. Several archaeozoological studies show slaughter profiles that include many individuals that are only a few months old and still breastfed (Chenal-Velarde and Chenevoix, 2011; Vigne, 2012). Chenal-Velarde and Chenevoix (2011) interpret the slaughter of very young animals as a desire to consume better quality meat at the expense of the animal's yield. However, the main reason given by Vigne (2012) is that the slaughter of suckled animals allows the dairy farm to continue to benefit from the milk of their mothers. Moreover, it is currently difficult to refine the discussion without further analysis of these resources. Furthermore, as the consumption of one does not exclude the consumption of the other, the use of isotopic geochemistry on different collagen amino acids could complete the answers (e.g. Cheung et al., 2021; Rey et al., 2022).

The plant diet is more difficult to characterize from the results, mainly due to the lack of a regional and contemporary plant isotopic reference. However, as expected, the plants consumed are represented exclusively by photosynthetic C3 species, while C4 plants have only been documented in this region since the end of the Bronze Age (Varalli et al., 2021). Although a diet without plant protein is inconceivable, its consumption may have been low compared to the animal component, a recurring phenomenon in many populations from this period (Goude and Fontugne, 2016; Rey et al., 2017). The only exceptions are a few individuals under 15 years, who emerged from the group with slightly more negative $\delta^{13}C$ (and sometimes $\delta^{15}N$) values, suggesting a higher plant intake. Thus, while the importance of plant production is undeniable (Baudais, 1994; Lundström-Baudais and Martin, 2011; Martin and Lundström-Baudais, 2013; Martin, 2015), the methods and protagonists involved in its consumption need to be better defined. The contribution of an isotopic reference system for the plant spectrum would make it possible to understand both agricultural and livestock strategies (Gavériaux et al., 2022), with perhaps a significant proportion dedicated not to humans but to livestock.

4.2.2. How they ate

The $\delta^{13}C$, $\delta^{15}N$ and $\delta^{34}S$ values of individuals from Barmaz I and II were compared in two steps. First, by testing the whole of the two groups ($n = 49$), then by testing only adults ($n = 36$), to avoid bias linked to the demographic profile of two areas, with Barmaz I containing a larger number of children. The isotopic composition distributions of $\delta^{13}C$ versus $\delta^{15}N$, $\delta^{34}S$ versus $\delta^{13}C$ and $\delta^{34}S$ versus $\delta^{15}N$ are shown in Fig. 7a-c. Comparison of the medians of the two groups shows that individuals in Barmaz II have higher and significantly different $\delta^{13}C$, $\delta^{15}N$ and $\delta^{34}S$ values than those in Barmaz I (Mann-Whitney $p = 0.032$; 0.0002; 0.0215). On the other hand, when immature were excluded from the tests, the $\delta^{13}C$ and $\delta^{15}N$ were still significantly different between the two groups. In general, it appears that individuals from Barmaz II either have better access to animal protein or consume a different resource that enriched their isotope ratios. It should also be noted that two individuals with very high $\delta^{13}C$ and $\delta^{15}N$ values are buried at Barmaz II (BAIIR14 and BAIIR17), one male and one female, both aged between 20 and 29 years old and buried next to each other. The consumption of a similar nitrogen-enriched resource and their proximity in death raises the question of the social or family link that may have united these individuals during their lives. Further analyses (aDNA and radiocarbon dating) will be carried out shortly.

A comparison of the medians of $\delta^{13}C$, $\delta^{15}N$ and $\delta^{34}S$ isotope values of male and female individuals shows no significant difference (Mann-Whitney $p = 0.3138$; 0.1782; 0.6038). Similarly, within groups there were no significant differences between male and female individuals.

Table 7
$^{87}Sr/^{86}Sr$ values of the dental enamel of individuals of Barmaz I and II (see Tab. 2 for the type of tooth sampled) (abbreviation: SD = 2σ standard deviation).

Sample	Sex	Age (y.o.)	Age group	$^{87}Sr/^{86}Sr$	± sd
BAI R02	male	> 40	adult	0.70855	0.0007
BAI R04	n.d.	10–12	immature	0.70912	0.0008
BAI R07A	n.d.	12–14	immature	0.70865	0.0007
BAI R08A	n.d.	15–17	adult	0.70889	0.0007
BAI R12A	male trend	< 60	adult	0.70845	0.0007
BAI R14A	n.d.	n.d.	adult	0.70863	0.0007
BAI R15	n.d.	4–7	immature	0.70878	0.0007
BAI R16A	female	20–29	adult	0.71007	0.0008
BAI R17B	n. d.	4–6	immature	0.70858	0.0008
BAI R18	male	> 30	adult	0.70852	0.0008
BAI R19	n.d.	14–17	adult	0.71016	0.0007
BAI R20	n.d.	> 40	adult	0.70941	0.0007
BAI R21	n.d.	6–10	immature	0.70884	0.0007
BAI R27	n.d.	7–10	immature	0.70867	0.0007
BAI R29A	n.d.	7–9	immature	0.70863	0.0006
BAI R31	n.d.	5.5–7.5	immature	0.70852	0.0007
BAI R32	n.d.	n.d.	adult	0.70916	0.0007
BAI R33A	n.d.	n.d.	adult	0.70850	0.0006
BAI R34A	female trend	n.d.	adult	0.70856	0.0007
BAI R35	female trend	n.d.	adult	0.71310	0.0007
BAI R36	female	< 60	adult	0.70848	0.0007
BAI R37A	female	< 60	adult	0.70823	0.0007
BAI R38A	female	> 60	adult	0.71016	0.0007
BAI R38B	n.d.	6–8	immature	0.70876	0.0007
BAI R40A	male	> 40	adult	0.70995	0.0008
BAI R41	n.d.	n.d.	adult	0.71090	0.0008
BAI R44A	female	n.d.	adult	0.70871	0.0006
BAI R45A	male trend	30–60	adult	0.71096	0.0007
BAI R46	female trend	> 50	adult	0.70900	0.0008
BAI R47	n.d.	7–9	immature	0.70893	0.0007
BAI R48A	male trend	> 40	adult	0.70935	0.0006
BAI R49	n.d.	n.d.	adult	0.70867	0.0006
BAII R01A	female	20–39	adult	0.70836	0.0007
BAII R03	female	> 26	adult	0.70835	0.0008
BAII R05	female	> 30	adult	0.70901	0.0006
BAII R06	n.d.	10–14	immature	0.70925	0.0007
BAII R07	n.d.	7–9	immature	0.70900	0.0007
BAII R09	n.d.	5.5–7.5	immature	0.70814	0.0007
BAII R10	female	> 30	adult	0.70951	0.0007
BAII R11A	male	> 40	adult	0.70893	0.0007
BAII R12	female	15–20	adult	0.70849	0.0007
BAII R13A	female	> 40	adult	0.70814	0.0007
BAII R14	female	18–26	adult	0.70899	0.0007
BAII R15	female	< 60	adult	0.70850	0.0007
BAII R17	male	20–29	adult	0.70825	0.0006
BAII R18	male	20–29	adult	0.70828	0.0007
BAII R19	male	26–39	adult	0.70892	0.0007
BAII R20	male	30–60	adult	0.70864	0.0008
BAII R21	female	< 60	adult	0.70808	0.0007

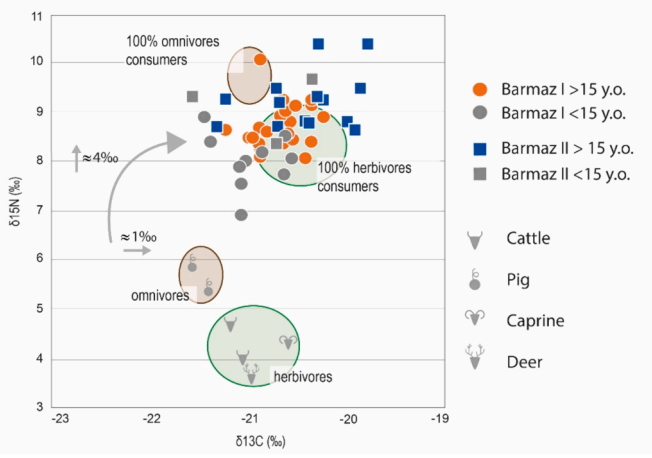

Fig. 6. Theoretical shifts and distribution of $\delta^{13}C$ and $\delta^{15}N$ values for all Barmaz individuals.

Thus, unlike other similar studies of Neolithic burials (Goude et al., 2014; Siebke et al., 2020), the Barmaz population appears to have drawn its protein resources from a similar environment, with the same access to resources for adults, whether male or female.

Several individuals, mostly children aged between 5 and 9 years old and buried at Barmaz I, have lower $\delta^{13}C$ values, suggesting an effect of the consumption of omnivorous proteins (for those with a high nitrogen content) and/or the consumption of plant proteins from a more closed environment than the rest of the group. While these children generally had lower carbon values than the adults, the same observation can be made for $\delta^{15}N$. It therefore seems that the youngest part of the population studied was given a specific diet, with an intake of plant and/or animal proteins from a more closed environment than the rest of the population. It should be noted that the absence of this trend among the children buried at Barmaz II may be due to the small number of individuals of this age or to a real difference in diet. However, there is a possibility that these low $\delta^{13}C$ and $\delta^{15}N$ values are not due to dietary practices, but to physiological factors that can affect these values. Firstly, an intense period of growth can lead to depleted ^{15}N values in bones (King et al., 2018). For example, Richards et al. (2002) found that individuals aged between 4 and 8 years had relatively low values, which may be the result of the body's physiological response to growth stress, leading to an imbalance in nitrogen ratios. Secondly, physiological stress, such as malnutrition, can affect the isotopic ratios recorded. This also involves a depletion of ^{15}N in the bone, but this time in relation to the cessation or slowing down of bone growth (Beaumont et al., 2013). This latter hypothesis is consistent with the observations made in the previous study by Abegg (2019), who noted a significant presence of porotic hyperostosis, *cribra orbitalia* and periosteal reaction in the individuals buried at Barmaz I, especially children. Although the etiology of these pathologies is neither clear nor defined, they are often associated with metabolic problems.

We saw above that the values of $\delta^{13}C$ and $\delta^{15}N$ also differ between adults from the two areas and are higher in individuals from Barmaz II. In fact, it seems that individuals from Barmaz I mainly consume animal proteins of herbivore origin, although some prefer proteins of omnivore origin. The Barmaz II individuals, however, have more scattered values and show more variation in diet within the group. Although it appears that individuals from Barmaz I and II obtained their resources from a similar biotope, they either did not have the same access to certain resources (enriched in ^{15}N) or they had certain criteria explaining why individuals from Barmaz II consumed a resource enriched in ^{15}N that individuals from Barmaz I did not. Although there are significant differences between the isotopic values of individuals from Barmaz I and II, indicating the consumption of a different resource, there is still a lack of data to characterize the resource itself. A study of the site fauna and slaughtering profiles (Sidi Maamar and Reynaud Savioz, forthcoming) and the isotopic characterization of freshwater resources would give us a better idea of the significance of the consumption of such a resource observed in only one of the two groups. Nevertheless, this result is particularly interesting when we have a look on the paleopathological study of Abegg (2019). She revealed marked differences between Barmaz I and II with a significantly higher rate of traumatic injuries (most of which were treated and/or healed) in Barmaz II individuals (Abegg, 2019; Abegg et al., forthcoming). Given the nature of the injuries, the hypothesis are that 1) the individuals buried at Barmaz II belonged to a different (discriminated?) group in terms of health and/or social status, which made them victims of certain occasional acts of violence; 2) that at Barmaz II, this group was involved in specialized activities that were more prone to accidents. In view of the isotopic results, it seems unlikely that the negative discrimination at Barmaz II corresponds to the relatively "richer and more varied" diet described above. Thus, the hypothesis that they carried out a specialized activity – perhaps giving them a special status – seems particularly interesting and could explain the differences observed in the subsistence methods and diets of these two groups.

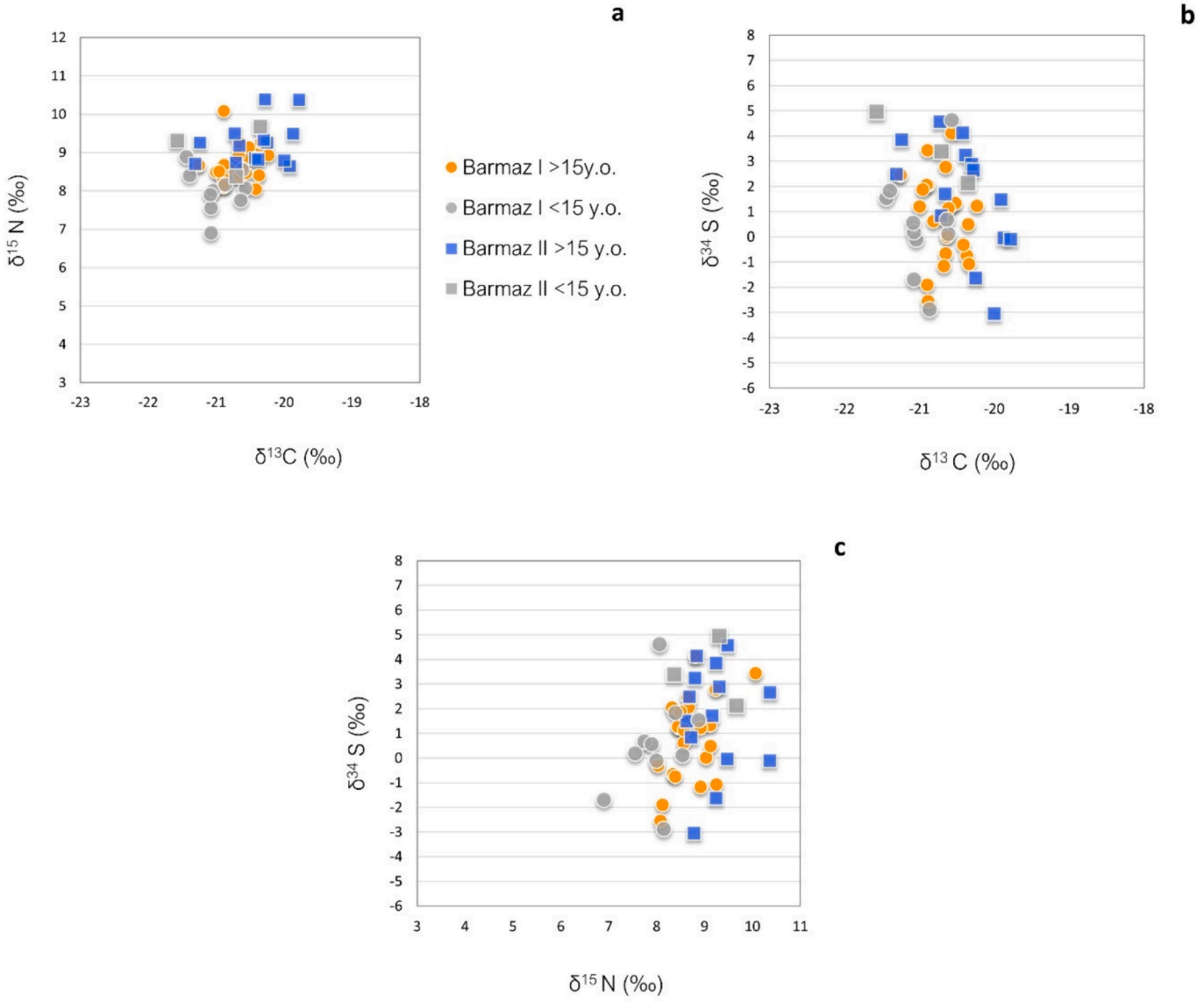

Fig. 7. Distribution of isotopic values $\delta^{13}C/\delta^{15}N$ (a), $\delta^{13}C/\delta^{34}S$ (b), $\delta^{34}S/\delta^{15}N$ (c) for all individuals from Barmaz I and II (n = 49).

4.3. *Individual life path*

The 49 individuals were subjected to strontium isotope analysis and compared with a reference frame of 5 contemporary faunal samples from the site itself. Of the 49 individuals, 42 fall within the thresholds reflecting the local environment of the Barmaz site, and no sex differences in $^{87}Sr/^{86}Sr$ values can be observed.

The results showed that only those buried at Barmaz I appear to have spent at least part of their childhood in a different environment. Firstly, they are all individuals over the age of 15, with the oldest being to be over 60. Both sexes are represented, with 3 females, 2 males and 2 of undetermined sex. 6 of the 7 individuals (BAIR16a, BAIR19, BAIR38a, BAIR40a, BAIR41 and BAIR45a) could have evolved in a similar environment before arriving in the Barmaz region. Only one (BAIR35, an adult female), has an extreme value above 0.713 and appears to be the only one representing its area of origin. However, identifying their potential area of origin is impossible. Despite the European distribution map of strontium isotope values published by Voerkelius et al. (2010), the Alpine region shows far too much variation to characterize the exact origin of these individuals.

Their distribution within the burial area is particularly interesting; 5 individuals with similar values were buried in the eastern part of the area, while BAIR19 and BAIR35 are further west (Fig. 8). Among the 5 individuals in the eastern concentration, two adults, one male (BAIR40A) and one female (BAIR38A), have very close $^{87}Sr/^{86}Sr$ and $\delta^{34}S$ values, but above all, identical $\delta^{13}C$ and $\delta^{15}N$ values. This situation reflects a probable common origin, but also implies similar dietary habits. Further radiocarbon and genetic analyses are currently underway and will help to clarify the link between these two individuals.

Non-locals represent 14 % (7/49) of the total population of Barmaz and 20 % (7/36) of the adults. In Barmaz I, they represent 22 % of the total population (7/32) and 32 % (7/22) of the adults while there is none in Barmaz II. Several studies have focused on the mobility of individuals during the Neolithic in the Alpine regions of Switzerland and Italy. Work on the Petit-Chasseur site in Sion (Valais, Switzerland) concerns the Final Neolithic and Bell Beaker periods (Chiaradia et al., 2003; Desideri, 2009; Desideri et al., 2010). These studies have shown that in collective monuments of the Final Neolithic, between 20 and 36 % of the population is of exogenous origin, including both adults and children. As in the case of Barmaz, their strontium isotopic compositions are always above those considered local to the region. Analyses carried out on Bell Beaker individuals show a similar percentage of individuals of

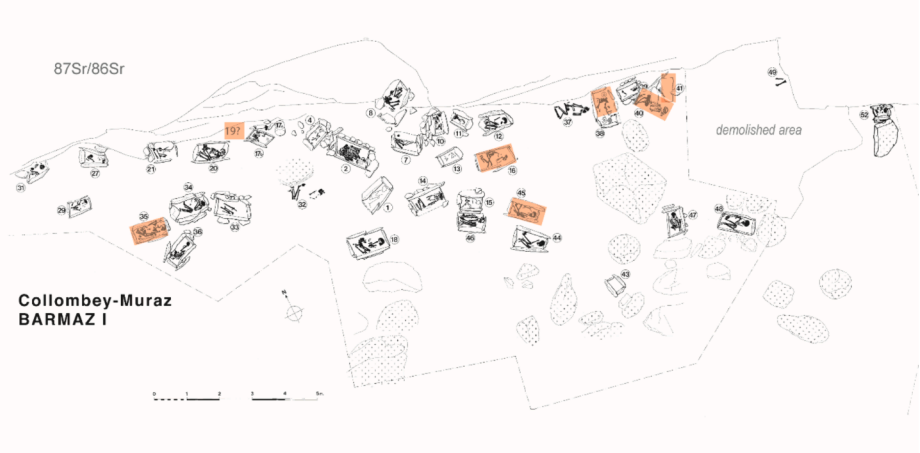

Fig. 8. Distribution of individuals considered to be non-local and buried at Barmaz I (in orange) (Honegger and Desideri 2003, modified).

exogenous origin as in the Final Neolithic (30 % of the population), but this time only the adults appear to be non-local, with values once again exclusively above the reference limits. Desideri (2019) has also studied the Bell Beaker burials in the Saint-Martin-de-Corléans necropolis in Aosta, Italy. The results are identical to those of their Swiss contemporaries, with a similar percentage of exogenous individuals represented only by adults (Desideri, 2019). In the case of both the Petit-Chasseur and Saint-Martin-de-Corléans dolmens, the collectivization of the burials and the high degree of fragmentation of the remains do not allow a comparison of the strontium values and the sex of the individuals. However, genetic analyses are currently underway, and we will be able to return to this subject in the near future.

Although the data from the dolmens relate to more recent periods, it is interesting to compare them with those from the Barmaz site. As with the Bell Beaker individuals from Petit-Chasseur and Saint-Martin-de-Corléans, the data from the Barmaz individuals reflect the mobility of adults only, some of whom may have the same origin. Similarly, all the isotopic compositions considered to be non-local are above the local limits. Another interesting feature is the homogeneity of the local values of Barmaz, which are comparable to those of Final Neolithic individuals, whereas Bell Beaker individuals show greater variability. From a diachronic point of view and at the scale of these sites, Middle Neolithic individuals appear to be less mobile than in the more recent phases of the Neolithic. Similarly, while the proportions of non-locals seem similar between the Final Neolithic and the Bell Beaker, the variability of values within Bell Beaker individuals suggests a greater mixing of populations. Finally, although the proportion of non-local individuals observed at Barmaz is lower than in more recent Neolithic phases in the same region (Desideri, 2009,2019), it is close to the proportions observed at French Middle Neolithic sites (Goude et al., 2012). Numerous recent studies have highlighted the greater variability of isotopic values in female individuals, which may be related to differential mobility and suggest a social structure partly determinated by patrilocality and patrilineality, as demonstrated by recent genetic data (e.g. Rivollat et al., 2020; 2022; 2023; Goude et al., 2020; Furtwängler et al., 2020; Siebke et al., 2020). For Valais region, no study has yet suggested a comparable social organization. Individuals considered as non-local are both males and females and the variability of isotopic values is similar for all individuals.

5. Conclusion

This study lays the foundations for a general discussion of the social behavior related with food and mobility in early Swiss agropastoral societies. The data show that protein intake was mainly based on animal resources, with perhaps one unidentified resource, the proportion of which varied between the burials in the two areas studied. Although the plant economy in Valais is relatively well known, the consumption of its products still raises a few questions, given the very high proportion of animal protein in the human diet. Perhaps a large proportion of the plants harvested were used to feed livestock rather than for human consumption.

This study has highlighted differences in dietary habits between the Barmaz I and II individuals, as well as differences in the selection of individuals buried, with the presence of individuals who grew up elsewhere only within the Barmaz I area. While previous studies have shown homogeneous Neolithic populations from a demographic and biological point of view (Eades, 1996; Desideri and Eades, 2002; Desideri, 2005; forthcoming), the paleopathological study revealed marked differences between Barmaz I and II (Abegg, 2019). A higher rate of injury, combined with the access to certain resources, raises the question of whether the individuals at Barmaz II belong to a slightly different social group, which could be explained by the practice of a ‘specialised activity’. However, no differences are observed in the structure of the burials, or the material buried with the dead.

Finally, when the data on food and mobility are cross-referenced, two main points emerge. First, growing up in a different environment does not seem to affect access to different resources during life. Secondly, whether in terms of previous studies, dietary habits, access to resources or mobility, the individuals buried at Barmaz – wether male or female – appear to have lived with equal opportunities, painting a picture of a society with egalitarian reflections.

CRediT authorship contribution statement

Déborah Rosselet-Christ: Writing – original draft, Visualization, Methodology, Investigation, Formal analysis, Conceptualization. **Gwenaëlle Goude:** Writing – review & editing, Supervision, Resources, Methodology, Investigation, Conceptualization. **Marie Besse:** Writing – review & editing, Supervision, Resources, Funding acquisition. **Matthieu Honegger:** Writing – review & editing, Resources. **Georgios Kottas:** Writing – original draft, Investigation. **Matteo Gios:** Resources, Investigation. **Jocelyne Desideri:** Writing – review & editing, Supervision, Resources, Project administration, Methodology, Funding acquisition, Conceptualization.

Declaration of competing interest

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

Data availability

they are contained in the manuscript

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Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jasrep.2024.104585.

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