Mobile elites at Frattesina: flows of people in a Late Bronze Age “port of trade” in Northern Italy investigated through strontium isotope analysis

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Abstract

Following a mid-12th century BC demographic crisis, Frattesina rose as a prominent hub in the networks linking continental Europe and the Mediterranean, thanks to its advantageous location. The remarkable variety of exotic materials and commodities indicate that Frattesina represented a key-node of long distance trade, which probably involved Aegean and Levantine merchants.

Strontium isotopes analyses reveal an intense mobility of people, and above all of elites, although mostly on a local scale, within a 50 km radius. Among non-indigenous people, we identified an outstanding warrior chief who we interpret as an expression of a new, more hierarchical society.

Introduction

It is interesting to compare movements of people and trajectories of trade in prehistory, but it is even more intriguing to investigate how these reorganise after periods of geopolitical instability. The Final Bronze Age in northern Italy saw the collapse of the *Terramare* system and the rise of Frattesina as a nodal centre between Mediterranean and Continental Europe. Below we use strontium isotope analysis to investigate the origins of elite and non-elite individuals in this community and to investigate the role that outsiders may have had in the rise of Frattesina.

Collapse of the *Terramare* system and regeneration: Frattesina and the transition to a new socio-political organization in Northern Italy

The middle centuries of the second millennium BC (1650-1150 BC) saw the rise and flourishing of the *Terramare* settlement system in the Po River plain. The level of social and economic organization these communities reached was unprecedented in Italian prehistory and thus the *Terramare* have always attracted the attention of European prehistorians.

The collapse of the system, around 1150 BC, was followed by a sudden and substantial depopulation of the central part of the Po Plain (Cardarelli 2009). At the beginning of the Final Bronze Age (second half of the 12th century BC), the southern part of the Po Valley was almost abandoned. In the northern part, a contrasting trajectory is evident: the great *terramara* at Fondo Paviani continued through the transition between the Recent (RBA) and Final Bronze Age (FBA), but experienced a phase of crisis in the early stages of the latter (FBA 1-2), during which the site was finally abandoned; at the same time, a new territorial system arose, pivoting around the socio-economic pole of Frattesina (Calzavara Capuis *et al.* 1984; Cupitò *et al.* 2015; Bietti Sestieri *et al.* 2015). Within the area of the same *Terramare* 'culture', responses to the crisis therefore led to different outcomes: economic factors, both in terms of internal carrying capacity and degree of openness to external relations, probably played a key role in determining different responses to the tensions—some of them relatively successful and others catastrophic.

It has been repeatedly stated that the collapse of the *Terramare* system might have been triggered by a series of concurrent factors, such as environmental crises (prolonged drought), over-exploitation of the land, and, hypothetically, famine or epidemics. Nevertheless, while environmental factors most likely acted as cofactors, a key explanation arguably lies in the socio-political and economic organisation of the system (Cardarelli 2009: 471–72): the communities of the *Terramare*, especially in the southern area, were probably not flexible enough to adapt their political structure and modes of production to the needs of a changing world. Moreover, the domino effect from the overall geo-political instability of the 12th century in a highly interconnected system such as the Mediterranean was undoubtedly another factor. The lack of indicators of Aegean and Levantine connections in the southern *Terramare* points to a more 'closed' system, on the edge of the 'globalised' world of the Late Bronze Age. On the northern side of the Po River, in contrast, the emergence in the largest *terramare* of possible incipient forms of institutionalised, well-connected elites is well documented, especially at Fondo Paviani, with locally produced Levantine and LH IIIC Aegean-Mycenaean style pottery (Bettelli *et al.* 2015). However, during the last phase of the *Terramare* (1300-1150 BC), individual burials do not exhibit the wealth or reflect the power that the society as a whole had, judging from the monumental and material evidence of the settlements (Cardarelli 2015).

The display of austere equality that dominated the Middle and Late Bronze Age 'urnfields', and also characterised urn cremations in the bi-ritual cemeteries of the *Terramare,* strongly limited funerary expressions of social differentiation. Internal inequalities nonetheless existed, between different co-resident extended families or segments of lineages comprising no more than some tens of individuals (e.g. at Casinalbo; Cardarelli *et al.* 2014, pp.722–728) and, above all, between large centres, such as the *terramara* at Fondo Paviani (16-20 ha), and dependent satellite settlements (Balista *et al.* 2005; Cupitò *et al.* 2015). It is reasonable to hypothesize that groups based at the nodes of the system attracted more prestige goods from exotic places, as well as individuals from distant areas, while small villages attracted people mainly within a local radius.

Within this dynamic cultural context, Frattesina's FBA funerary evidence documents a subsequent and more elaborate display of power and wealth concentrated in the elites—a privileged segment of society, probably with its own entourage, is clearly represented by a few burials in Frattesina's cemetery (Le Narde) through several indicators of prestige.

Over the last decade, the archaeological debate has concentrated on the origin of these individuals, and more intriguingly the founders of Frattesina. Was Frattesina a primarily indigenous community, which developed out of local dynamics and regeneration from the ashes of the *Terramare* system, or did non-local groups from the Eastern Mediterranean contribute to its rise and, if so, to what extent?

Frattesina: between the Mediterranean and Central Europe

Frattesina di Fratta Polesine is unique among Late Bronze sites in Northern Italy for its outstanding evidence of specialized workshops, exotic imports, and rich cemeteries (Bietti Sestieri 2008; Bietti Sestieri *et al.* 2015). The settlement extends over 20 hectares (equally divided into a 10 ha core and peripheral areas for cattle penning and primary production) and is located on the right bank of the Po di Adria palaeochannel (Figure 1), approximately 8 km south of the present course of the Adige River and 30-40 km from the Bronze Age Adriatic coastline and the delta of the River Po. The occupation of a strategic position at the crossroads between mainland, fluvial and maritime routes from the Alps to the Mediterranean must be one reason for its economic prosperity. Definitions of Frattesina as a "central place", "primary node", "port of trade" or "*emporium*" recur in the works of many scholars (Pearce 2000; Bietti Sestieri 2008; Harding 2013; Kristiansen & Suchowska-Ducke 2015).

Since the late 1960s, a long series of archaeological investigations has been conducted on both the settlement and its two urnfields, Fondo Zanotto and Le Narde. The latter has been more extensively excavated and more deeply analysed, both archaeologically and osteologically (L. Salzani 1989; Luciano Salzani 1990; Luciano Salzani & Colonna 2010; Cavazzuti 2011; Cardarelli *et al.* 2015).

The excavations at Le Narde have targeted two distinct sectors (Narde 1 and Narde 2), yielding respectively more than 600 and 200 urn cremations, as well as 3 and 22 inhumations, which extend from the FBA 1 (c. 1150 BC), soon after the collapse of the *Terramare* culture, to the earliest phases of the EIA (c. 950/925 BC). In both sectors the ratio between FBA 1-2 (phase 1) and FBA 3-EIA 1 (phase 2) burials is balanced, with a slight increase in burials in the latter phase (respectively 40% and 60%).

At Narde 1, the large burial groups expand both horizontally and vertically: the outcome of this progressive vertical growth is a large, dense mound that reaches up to five levels of depositions, indicative of a strong will to emphasise membership of a specific corporate group (Leonardi & Cupitò 2004; Cardarelli *et al.* 2015; Figure 2).

Despite the damage caused by a recent drainage channel crossing the cemetery, the topographic organization of the Narde 2 sector appears quite clear, and rather different to Narde 1. Burials are organized spatially in larger and smaller groups, from 15 to 60 graves each, which tend not to be superimposed, but rather to expand horizontally (Figure 3).

In a recent analysis of grave goods and sex/age categories of individuals, five different ranks of adult males, females and subadults have been identified, with an increasing quantity and quality of grave goods (Cardarelli *et al.* 2015). The richest among the adult males, characterized by swords and toiletry articles, are represented by two graves (T. 168 and T. 227), both located in Narde 1, at the centre of two distinct burial groups of more than 100 graves (L. Salzani 1989; Bietti Sestieri 2008) (Figure 2). Another four graves contain only the rivets instead of the whole sword, probably a *pars pro toto* symbolizing their warrior status (T. 32. 154, 177, 273) (Leonardi 2010). Similarly, the nine richest female graves, containing prestige goods such as amber and glass beads, are buried almost exclusively in Narde 1, with only one in Narde 2. Narde 1, then, appears as the area designated for elite groups and their entourage, while Narde 2 could have been reserved for less prestigious yet still dominant social groups.

The analyses of human remains: demographic data and first indicators of mobility

Osteological analyses have been undertaken on 472 burials: 266 from Narde 1, and 206 from Narde 2 (Table 1). Sex and age were determined through a combination of methods analysing morphologies and metric traits (Ferembach *et al.* 1980; Gonçalves *et al.* 2013; Cunningham *et al.* 2016; Cavazzuti *et al.* in press).

In both cases, the sex ratio is close to 1:1, although adult males prevail at Narde 1, while adult females predominate slightly at Narde 2. The most marked difference between the two sectors is in the frequency of subadults: 21% at Narde 1 and 31% at Narde 2. This discrepancy can be observed in all the subadult age classes, and most clearly among *Infans 2* (7-12 years), since at Narde 2 these individuals are twice as common as at Narde 1.

These diverging mortality rates among children might mirror different life expectancies and life conditions (Cardarelli *et al.* 2015), albeit with different degrees of inclusion of adult strangers and newcomers. In this scenario, Narde 1's elite groups might have incorporated significant immigration, while those buried at Narde 2 remained closer to the traditional demographic structure of kinship-based societies. In this paper, isotopic analysis is used to test these 'inequalities'.

Materials

Our sampling strategy aimed to analyse individuals' strontium isotope ratios, and therefore mobility, in relation to osteological and archaeological data. Samples were consequently selected taking into account burial sector (Narde 1 and Narde 2), funerary rite (cremation vs inhumation), sex and age at death, chronology, and grave goods class. In order to facilitate data correlation, the five previously published grave goods classes (Cardarelli *et al.* 2015) were merged into three broader groups defined: by outstanding combinations of fibulae and ornaments in female burials, as well as associations of weapons and utensils, also with prestige indicators, in those of men (Class 1); by pins or fibulae (fibulae were also combined with smaller ornaments and/or a spindle whorl), respectively in male and female graves (Class 2); and by the absence of grave goods or very simple assemblages (Class 3).

Of the 46 sampled individuals, 40 were cremated and 6 inhumed. Given the almost total absence of tooth enamel in cremations, we targeted the *pars petrosa* of the temporal bone, which is frequently preserved in urn cremations. The petrous portion begins forming *in utero* at approximately 16–18 gestational weeks and becomes fully ossified at the time of birth. The otic capsule in the inner part of the petrous portion does not undergo any further remodelling after the age of 2 years (M Sølvsten Sørensen *et al.* 1992; Mads Sølvsten Sørensen 1994; Jeffery & Spoor 2004). Considering that the petrous portion forms primarily before the end of weaning, its strontium isotope ratio is assumed to reflect the origin of the food consumed by the woman who breastfed the infant. It also seems reasonable to assume that in the vast majority of cases the infant's mother/wet nurse did not change over the time of breastfeeding, did not move extensively, and did not consume foods of a different origin. As strontium isotope composition in bone does not significantly change as a consequence of calcination, and is then resistant to diagenesis, the petrous portion is suitable for strontium isotope analysis (Harbeck *et al.* 2011; Harvig *et al.* 2014; Snoeck *et al.* 2015). In order to test the reliability and consistency of the *pars petrosa* results, we also sampled and analysed two subadults' exceptionally surviving first permanent molar (M1) crowns, which are characterized by approximately the same age of formation as the petrous portion (burials n.197 and n.208).

In the case of the prestigious "warrior-chief" burial (n.168) the cortical tissue of the femur was also sampled. Since bone tissue remodels in life, its biogenic strontium isotope ratio reflects the place(s) where he spent the last decades of life (Hedges *et al.* 2007). Grave n.154, containing only rivets to symbolize warrior status, was also sampled.

For inhumations, we sampled enamel from permanent second molars (M2), whose crowns develop between 3 and 8 years of age (AlQahtani *et al.* 2010), and thus avoid breastfeeding effects for future oxygen isotope analysis. In two cases (T. 25 and T. 59), we also analysed the enamel of permanent third molars (M3), forming between 8 and 15 years of age, for identifying possible movements of the individuals between childhood and adolescence.

Biologically available strontium baselines were collected from a database of 199 $^{87}Sr/^{86}Sr$ values gathered from the existing literature and 35 produced in the framework of the Ex-SPACE project, aiming to represent all the geolithological units of the region (Table 1-SM).

Strontium isotope analysis: general principles and application to Northern Italy

Supplementary

Methods

Supplementary

Results

The results of the strontium isotope analysis in relation to archaeological and osteological data are shown in Table 3. The 'isoscape' of the Frattesina area, and more generally for northeastern Italy, is shown in Figure 4.

Two tests were performed for burials n.197 and 208 to verify the correspondence between the $^{87}Sr/^{86}Sr$ values measured on petrous portions and first molar crowns. Encouragingly, in both cases the values are very similar (0.708803 and 0.708851; 0.708830 and 0.708862), thus confirming that the petrous portion represents a good indicator of childhood origin (Harvig *et al.* 2014). The inhumations with both M2 and M3 (burials n.25 and 59 from Narde 2) show no significant shift in the strontium isotope composition in the two phases of life.

Of the 46 analysed individuals, 29 (63%) are compatible with the 0-20 km range $^{87}Sr/^{86}Sr$ baselines (0.70853-0.70934), while the other 17 (37%) are incompatible (Figure 5). However, the strontium isotope ratios of these 'outsiders' fall within the 20-50 km range baseline (0.70772-0.71022), with only two exceptions (n.44 and 45 from Narde 2), which are just below the lowest values of this range. The community of Frattesina therefore appears to have been largely "local", although it included a significant flow of people from the broader hinterland, potentially from both north and south of the Po River. The patterns of mobility among males and females do not differ significantly. Interestingly, some subadults, despite their young age, also moved to Frattesina, where they died within a few years (unless their ashes were moved from elsewhere). This probably indicates that mobility could involve entire families and not just single individuals.

Diachronic variations in the percentage of non-local individuals might reflect the transition from an early stage in which people from different places contributed to enlarge the settlement, to a phase of stabilization and internal growth, with only a few newcomers to maintain the relationship with the hinterland (Figure 6, top). The rare inhumations are all compatible with the 0-20 km baselines, while cremations are widespread both on a local and broader radius (Figure 6, bottom).

Important indications are given by the $^{87}Sr/^{86}Sr$ values grouped by burial ground (Narde 1 and Narde 2) and grave good class. While Narde 2 individuals mainly concentrate within the interval of the local strontium isotope ratio, excepting a few outsiders (15%), the Narde 1 group includes a higher proportion of people of different origins (33%), though all compatible with origins in the broader hinterland, including n.154, marked as warrior by the presence of rivets (Figure 7, top). Considering the grave good classes (Figure 7, bottom), a more evident mobility is documented among the 'richer' burials (classes 1 and 2), while class 3 burials are mostly local.

The concentration of non-local individuals amongst Narde 1 burials could also provide an explanation for the anomalously high proportion of adult individuals—mostly males—buried in this sector. Narde 2 may be characterized as a localised and kinship-based structure, while the more privileged social groups of Narde 1 show a greater degree of mobility, and therefore tend to incorporate more non-local adults. From this perspective, growing social inequalities may have triggered mobility, both among the members of the elite themselves and in the subaltern classes, now probably more strongly tied to the elite by constraints of power and economic bonds than in the past.

In this way, our analyses document the extent to which social inequalities and mobility were interconnected in the Late Bronze Age and the geographical scale of the social network, at least concerning the flow of people. For a well-placed community, to participate in the 'global' arena of trade, the maintenance of the socio-political order over the territory of the polity was decisive.

Mobile elites and the "warrior-chief" at Frattesina

Burial n.168 in Narde 1, mentioned above, might have had a warrior-chief status as symbolized by a rare Allerona-type sword of the short variety (Bianco Peroni 1970), which was ritually broken and deposed in pieces inside the urn, along with a bronze pin, a pair of tweezers and other ornaments (Figure 8). For this individual, identified osteologically as an adult male, we analysed both the petrous portion as an indicator of childhood origin and the femur's cortical bone as a possible proxy for the place where he spent his last years of life. The petrous portion yielded a strontium isotope ratio (0.70983) that is not compatible with the local 0-20 km baseline (Table 3) but fits within the 20-50 km range. By contrast, the value obtained on the cortical tissue of the femur (0.70924) is consistent with the local range of Frattesina. This means that this individual moved to the site in a period later than early childhood (which is difficult to establish, but was possibly during youth or early adulthood) and he probably spent the last years of life there, at the apex of the community.

It is well known that assessing the provenance of an individual through strontium isotope analysis alone is not a straightforward task, as different places might be characterized by similar ratios. Our interpretation above considers only the closest possible places of origin. Considering the area of Northern Italy, however, the geolithological zone that shows the closest values is the easternmost part of the Verona plain, around 60 km to the west. In particular, the $^{87}Sr/^{86}Sr$ baselines from the Middle-Late Bronze Age *terramara* at Fondo Paviani/Scalvinetto (0.7097-0.7101), also analysed in the framework of the Ex-SPACE project, seem to match with the petrous portion of burial n.168.

Marshall Sahlins, in his famous paper entitled "*The Stranger-King: Or Dumézil among the Fijians*" (1981 [2008]), compares the dynamics of power in the Fiji Islands and in the Indo-European tradition and argues that in human societies there is a tendency to locate power as originating from the outside (Sahlins 1981; Sahlins 2008; see also Ling & Rowlands 2015). Sahlins focuses on origin myths across ancient polities in the Indo-European language area, which systematically feature a dichotomy between what the Romans called *gravitas* and *celeritas*. *Gravitas* refers to the conservative, peaceful and productive character of an established native community, while *celeritas* represents the disruptive transformative violence personified in the *Stranger King*, who "erupts upon a pastoral scene of peaceful husbandry and political equality (or at least limited authority)" (Sahlins 1981: 112).

In the case of Frattesina burial n.168, we are likely dealing neither with a true king nor with a true stranger. Despite its singularity, his grave mirrors those of the rest of the community and is included in a large collective, or at least not evidently exclusive, burial mound. A prominent 'warrior-chief' would be a more appropriate definition. Moreover, in all probability, his place of origin was not so far to define him as a 'stranger'. Nonetheless, Sahlins' archetype of the 'stranger-king' evokes the power of alterity, and burial n.168 perfectly embodies Sahlins' *celeritas*, which breaks with the *gravitas* of the former *Terramare* tradition and guides what survived the collapse towards a new social model.

Since the discovery of Frattesina and its cemeteries, Italian scholars have engaged in a long debate on the mechanisms underlying the origin and economic success of Frattesina and the degree of involvement in this process of the foreign (Cypriot/Levantine) component testified by archaeological finds (Cupitò *et al.* 2015). The new isotopic data presented here demonstrate that, although some individuals might ulimately have come from the Levant, where available $^{87}Sr/^{86}Sr$ baseline range from 0.7079-0.7086 (Sheridan & Gregoricka 2015; Gregoricka & Guise Sheridan 2016), or from other exotic places, they would nonetheless represent a minority of the population and, in any case, not the upper segment of the elite segment.

Conclusions

Advances in recent years in mobility studies, isotopes and ancient DNA have revived the interpretative tensions between the paradigms of migration and local development. The current results from Frattesina display a complex pattern, in which regional mobility, territorial organisation, socio-economic growth and political power are deeply intertwined. We may infer that mobility patterns during Frattesina's formative phase are compatible with the local/regional dynamics of an area in a phase of political re-organization. Through a system of alliances, the nascent elite of Narde 1, which was less reliant on traditional kinship ties than the population represented by Narde 2, extended its influence over wider territories, less densely populated than in the past, and rose as a recognised partner in long-distance trade networks, thus inheriting the role previously held by centres such as Fondo Paviani—a legacy that might also have included a certain degree of elite transfer from the latter, as the isotopic evidence hints.

As far as the concept of elite mobility is concerned, the rich ensemble of myths concerning the origin of Rome demonstrates that, at the formative stages of a new centre, even an outsider could rise to the apex of political power. The legend of Titus Tatius, king of the Sabines tells how, as a result of the chain of events generated by the rape of the Sabine women, he reigned over Rome together with Romulus for five years (Carandini 2010). Beyond the historicity of the character, Titus Tatius' story offers an instantiation of Sahlins' concept of new powers (or allies) coming from outside and accounts for the varied origins of Rome's first lineages, even at the highest level of the social scale—a scenario that might resemble that suggested for Frattesina on the basis of the evidence presented and discussed here.

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Figures

Figure 1. Aerial photo of Frattesina site (from Regione Veneto website, http://mapserver.iuav.it/website/foto_aeree/). In white, the extension of the settlement and the two burial areas, Narde (comprising Narde 1 and Narde 2 sectors) and Fondo Zanotto. The

settlement and Narde cemetery were separated by the Po di Adria palaeochannel, still visible in the landscape.

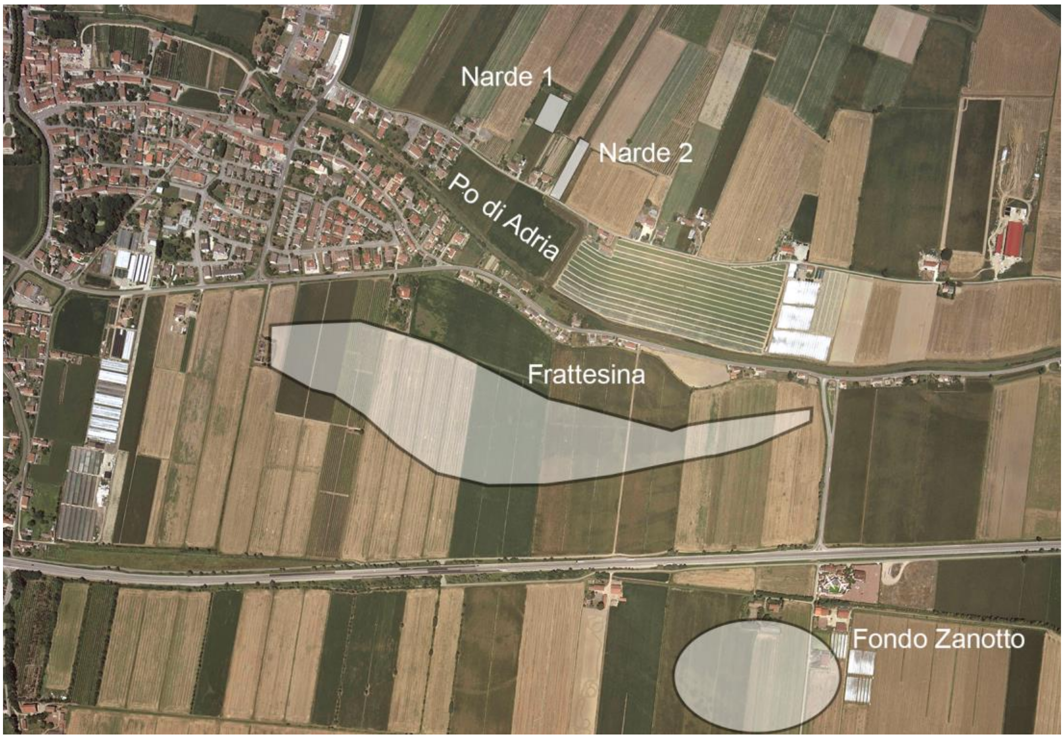


Figure 2. Map of Narde 1 burial sector (top) with the location of burials n. 168 and 227, and section of the mound (bottom), formed by the superimposition of urns (after Salzani 1989, 1990).

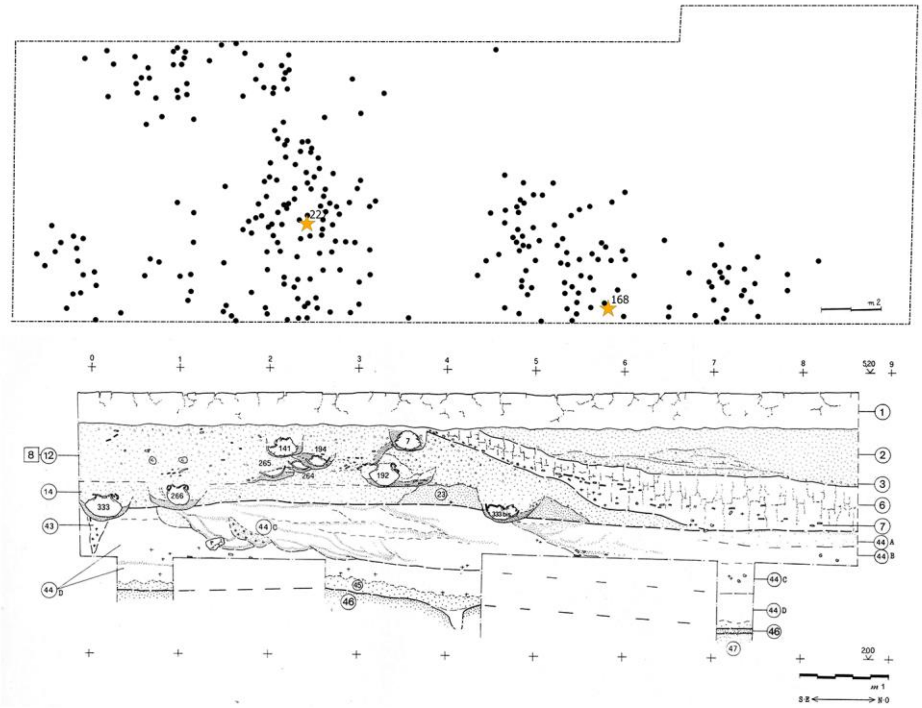


Figure 3. Map of Narde 2 burial sector, crossed by a modern irrigation channel (in blue). In detail, one burial group (after Salzani & Colonna 2010).

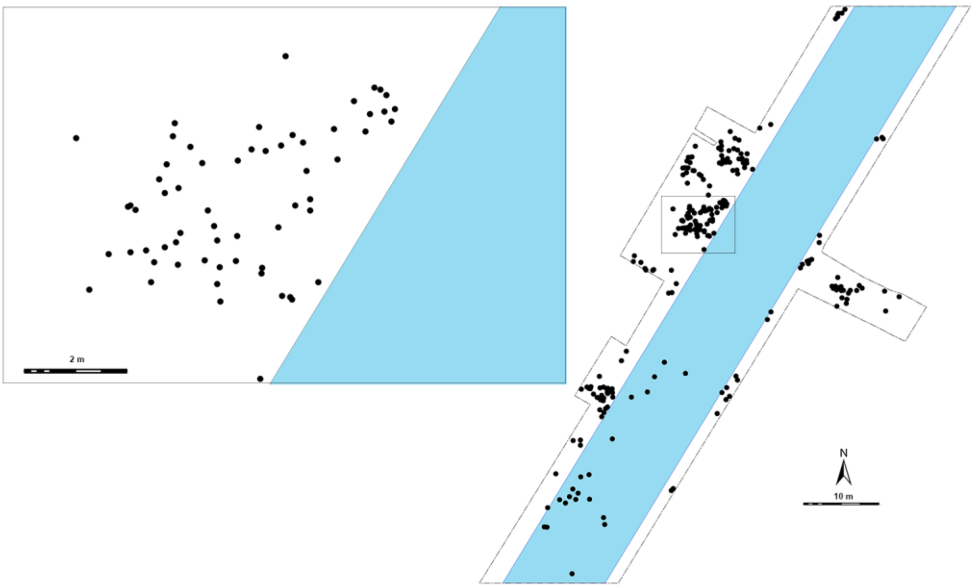


Figure 4. Geolithological map of Frattesina and its territory. Circles around the site represent the two buffer zones (immediate hinterland and broader hinterland); markers indicate the $^{87}Sr/^{86}Sr$ baseline samples (dots=modern plants; squares=spring waters; pentagons=river waters; triangles=snails; inverted triangles=archaeological fauna; rhombi=soil leachates). Numbers indicate the zones detailed in Table SM1 (map under a CC BY license, with permission from http://wms.pcn.minambiente.it/ogc?map=/ms_ogc/WMS_v1.3/Vettoriali/Carta_geolitologica)

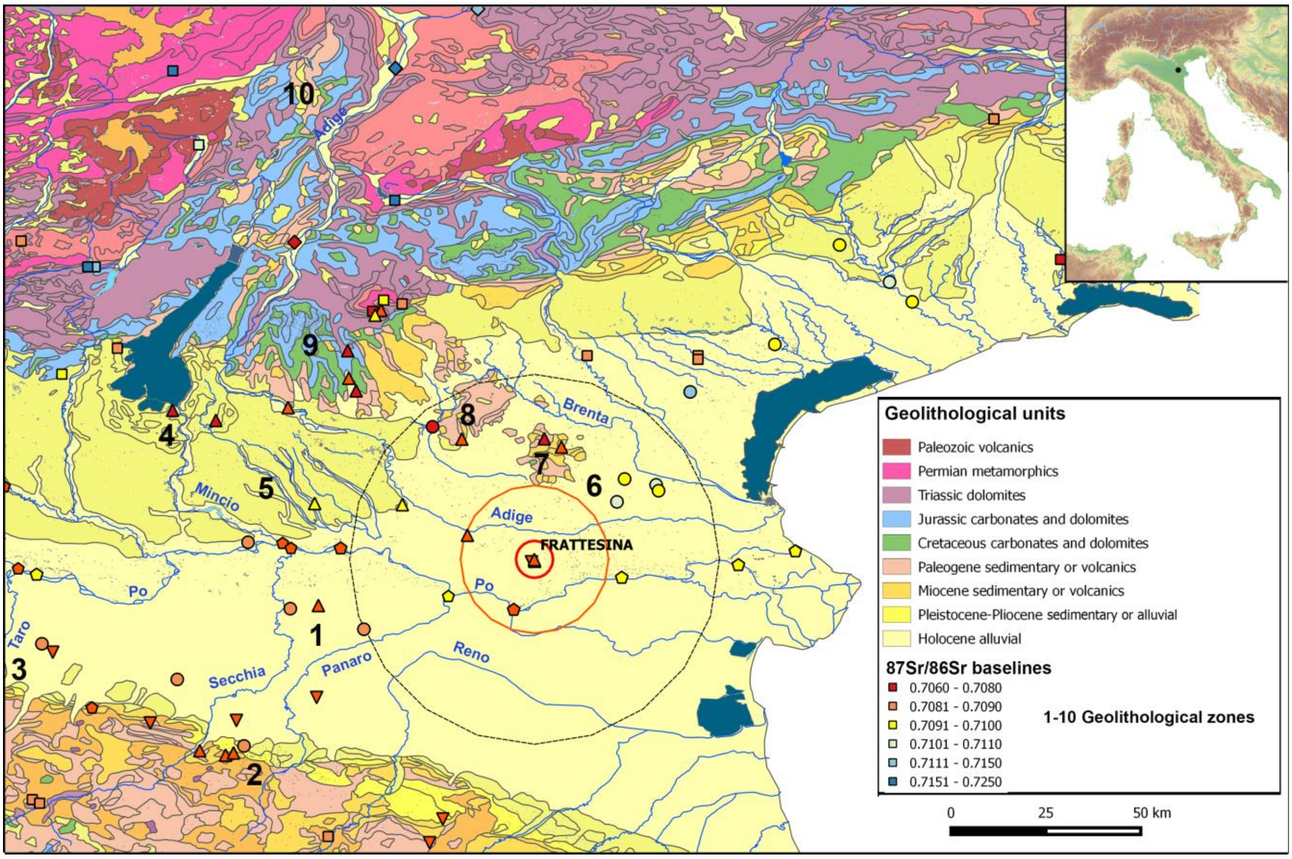


Figure 5. Violin plot of strontium isotope ratios for baseline samples and humans grouped by sex/age category. Each dot represents a single individual/baseline sample and the width of the outer curve the kernel density of the distribution.

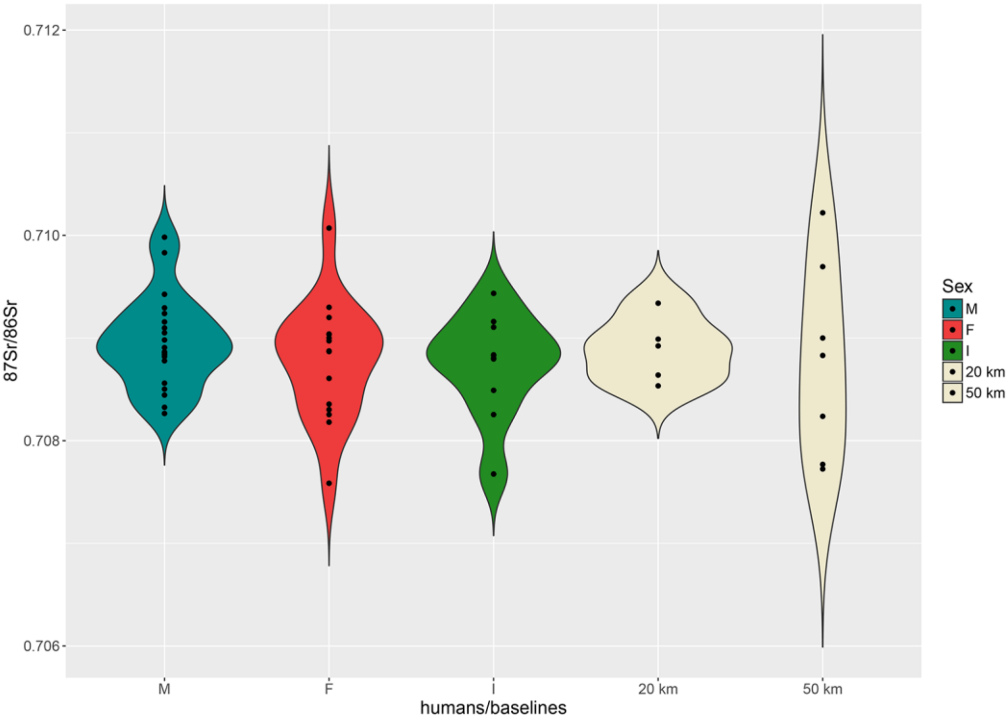


Figure 6. Violin plots of strontium isotope ratios of baseline samples and humans grouped by chronological phase (top) and type of funerary ritual (bottom). In the top chart, "NA" refers to burials that could not be assigned to a specific chronological phase.

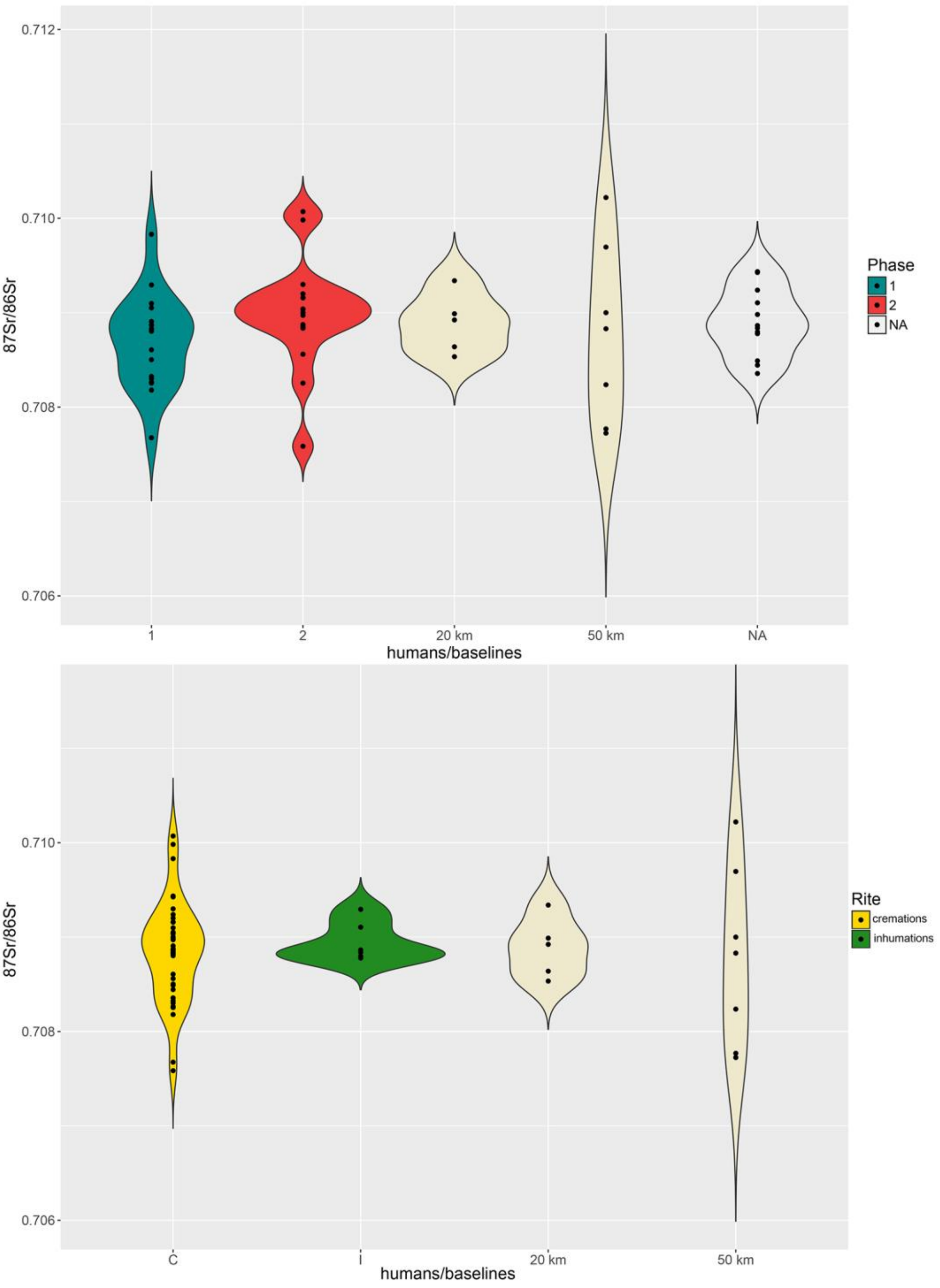


Figure 7. Violin plots of strontium isotope ratios of baselines and humans grouped by burial area (top) and grave good classes (bottom).

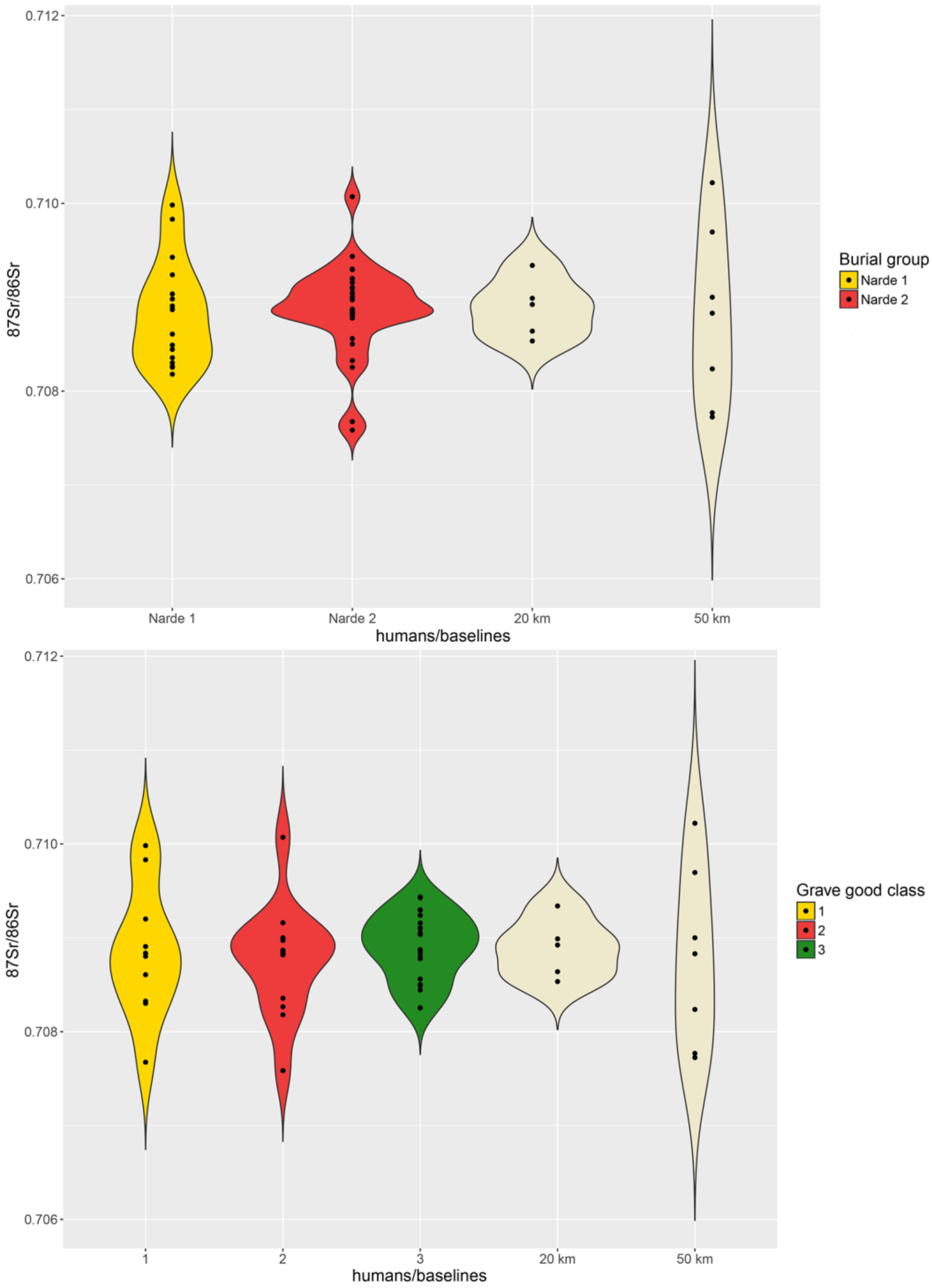
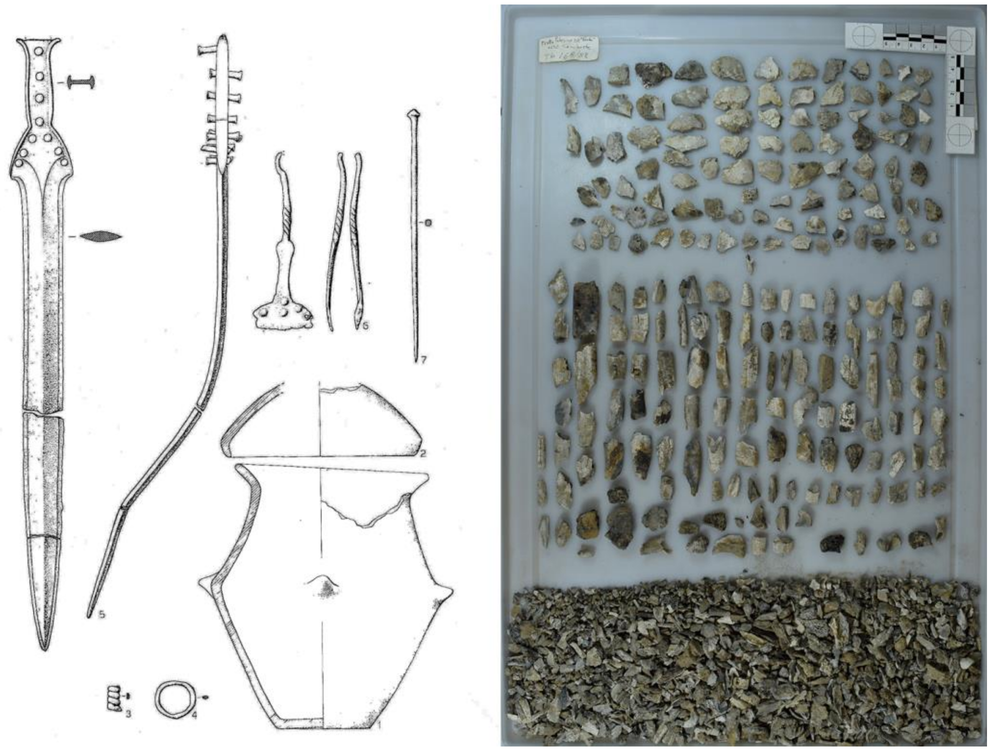


Figure 8. The grave goods and cremated bones of burial n.168 at Narde 1 (after Salzani 1989). Urn height 26 cm, sword length 46 cm.



Tables

	N	% Adult/juvenile males	% Adult/juvenile females	% Undet. sex adults	% Subadults	% Infans 1(0-2)	% Infans 1 (3-6)	% Infans 2 (7-12)	% Juvenis (13-20)	% Adultus (21-40)	% Maturus/senilis (40+)
Narde 1	266	34	30	15	21	7	9	3	5	59	17
Narde 2	206	27	34	8	31	8	12	7	8	53	12

Table 1. Frequency of categories of individuals at Narde 1 and Narde 2.

	Burial sector		**Funerary rite**		**Grave good class**				**Phase**			**Sex/age category**		
	Narde 1	Narde 2	Cremations	Inhumations	1	2	3	NA	1	2	NA	Adult male	Adult female	Subadults
Number of sampled individuals	17	29	40	6	10	13	22	1	18	16	12	20	16	10

Table 2. Sampling strategy. Number of individuals sampled for each archaeological and osteological parameter.

Burial group-number	**Sampled material**	**Rite**	**Sex/Age**	**Grave good class**	**Phase**	**$^{87}Sr/^{86}Sr$**	**2SE**
Narde1-21	petrous	C	F/Ad	1	1	0.708607	0.000019
Narde1-28	petrous	C	M/Ad	3	NA	0.709239	0.000019
Narde1-57	petrous	C	F/Ad	3	2	0.708874	0.000025
Narde1-70	petrous	C	M/Mat	3	NA	0.709426	0.00002
Narde1-76	petrous	C	F/Ad	2	1	0.708868	0.000017
Narde1-112	petrous	C	I/Inf1	3	1	0.708254	0.00002
Narde1-135	petrous	C	F/Ad	2	1	0.708180	0.00002
Narde1-154	petrous	C	M/Mat	1	1	0.708907	0.000019
Narde1-156	petrous	C	F/Ad	3	2	0.709035	0.000019

Narde1-168	femur	C	M/Ad	1	1	0.709243	0.000017
Narde1-168	petrous	C	M/Ad	1	1	0.709831	0.000015
Narde1-190	petrous	C	M /Mat	2	1	0.708265	0.000022
Narde1-233	petrous	C	M/Ad	1	2	0.709982	0.000022
Narde1-239	petrous	C	F/Ad	2	NA	0.708356	0.000015
Narde1-330	petrous	C	I/Inf1	NA	NA	0.708490	0.000023
Narde1-347	petrous	C	F/Ad	1	1	0.708302	0.00002
Narde1-511	petrous	C	M/Ad	2	NA	0.708981	0.000022
Narde1-545	petrous	C	M/Ad	3	NA	0.708444	0.000022
Narde2-13	M2	I	I/Inf2	3	NA	0.709105	0.000018
Narde2-22	petrous	C	M/Ad	2	2	0.708852	0.000019
Narde2-23	M2	I	M	3	NA	0.708864	0.000023
Narde2-25	M2	I	I/Juv	3	NA	0.708796	0.000020
Narde2-25	M3	I	I/Juv	3	NA	0.708905	0.000021
Narde2-33	petrous	C	F/Ad	2	2	0.710071	0.000021
Narde2-40	petrous	C	M/Ad	3	2	0.708560	0.000022
Narde2-44	petrous	C	I/Inf2	1	1	0.707675	0.000021
Narde2-45	petrous	C	F/Juv	2	2	0.707585	0.000022
Narde2-49	petrous	C	M/Ad	3	1	0.709098	0.000017
Narde2-53	petrous	C	M/Ad	2	1	0.708819	0.000028
Narde2-56	petrous	C	F/Ad	1	2	0.709200	0.000015
Narde2-58	M2	I	M/Mat	3	NA	0.708837	0.000017
Narde2-59	M2	I	M/Ad	3	NA	0.708778	0.000021
Narde2-59	M3	I	M/Ad	3	NA	0.708915	0.000025
Narde2-70	petrous	C	I/Inf1	3	NA	0.709435	0.000024
Narde2-85	petrous	C	F/Juv	3	2	0.709299	0.000019
Narde2-90	petrous	C	F/Ad	2	2	0.708972	0.000014
Narde2-99	petrous	C	M/Ad	3	2	0.709157	0.000017
Narde2-109	petrous	C	F/Ad	3	2	0.709039	0.000017
Narde2-112	petrous	C	F/Ad	3	2	0.708254	0.000020
Narde2-116	petrous	C	M/Mat	3	1	0.708502	0.000028
Narde2-128	petrous	C	M/Ad	3	1	0.709051	0.000016
Narde2-131	petrous	C	I/Juv	1	2	0.708836	0.000028
Narde2-168	petrous	C	F/Ad	2	2	0.709000	0.000016
Narde2-168	petrous	C	M/Mat	1	1	0.708325	0.000020
Narde2-181	M2	I	M/Mat	3	1	0.709294	0.000011

Narde2-197	petrous	C	I/Inf1	1	1	0.708803	0.000019
Narde2-197	M1	C	I/Inf1	1	1	0.708851	0.000016
Narde2-208	petrous	C	I/Inf1	2	1	0.708830	0.000022
Narde2-208	M1	C	I/Inf1	2	1	0.708862	0.000021
Narde2-216	petrous	C	F/Ad	3	1	0.708872	0.000015
Narde2-240	petrous	C	I/Juv	2	2	0.709160	0.000016
Frattesina	pig tooth enamel					0.708923	0.000011
Frattesina	snail					0.708534	0.000015
Frattesina	snail					0.708639	0.000026
Frattesina	soil					0.709339	0.000016
Badia P.	snail					0.708989	0.000011

Table 3. Results of the $^{87}Sr/^{86}Sr$ analyses (Rite: C=cremation, I=inhumation; Age: Inf1=0-6y, Inf2=7-12y, Juv=13-20y, Ad=21-40y, Mat= +40y).

Mobile elites at Frattesina: flows of people in a Late Bronze Age "port of trade" in Northern Italy investigated through strontium isotope analysis

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Supplementary information

1. Strontium isotope analysis: general principles and application to Northern Italy

Strontium isotope ratios in odontoskeletal remains are regularly employed to assess the provenance and trace the mobility of individuals in different phases of their lives. These are determined by comparing the ratio between strontium-87 (^{87}Sr) and strontium-86 (^{86}Sr) in bones/teeth, with the local baseline values measured in faunal/vegetal samples (modern and/or ancient) from the archaeological site or its geologically coherent immediate hinterland. The technique has been in use for more than 30 years in bioarchaeological research and is described in detail in a number of publications (e.g. Grupe *et al.* 1997; Montgomery *et al.* 2000; Bentley & Knipper 2005; Douglas Price *et al.* 2012; Giblin *et al.* 2013; Scheeres *et al.* 2013; Harvig *et al.* 2014; Sjögren *et al.* 2016).

As radiogenic strontium-87 (^{87}Sr) originates over time from the radioactive decay of rubidium-87 (^{87}Rb; half-life of 48.8 Ma), the ratio $^{87}Sr/^{86}Sr$ depends on the age of a given bedrock, but also on its geochemical nature. Older geological units (>100 Ma), such as Palaeozoic metamorphic and Mesozoic igneous rocks in the Alps, generally display higher $^{87}Sr/^{86}Sr$ values (≥0.71), while younger materials, such as Cenozoic marine carbonates and chalks in the Apennines, show lower ratios (≤0.709). Sediments in alluvial plains reflect the ratio of their parent material, or an admixture of the ratios that characterize the different geological units affected by the erosive activity of the rivers in the uplands.

Frattesina is located on the right bank of the Po di Adria palaeoriver, and therefore the local soils are composed of an admixture of the alluvial sediments collected from both the right (Apennine) and left (Alpine) tributaries. The River Adige runs not far north of the site, carrying exclusively sediments of Alpine origin. Other alluvial basins characterize the area within 50 km: the Brenta river valley in the north (Alpine origin) and the Reno and Panaro river valleys in the south (Apennine origin). Hence, $^{87}Sr/^{86}Sr$ values are anticipated to vary significantly within a relatively small radius.

Bioavailable strontium baselines have been mapped using an open-source geolithological map of Northern Italy (see http://sgi.isprambiente.it/GMV2/index.html), through Quantum GIS software

(Figure 4). Ten different "geolithological zones" have been identified, where strontium isotope ratios are available and a framework of northeastern Italy has been summarized in Table and Figure 4.

Thirty-five new baseline values have been produced within the present study, analysing animal tooth enamel from Bronze Age sites (Sant'Eurosia, Casinalbo, Fondo Paviani) or modern snails found on targeted geolithological units at different distances. Ancient faunal remains have been considered to represent an average bioavailable Sr isotope composition over their feeding area (Bentley 2006; Price *et al.* 2002). However, it is very unlikely that humans and domestic animals ate food from distinct locations, marked by different isotope compositions.

Tafuri *et al.*'s recent work has indeed demonstrated for the *Terramara* at Fondo Paviani (as well as for other *Terramare* sites) that cattle, sheep/goats and domestic pigs were fed with C_4 plants, presumably millet (Tafuri *et al.* 2018), which was also identified in the pollen series and phytolith record from the site (Dal Corso *et al.* 2017). This means that, during the Terramare period and also presumably at Frattesina, animals were almost certainly fed with fodder cultivated in the surrounding fields, and for this reason their strontium isotope composition most likely reflects the local baseline. Obviously, animals could also be part of gifts/exchanges with other distant communities and, therefore, this source has to be considered critically in comparison with other sources, but aids in validating the inferred bioavailable ranges. For our study, we have added snail shells, also used by several authors as an indicator of the locally bioavailable strontium source (Emery *et al.* 2018; Frei & Price 2012; Bentley *et al.* 2002; Wright 2005; Nafplioti 2011; Laffoon *et al.* 2012; Shishlina *et al.* 2016; Panagiotopoulou *et al.* 2018; Evans *et al.* 2010). Some authors have pointed out that land snail shell $^{87}Sr/^{86}Sr$ can be biased towards values for soil carbonates; nonetheless their values are usually close to those of ground vegetation (Maurer *et al.* 2012).

The analysis of vine branches for wine 'authentication' or geographic traceability both north and south of the River Po represents another source of biologically available strontium baselines (Aviani 2013; Trincherini *et al.* 2014; Durante *et al.* 2015; Durante *et al.* 2016).

We have also taken into account chemical analyses of natural mineral waters (Voerkelius *et al.* 2010). The work by Voerkelius *et al.* is relevant for comparison with the nearest baselines, but strontium isotope ratios from spring waters can only be used with caution, as they represent a very locally-specific kind of evidence, while an individual's diet is an admixture of different sources from a specific, but wider, area.

The Po Plain is one of the most intensely exploited regions of Europe, with extremely few uncultivated, non-urbanized areas. A very recent detailed Sr isotope survey in Poland (Zieliński *et al.* 2016; Zieliński *et al.* 2018) showed that the modern biosphere (animals) and hydrosphere (surface waters) can be contaminated by anthropogenic strontium derived from agriculture, industrial and municipal sources. For that reason, comparison of multiple sample types is necessary to achieve a robust isoscape. Following Emery *et al.*'s 'first map' (Emery *et al.* 2018), inspired by a number of examples, all of them interpolating a variety of strontium sources (Evans *et al.* 2010; Nafplioti 2011; Maurer *et al.* 2012; Hartman & Richards 2014; Willmes *et al.* 2014; Laffoon *et al.* 2017), we have considered previous studies, in order to make a comparison between three different sources, namely ancient animals, modern snail shells and modern plants.

However, compared to other 'isoscapes', the strontium isotope map of Italy still lacks in spatial resolution and critical assessment of baselines, which need to be enhanced.

The variation in the currently available strontium isotope ratios for each of the ten geolithological zones is shown in Table 1-SM.

Concerning the different sources of strontium used for baselines, the $^{87}Sr/^{86}Sr$ obtained from different sources at Frattesina appear rather homogenous (0.70853, 0.708639 and 0.70898 for modern snails, 0.70892 for archaeological fauna). We can also compare the values obtained for Emilian Pliocene/Pleistocene limestone: the bedrock yielded a mean $^{87}Sr/^{86}Sr$ of 0.7087, soils 0.7087, snail shell 0.7085, springwater 0.7088, and wine 0.7090. Similarly geolithological zones 1, 2, 7-9 all display narrow ranges from a variety of samples and lithologies. We can therefore conclude that even if there is a slight variation of the isotopic composition, these are nonetheless relatively small, and the eventual impact of anthropogenic strontium (fertilizer/pollution) is negligible. Additional sources for local baselines are nonetheless necessary to refine the preliminary framework presented here.

Buffer zones were drawn around Frattesina at three different radii: 5 km (site catchment area, direct control), 20 km (immediate hinterland), 50 km (broader hinterland), in order to model individual mobility in the territory. Since $^{87}Sr/^{86}Sr$ values within the 5 and 20 km radii are rather uniform in this area, the two buffer zones were unified in a larger 0-20 km zone.

Zone number	**Zone name**	**Geolithology**	**$^{87}Sr/^{86}Sr$ min**	**$^{87}Sr/^{86}Sr$ max**	**$^{87}Sr/^{86}Sr$ mean**	**References**
1	Emilian plain	Holocene alluvial sediments (derived from zone 2 or 3)	0.7084	0.7090	0.7087	Trincherini *et al.* 2014; Durante *et al.* 2015; present study
2	Emilian Apennines	Cenozoic marine sediments (sandstones, limestones, marls, turbidites, flysches, sands, clays, chalks)	0.7085	0.7090	0.7088	Vaiani 2000; Scheeres *et al.* 2013; Durante *et al.* 2015; Argentino *et al.* 2017; present study

3	Upper Taro River valley	Mesozoic ophiolites/green stones and Cenozoic marine sediments	0.7092	0.7109	0.7101	Voerkelius *et al.* 2010
4	Garda's moraine amphitheatre	Pleistocene moraine deposits (from zones 6 and 10)	0.7079	0.7080	0.7080	Present study
5	Mantova or Verona plain	Pleistocene alluvial sediments (from zones 6 and 10)	0.7088	0.7089	0.7089	Francisci *et al.* 2017; present study
6	Lower Adige and Lower Brenta valleys	Pleistocene/Holocene alluvial sediments (from zones 6, 9, 10)	0.7089	0.7107	0.7097	Aviani 2013
7	Colli Euganei	Palaeogene-Miocene volcanics, carbonates, dolomites, marls,	0.7077	0.7088	0.7081	Aviani 2013; present study
8	Colli Berici	Palaeogene-Miocene volcanics, carbonates, dolomites, marls,	0.7072	0.7082	0.7077	Present study
9	Monti Lessini	Mesozoic carbonates and dolomites; Cenozoic basalts	0.7076	0.7084	0.7079	Present study
10	Alps (upper Adige/Isarco river valleys)	Palaeozoic metamorphics and volcanics	0.7132	0.7236	0.7202	Müller *et al.* 2003

Table 1-SM. The ten identified geolithological zones, $^{87}Sr/^{86}Sr$ baselines (minimum, maximum, mean values), and related references.

2. Methods

Cremated bone samples were drilled using the method reported by Harvig *et al.* (2014) and pre-treated following Snoeck *et al.* (2016: 401).

In addition to bioavailable strontium isotope values from the literature (Table 1-SM), baseline samples were taken from pig tooth enamel from the Frattesina settlement and snails from different locations within 20 km of the site.

The demineralization of the samples was performed by acid decomposition: a portion of about 50 mg of samples was dissolved in 10 ml of NHO3 UP 4M.

Ultrapure HNO3 obtained from a sub-boiling system (DuoPUR, Milestone, Bergamo, Italia) and ultrapure 18.2 MΩ water from a Milli-Q (Millipore, USA) system were used for the sample dissolution. HCl of hyperpure grade (Panreac, Barcelona, Spain) was used for sample treatment. SRM-987 isotopic standard from the National Standards and Technology (NIST, Gaithersburg, MD, USA) was used for external precision measurement and method validation. The certified NIST value for the isotopic ratio is $^{87}Sr/^{86}Sr = 0.71034 \pm 0.00026$, which corresponds to an internal precision equal to 0.037%.

The sample solution was loaded into a chromatographic extraction column packed with Sr-resin (Triskem, Bruz, France) where Sr and also Na, K and Ca are retained. A Sr-resin specific method was used (Trincherini *et al.* 2014; Brescia *et al.* 2005) for the elution of the elements and was performed in three steps, using respectively: 5mL 2M HNO3 (fraction 1), 5mL 8M HNO3 (fraction 2) and 5mL of ultrapure Milli-Q for the elution of Sr (fraction 3). The content of Sr, Rb, Na, K and Ca was measured in the solution obtained after mineralization of the samples (a small aliquot of 100 µL was collected just after mineralization) and in each of the three solutions eluted from the chromatographic column. The measurements were performed using the Agilent 7500a ICP mass spectrometer. The solution obtained from the third step of the elution (fraction 3) was then evaporated to dryness and the residue was dissolved in about 50 µL of 1% nitric acid solution, in order to ensure a concentration of Sr suitable for TIMS analysis (≈ 200 µg g-1).

A Thermal Ionization Mass Spectrometer model MAT 262 VMC from Finnigan (Bremen, Germany), located at the Laboratory of Isotopic Mass Spectrometry (LIMS) of Laboratori Nazionali del Gran Sasso (LNGS) was used for isotope analysis. The instrument is equipped with 5 Faraday cups placed in a variable multicollector, with extensive optical geometry, but corresponding to a system that has a conventional geometry, with a 64 cm deflection radius. A characteristic of the thermal ionization source is the stability of the signal, which guarantees a high precision of the measurement. "Zone refined" rhenium filaments were used for sample loading. The double filament technique was adopted. The software Spectromat (Bremen, Germany) was used for data acquisition and analysis;

mass calibration and gain calibration were performed daily (Wieser & Schwieters 2005). Six blocks of ten replicates were acquired for each measurement reaching an associated average internal precision ≤ 0.003%.

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