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Rituals on the move? Unusual dietary habits among non-local elite female “priestesses” at the Hallstatt period cemetery of Modřice, Czech Republic

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Abstract

Dietary analysis using the $\delta^{13}C$ and $\delta^{15}N$ values of 24 individuals and mobility analysis using the $^{87}Sr/^{86}Sr$ ratios of 23 inhumations and 24 cremation burials from the Hallstatt period cemetery at Modřice, Czech Republic, revealed variable dietary structures and degrees of mobility connected with the cemetery's division into separated burial districts. Surprisingly, the lavishly furnished burials of elite females with a likely religious role in the society display some of the lowest dietary proportions of animal protein at the site. Furthermore, their tendency towards non-local $^{87}Sr/^{86}Sr$ ratios implies their non-local origins. These characteristics, along with their allocation into the demographically unique burial district II lacking identified male burials, suggest the deliberate and possibly ritual nature of their dietary omission of meats and/or milk products. The typology of the grave goods accompanying the burials of these elite females, and their unusual attire, suggest links to the South-Eastern Pre-Alpine areas, which might be indicative of a larger trend within the Hallstatt culture. Additional isotopically distinct individuals from Modřice are also discussed, including a potential movement of specialists from the Western Hallstatt culture areas.

Introduction

The Early Iron Age in Europe is inseparably linked to the so-called Hallstatt Culture. Named after the famous salt-mining centre at Hallstatt, Austria, this culture, sometimes considered to be proto-Celtic, ranged across an area stretching from today's France to Hungary (Metzner-Nebelsick 2018). Notable regional variation is apparent, and the culture is traditionally separated into two distinct cultural spheres – the Western and Eastern Hallstatt cultures (Metzner-Nebelsick 2018). In the east, cremation was the dominant burial type, while in the west inhumations were prevalent, with mostly male elites characteristically interred with swords and lavish wagon burials (Metzner-Nebelsick 2018). During the 8th -5th centuries BCE, the society became highly stratified, with clearly identifiable elites in the archaeological record. A ruling elite, possibly closely related (Gretzinger et al. 2024), established its position with hereditary social status (Metzner-Nebelsick 2009; Golec et al. 2023), and other social strata such as craftsmen or religious specialists became apparent (Glunz-Hüsken 2017; Metzner-Nebelsick 2018). Some of the graves might even have become centrepieces of heroized ancestral worship (Metzner-Nebelsick 2018), and in some regions archaeology hints at ongoing centralisation and proto-urbanistic processes (Mírová and Golec 2018; Golec and Mírová 2020; Stegmaier 2021; Chaume 2022). One of the common ways of expressing the elite status of the deceased was their burial with imported prestige items (Trefný 2017; Glunz-Hüsken 2017; Mírová and Golec 2018). The frequent presence of these non-local items in graves and hoards evidence a high degree of interconnectedness in Early Iron Age Europe through trade (Golec and Fojtík 2020), and attest to the prevalent exchange of ideas and cultural elements, as well as forms of expression of economic and political power (Trefný 2017). The local production of these items with foreign elements in some areas also indicates adoptions of these cultural norms, and suggests the potential residential mobility of certain individuals.

The Hallstatt period inhabitants of Moravia in the eastern part of today's Czech Republic sat at a figurative cultural crossroads. The Amber Route, connecting the Baltics with Lower Austria and the Adriatic, passed through this region, bringing amber from the north and luxury goods from the south (Makarová 2017; Mírová and Golec 2018; Golec et al. 2023). Links to the western Hallstatt culture group were provided by the Pannonia-Labe (Elbe) and Danubian Routes (Chmelo 2017; Mírová and Golec 2018). Moravia hosted two major groups of the Hallstatt culture in the 8th -5th centuries – Horákov and Platěnice (Makarová 2017; Golec and Mírová 2020), as shown on Fig. 1. Although both are assigned to the Eastern Hallstatt cultural sphere, notable differences exist between them. For the Platěnice group, cremations and depositions of items in hoards are typical, along with continuous development from the Urnfield period and closer links to the Lusatian culture to the north, whereas the Horákov group maintained close relations with the Upper Danubian region and was clearly influenced by both the Western Hallstatt culture, as is apparent from, e.g., the presence of wagon burials, and the eastern Alpine area (Makarová 2017).

This study aims to explore the life histories of the Horákov people buried in the Modřice cemetery by using analyses of stable carbon, nitrogen and strontium isotopes. Isotopic analyses are an integral part of bioarchaeological research. The isotopic composition of tissues reflects dietary intake, in accordance with the principle that "you are what you eat" (Lee-Thorp 2008). Carbon ($\delta^{13}C$) isotope values identify dietary contributions from C4 plants and marine organisms, which consistently exhibit higher $\delta^{13}C$ values than terrestrial C3 plants (DeNiro and Epstein 1978; Ambrose and Norr 1993). Nitrogen ($\delta^{15}N$) isotope values indicate trophic position within the local food web, as they show enrichment of 3–6‰ along the food chain (Hedges and Reynard 2007; Fernandes et al. 2012; O'Connell et al., 2012). For $\delta^{13}C$ differences between prey and higher-level consumers are generally smaller (~ 1‰; Bocherens and Drucker 2003; Lee-Thorp 2008). Compared to terrestrial foods, aquatic resources display elevated $\delta^{15}N$ due to their typically longer food chains. In freshwater environments, however, both $\delta^{13}C$ and $\delta^{15}N$ are highly variable (Dufour et al. 1999; Katzenberg and Weber 1999). Strontium ($^{87}Sr/^{86}Sr$) isotopic ratios are useful in assessing human mobility due to their regional variability. In organisms, $^{87}Sr/^{86}Sr$ ratios are inherited from local bedrock through erosion, as well as through aerial and water-borne deposition, with little to no change throughout locally based food chains (see e.g., Bentley 2006; Montgomery 2010). In human tooth enamel, $^{87}Sr/^{86}Sr$ ratios reflect the isotopic composition of the diet consumed during its formation. Thus, individuals non-local to the studied site can be identified, providing an insight into intra-life mobility. Due to their resistance to diagenetic contamination, calcined bones can be analysed as well, making the mobility studies of cremation burials possible (Snoeck et al. 2015).

The Modřice archaeological site

The partially excavated cemetery at Modřice (GPS: 49°6'51"N, 16°36'18"E), dated to the 8th -4th centuries BCE, is the largest Hallstatt period burial ground in Southern Moravia identified to date. The site lies on the southern outskirts of the city of Brno, Czech Republic, in the centre of a region where a higher density of elite burials has been documented (Mírová a Golec 2018; Kos et al. 2022), and where

strong centralisation processes in the Horákov group society during the later phases of the Hallstatt period are suggested (Mírová and Golec 2018).

The burial area covers 6 ha with a total of 100 identified graves. The cemetery is bi-ritual with both inhumations and cremations, featuring little uniformity in the overall burial rite. Graves were usually used for multiple burials, often with both burial types. In total, there were 82 identified cremations with a minimum of 38 individuals, and 41 inhumations with 30 preserved skeletons. Inhumations were mostly in the supine position but crouched (flexed) burials are also present. The graves display no unity in terms of orientation. The composition of the funeral ceramics at Modřice has a markedly mixed character, with strong influences from both the Western Hallstatt culture and the South-Eastern Pre-Alpine area, with signs of acculturalisation (Kos et al. 2022). Influences from other regions such as Lower Austria or Silesia are also visible and multiple items of various styles are often present within a single grave (Kos 2011; 2014). An uncommon feature at Modřice (Golec and Fojtík 2020) is its division into 7 burial districts, as shown in Fig. 2. Although only 3 have been studied in greater detail, there are minor differences in the composition of the grave goods. In districts I, II and III Bavarian style pottery was found in greater numbers, while it is completely absent in district VI, where amber jewellery is much more prevalent. District II also stands apart from the other districts in its demographic composition, as it was used predominantly for burials of females and children, with no clearly identified male burials.

The site included an elite wagon grave (grave 3815, district VI) which ranks among the most prominent in the Brno area (Makarová 2017; Golec Mírová et al. 2024). A notable attribute of this grave was an above-ground “house of the dead”, that was continuously developed and expanded throughout the lifespan of the cemetery and used for at least two, and possibly up to four, subsequent burials (Mírová a Golec 2018; Kos et al. 2022). It might have served as a dynastic burial site for a prominent elite family, and/or as an important ritual centrepiece of the society. Another type of elite burial at Modřice are the female burials of the so-called “priestesses” (graves 818, 827), located within district II. These females were buried in very large burial chambers with outstandingly rich grave good assemblages. Their denomination as “priestesses” is based on a garniture analogous to the ritual site of the Býčí skála cave and the votive depot at Roštín (cf. Golec 2017; Golec and Fojtík 2020; Golec and Kos 2020), a presence of votive goods such as belt pendants, and unusual attire. The latter included elaborate bronze circular patches and belts, necklaces, glass, amber and bronze beads etc. (cf., e.g., Egg 1996; Stegmann-Rajtár 2005; Podborský 2006; Bergonzi 2007; Iaia 2007), as shown on Fig. 3. The style of the pottery and other goods suggests a connection with the regions of the South-Eastern Pre-Alpine area, with an emphasis on water-related healing deities of the Venetic type (e.g., Pora-Reitia, Casale, San Pietro Montagnon/Montegrotto: Tirelli 2013; Gambacurta 2013).

Material and methods

All of the osteological and archaeological data for the analysed human remains are available in Kos et al., 2022. Carbon and nitrogen isotope values were measured in the rib bone collagen of 24 inhumations.

The sample set consists of 6 males or probable males, 8 females or probable females, and 10 undetermined individuals, including 4 subadults, all older than 9 years of age.

The collagen extraction was performed at the Department of Anthropology, National Museum, Prague, Czech Republic, following the protocol by Longin (1971) as modified by Boecherens (1992). In short, bone surfaces were mechanically abraded and ultrasonically cleaned in deionised water. After drying, bones were crushed into approx. 0.7 mm fragments and subsequently treated with 1 M HCl for 20 minutes, 0.125 M NaOH for 20 hours and 0.01 M HCl at 100°C for 17 hours. After filtration and freeze-drying, $\delta^{13}C$ and $\delta^{15}N$ values were measured by Elemental Analysis – Isotope Ratio Mass Spectrometry (EA-IRMS), performed at Isolab Scientific, Crewe, UK. Stable carbon and nitrogen isotopic compositions were calibrated relative to the VPDB and AIR scales using IAEA-CH-6 and IAEA-N-1 inter-laboratory comparison standards. Measurement uncertainty was monitored using in-house standards: IA-R068 (soy protein, $\delta^{13}C_{V-PDB}$ = -25.22‰, $\delta^{15}N_{AIR}$ = 0.99‰), IA-R038 (L-alanine, $\delta^{13}C_{V-PDB}$ = -24.99‰, $\delta^{15}N_{AIR}$ = -0.65‰), IA-R069 (tuna protein, $\delta^{13}C_{V-PDB}$ = -18.88‰, $\delta^{15}N_{AIR}$ = 11.60‰) and a mixture of IAEA-C7 (oxalic acid, $\delta^{13}C_{V-PDB}$ = -14.48‰) and IA-R046 (ammonium sulphate, $\delta^{15}N_{AIR}$ = 22.04‰). The total analytical uncertainty as defined by Szpak et al. (2017) was estimated to be ± 0.16‰ for $\delta^{13}C$ values and ± 0.18‰ for $\delta^{15}N$ values.

From 23 of these individuals tooth enamel of the 1st (or 2nd molar where M1 was unavailable) was collected for mobility analysis using strontium isotopes. Mobility analysis was also performed on an additional 24 cremation burials, of which 10 were subadults, with at least 6 of them dying before reaching 6 years of age. Age estimation was not possible for further 5 individuals. Sex was estimated in only 6 cases and included 1 probable female and 5 probable males. All samples come from long bone fragments as no petrous bones were preserved. The main criterion for cremation sampling was signs of calcination of the bones (a clearly white colour), which was confirmed by FTIR prior to the analysis. For details see Supplementary material S1.

The sample preparation for strontium analysis followed the protocol described by Snoeck et al. (2015). In short, bone and teeth surfaces were mechanically abraded using a diamond coated drill and ultrasonically cleaned in deionised water for at least 30 minutes. Ultrasonication in 1 M acetic acid followed, 30 minutes for teeth and 3 minutes for calcined bones. The cleaning was finalised by several rinses and an additional ultrasonication in deionised water for 10 minutes. The water and acid were frequently changed through the process. After drying, the bone or enamel powder was collected in sealed microtubes by drilling into the bone fragment or tooth crown. Sr separation was performed in a clean laboratory of the Geological Institute of the Czech Academy of Sciences, Prague, Czech Republic. Tooth enamel was decomposed at 80°C using 2 ml of 14 M HNO_3 for ~ 3 h, dried down, and re-dissolved using 1 ml of 1 M HNO_3. Sr separation was achieved by the ion exchange technique with a Sr-specific resin (Pin et al., 2014). The $^{87}Sr/^{86}Sr$ isotopic analyses were carried out on W filaments in the presence of a Ta activator using a Thermo Triton Plus thermal ionization mass spectrometer (TIMS). The NIST SRM 987 solution yielded a $^{87}Sr/^{86}Sr$ ratio of 0.710251 ± 0.000014 (2SD, n = 39) during the study.

Dietary analysis is supported by comparative bone collagen samples from 7 bovids, 7 pigs and 6 sheep/goats. The local $^{87}Sr/^{86}Sr$ range was estimated as 0.7097–0.7119 based on measurements of 10 pig tooth enamel samples, 2 water samples and 5 homogenised plant samples. Due to the limited availability of reference samples, however, this range very likely overestimates the influence of more radiogenic areas compared to areas with lower $^{87}Sr/^{86}Sr$ ratios that were more suitable for food procurement. More details are provided in Supplementary Material S1.

Results

The measured $\delta^{13}C$ and $\delta^{15}N$ values and $^{87}Sr/^{86}Sr$ ratios are provided in Supplementary Material S2 and presented in Figs. 4 and 5. All but three collagen samples passed the quality criteria, the exceptions being human remains from graves 1860 and 3815 and animal sample MODF09, where extraction failed to provide any measurable collagen.

The $\delta^{13}C$ and $\delta^{15}N$ values of animals, shown in Fig. 4, averaged − 20.8 ± 0.7‰ and 7.6 ± 1.4‰, respectively. No species-based differences are apparent in $\delta^{13}C$ (Kruskal-Wallis, p = 0.1453) but are present in $\delta^{15}N$ (Kruskal-Wallis, p = 0.0020), with bovids having notably lower values.

Human $\delta^{13}C$ values averaged − 18.5 ± 0.6‰, ranging from − 20.1 to -17.8‰, while $\delta^{15}N$ values averaged 9.9 ± 0.8‰, in the range 8.5 to 11.7‰. Human $^{87}Sr/^{86}Sr$ ratios ranged from 0.70979 to 0.71346, with an average of 0.71086 ± 0.00084. Measured $^{87}Sr/^{86}Sr$ ratios differed significantly (Wilcoxon test, p = 0.0019) based on the burial rite, with average $^{87}Sr/^{86}Sr$ ratios of 0.71130 ± 0.000998 for inhumations and 0.71043 ± 0.00027 for cremations. Among inhumations, significant differences in $\delta^{15}N$ were present based on burial district (ANOVA, p = 0.0030). Although this significance is lost for $\delta^{13}C$ (Kruskal-Wallis, p = 0.3823), likely due to the high variability in district VI as can be seen in Fig. 6, $\delta^{13}C$ values of each district differ too. District-based differences were significant for $^{87}Sr/^{86}Sr$ as well (Kruskal-Wallis, p = 0.0257), with generally higher and more variable $^{87}Sr/^{86}Sr$ ratios in districts I and II and lower $^{87}Sr/^{86}Sr$ ratios in districts III and VI. For inhumations, no sex-based differences were identified in $\delta^{13}C$ (Welch t-test, p = 0.3394), $\delta^{15}N$ (Wilcoxon test, p = 0.3453) or $^{87}Sr/^{86}Sr$ (Wilcoxon test, p = 0.9546).

Discussion

The animal diet generally appears to be based on C3 plants, with no or only very limited input from C4 plants. One pig specimen was fed human refuse, as its isotopic values are almost identical to human. Conversely, with human $\delta^{13}C$ values averaging − 18.4‰, millet likely represented an important, although not dominant, dietary component, as a $\delta^{13}C$ value of -18‰ is generally considered a borderline indicator of substantial C4 plant consumption (Le Huray and Schutkowski 2005). The average difference of 2.3‰ between the $\delta^{13}C$ values of fauna and humans, exceeding the trophic step increase of ~ 1‰, also confirms that millet was used exclusively for human consumption. Dietary outliers are present as well,

however, as no millet was likely consumed by a female from grave 808 (δ^{13}C value of -20.1‰). Animal protein intake at Modřice appears highly variable, as the range in human δ^{15}N values is within a trophic step increase, reaching 3.2‰. Clearly, individuals with δ^{15}N values over 11‰ (graves 2898, 3808, 3814) consumed substantial amounts of meat and/or dairy products or freshwater fish, whereas in others this protein intake was considerably more limited. Unfortunately, it is not possible to link high animal protein consumption with any burial aspect, as the archaeological information in the aforementioned cases is very limited. Interestingly, grave 2898 is a crouched burial of a presumed female located in the entrance of the “house of the dead”, containing elite wagon grave 3815, the latter unfortunately failing to yield any measurable collagen. An analogous crouched female burial in the doorway of a “temple” at Modřice (grave 802), however, displays a rather unremarkable diet, with average animal protein and slightly higher millet consumption.

This latter burial (grave 802) is, on the other hand, one of the 7 non-local individuals with $^{87}Sr/^{86}Sr$ ratios outside of the estimated local range, a group that also include the elite female from grave 818. The total number of migrants, however, is likely underestimated (see Supplementary material S1). The highest $^{87}Sr/^{86}Sr$ ratio (0.71327) was measured in the male from grave 822, identified as a bronze-working craftsman on the basis of semi-finished bronzeworking products in the grave. Interestingly, the strong typological similarity between the accompanying grave goods and South German artefacts corresponds well with the similarly elevated $^{87}Sr/^{86}Sr$ ratios that were reported in the vicinity of the Hallstatt period Magdalenenberg tumulus in Baden-Württemberg (Oelze et al. 2012). Although an exact place of origin cannot be assessed with certainty, it implies that this might have been a western Hallstatt immigrant who settled in the Modřice area. There, he might even have established a workshop, as crafts similar to his wares were found in other graves at the site (Kos et al. 2022). As such, this may attest to the presumed mobility of such craftsmen and prospectors from the Western Hallstatt culture areas, in search of new resources (Chmelo 2017).

The significantly lower variability of $^{87}Sr/^{86}Sr$ ratios in cremation burials compared to inhumations might suggest that cremation was reserved for inhabitants of local origin. This is, however, unlikely in the case of Modřice. The results are affected by the high prevalence of subadults (10 out of 24), for whom a local origin can be reasonably expected, and by measurements originating from long bones. As bones constantly remodel (Hedges et al. 2007), the measured $^{87}Sr/^{86}Sr$ ratios represent only late life histories, thus leading to a much shorter time period during which migration must occur to be detectable.

Still, two notable outliers are present among the cremations, as shown on Fig. 5. The grave good assemblage of grave 895 in burial district II is not particularly remarkable, but it is nevertheless one of the oldest graves at Modřice and, therefore, might be that of one of the founders of the community. The bone of this isotopically outlying individual displays the highest $^{87}Sr/^{86}Sr$ ratio of the cremation burials, which mimics the elevated $^{87}Sr/^{86}Sr$ ratios of the skeletal inhumations, even though it is located within the estimated local range. As the sampled material originated from a long bone, it is possible that the individual was not of local origin but came from an isotopically different area, and only in the last phase

of life were the non-local $^{87}Sr/^{86}Sr$ ratios partially overwritten by the local strontium due to bone remodelling. The style of the accompanying ceramics also suggests connections to the South-Eastern Pre-Alpine area or Bavaria, further supporting such a hypothesis. The adult male from grave 2892 also displays an outlying $^{87}Sr/^{86}Sr$ ratio (0.70979), the lowest in the whole dataset. This burial was located on the southern side of the four-column above-ground construction interpreted as a “temple”, bearing some degree of similarity to the crouched female “doorway” inhumations (graves 802 and 2898).

Burial districts as the main separator in isotopic data

Distinct differences in both diet and mobility based on the location of the burial strongly suggest that the separation of the cemetery into burial districts, an uncommon feature within the Horákov group, might have stemmed from the presence of different social or cultural groups within the Modřice population. From a dietary perspective, as can be seen in Fig. 6, each of the analysed burial districts displays a different dietary structure. The highest variability occurs in district VI; it includes the individuals with the highest $\delta^{15}N$ values (avg. 10.3‰), with 3 cases reaching over 11‰. Inhumations with some of the lowest $\delta^{15}N$ values, however, are also present in district VI. The difference between the lowest and the highest $\delta^{15}N$ values within this district reaches 2.43‰, being close to the trophic level difference. In terms of carbon, district VI also contains individuals with both rather low and high millet consumptions.

This is in stark contrast with district I which, excluding the outlier from grave 808, displays a rather unified dietary structure, with an average $\delta^{13}C$ value of -18.0 ± 0.2‰, signifying the highest presence of millet in the diet among all the districts. Also, the $\delta^{15}N$ values in district I are slightly lower and notably less variable in comparison to district VI.

For $\delta^{15}N$, the two analysed burials from district III are comparable to district I, but their $\delta^{13}C$ values indicate notably lower millet consumption. The most striking results, however, came from the four analysed burials in district II. With an average $\delta^{13}C$ of -18.5‰, the rate of millet consumption here seems intermediate between districts I and III. These inhumations, however, had the lowest $\delta^{15}N$ values (avg. 8.9‰) in the whole dataset, with a mean human/herbivore spacing of 1.7‰ in $\delta^{15}N$, indicating a generally low intake of animal protein. This is somewhat surprising. The predominance of females and children in the district II may suggest that there was a sex-based difference in access to certain food items, but the overall results at Modřice indicate no such thing. Moreover, no sex-based differences in animal protein consumption have been reported from other contemporary sites (Oelze et al. 2012; Knipper et al. 2014; Nicholls et al. 2020; Armit et al. 2023), with the exception of Magdalenska Gora, where, however, the smaller isotopic variation of females was likely caused by their small numbers (Murray and Schoeninger 1988). The situation is even more confusing as some of the richest burials at Modřice, namely those of the so-called “priestesses” from graves 818 and 827, come from district II. The top echelons of Early Iron Age societies, however, were able access, and indeed did consume, diets rich in animal protein (Oelze et al. 2012; Knipper et al. 2014). Yet this was apparently not true of these elite females at Modřice.

Furthermore, the female from grave 818 was affected by five instances of dental caries, but the male skeleton from grave 3803 (district VI) with an isotopically very similar diet displays several pathologies that can be linked to malnutrition, such as dental hypoplasia and skull bone porosity. Of the four burials in district II for which carbon and nitrogen data are available, only burial 829 had cribra orbitalia, which, however, were accompanied by signs of intensive physical labour. This could indicate that while the elite females in district II might have had a diet notably lacking in animal protein, they were still fed with sufficiently nutritious foods. These pieces of information suggest that the dietary omission of meats and/or dairy may have been deliberate.

Interestingly, an isotopic study has also reported dietary differences between tumuli within a single burial site in Slovenia (Murray and Schoeninger 1988), as has an archaeobotanical investigation of food offerings in Croatia (Šoštarić et al. 2016). In neither case, however, a connection to a particular biological or social aspect was made.

As can be seen in Fig. 7, the burial districts at Modřice also display significantly different mobility profiles. In the districts III and VI there is a clear tendency towards lower $^{87}Sr/^{86}Sr$ ratios, with only one individual having an $^{87}Sr/^{86}Sr$ ratio above the upper local range limit. Coincidentally, this individual is the male from grave 3803, with a diet isotopically similar to that of the elite female from grave 818. Archaeological information in his case, however, is limited, as the grave was likely robbed.

In burial district I, by contrast, four out of eight analysed individuals, including the specialised craftsman from grave 822, display $^{87}Sr/^{86}Sr$ ratios outside the estimated local range. All were buried with artefacts that can be linked with the Western Hallstatt cultural areas, particularly Southern Germany. As previously noted, similarly elevated $^{87}Sr/^{86}Sr$ ratios have been reported from Magdalenenberg (Oelze et al. 2012). While matching local ratios cannot be used as evidence of mobility, $^{87}Sr/^{86}Sr$ ratios of around 0.7105 were also reported for the vicinity of the Hallstatt settlement at Heuneburg in Baden-Württemberg (Stephan 2009; Oelze et al. 2012). Although due to the high mobility of goods through trade, and the prestige status of imported items, non-local objects in graves cannot be considered to be a solid evidence for the non-local origin of an interred individual, it is noteworthy that in the district with a generally higher number of Bavarian-style ceramics such connections are possible.

In district II there is an apparent tendency towards higher $^{87}Sr/^{86}Sr$ ratios, with the lowest ratio of 0.71110 being measured in a 9 year old subadult (grave 1865). The highest ratio (the 3rd highest in the dataset) was measured in elite burial 818, indicating that this female was not of local origin, with a grave good assemblage displaying strong connections to the South-Eastern Pre-Alpine region. Given that the estimated local range may not be accurate due to over-representation of the higher $^{87}Sr/^{86}Sr$ ratios (see Supplementary material S1), and that district II has the highest mean $^{87}Sr/^{86}Sr$ ratio and also includes the cremation burial (895) of a potential non-local founder, the data points towards a generally higher mobility of the individuals buried in this district II. Coupled with their unusual diet lacking animal protein and a demographic profile containing predominantly females and children, it further underlines that this was a special group of individuals.

It could be argued that the variability in $^{87}Sr/^{86}Sr$ ratios described is a consequence of multiple areas of food procurement at Modřice, which would go well with the noted differences in dietary structure. This is, however, an unlikely explanation. The geological area of Modřice is rather uniform, with very fertile soils being located in lowlands around the Svratka river. Additionally, as shown on Fig. 8, the greatest variability in $^{87}Sr/^{86}Sr$ ratios is seen in district I, which has the least variable dietary structure, while the most variable diet is in the least mobile district VI. More areas of food procurement ought also to be visible in a higher $^{87}Sr/^{86}Sr$ variability of the cremations.

Elite females in Hallstatt society

It is clear from the archaeological record that during 8th -5th centuries BCE females were able to achieve elite social status throughout the Hallstatt world. The limited genetic data show that matrilinear lineages were important for Hallstatt period elites (Armit et al. 2023; Gretzinger et al. 2024), and females were clearly able to achieve a prominent position in the hereditary system of the hierarchical social structure (Metzner-Nebelsick 2009). Female wagon burials, their outfitting often indistinguishable from those of men, clearly demonstrate that women were able to attain elite status and possibly even become figures of ancestral worship (Metzner-Nebelsick 2009). Wagon grave 3815 from Modřice, with a continuously developed “house of the dead”, can easily be assigned to the top stratum of society. Although the female buried there represents a subsequent burial that occurred sometime after the partial exhumation of a prominent warrior (Mírová and Golec 2018; Kos et al. 2022), tooth enamel $^{87}Sr/^{86}Sr$ ratio indicating a local origin supports the idea of this female being a member of another generation of a locally established elite with possibly hereditary status. Unfortunately, it was not possible to obtain any additional isotopic data from this grave for further interpretation and comparisons.

Apart from wagon burials, which are absent from the eastern Hallstatt culture group, a different kind of lavishly furnished female burial exists. Although the form of items varies regionally (Metzner-Nebelsick 2007), these females were usually adorned with elaborate jewellery and prestigious goods made of gold or bronze, and provided with tableware (Glunz-Hüsken 2017; Krausse et al. 2017; Wendling 2020; Golec et al. 2023). These graves are also often furnished with religious or ritual objects (Metzner-Nebelsick 2007; Pinagli 2013; Glunz-Hüsken 2017; Wendling 2020; Golec et al. 2023), and symbolism connected to textile production is prevalent throughout Central Europe (Metzner-Nebelsick 2007; 2009; Pinagli 2013; Huth and Kondziella 2017; Wendling 2020; Ložnjak Dizdar et al. 2023). A ritual or symbolic aspect to textile production itself, a female dominated field, has been proposed by multiple researchers (Metzner-Nebelsick 2007; 2009; Pinagli 2013; Huth and Kondziella 2017; Frie 2021). The elite females (graves 818 and 827) from Modřice fall well within this group of ritualistic weavers, with their particular funeral attires and the presence of spindle whorls as well as other ritual or unusual objects in graves. The particular isotopic and demographic attributes of district II, along with similarities in funeral items in lesser and less lavish graves, suggest that their position or role in the society might have been shared with other members of this burial group. As such, the special dietary pattern may represent an additional piece of evidence indicating that the role of these women in society might have been religious.

The connection between diet and ritual in the Hallstatt period can be inferred from the inclusion of various types of pottery, tableware and dishes, along with food items, in graves and hoards (Golec et al. 2022). Apparently feasting was an important part of Hallstatt period rituals (Dietler 1999; Rosiak et al. 2024). A mix of fresh and durable food items, meats and animal parts, cooked meals as well as items intended as a food supply were included in burials (Šoštarić et al. 2016; Kyselý 2018; Hladíková and Kmeťová 2019). Foods intended for the direct consumption of attendees were likely present during the funeral as well (Kyselý 2018; Hladíková and Kmeťová 2019; Golec et al. 2022). Libations and the drinking of alcoholic beverages were also an important aspect of the rite (Huth and Kondziella 2017; Józefowska et al. 2024; Rosiak et al. 2024), in which females might have played a central role (Metzner-Nebelsick 2007; 2018). Apart from funerals, the existence of a food taboo concerning the consumption of freshwater molluscs has been proposed (Metzner-Nebelsick 2023). This implies a certain symbolism of foods and their consumption in the spiritual world of the Hallstatt period and, recalling the likely deliberate omission of animal protein in the diet of Modřice's elite females, it can be questioned whether some form of this symbolism was present in the ordinary lives of individuals engaged in the ritual aspects of the society as well.

The unusual features of the clothing of the females from Modřice also contain strong links to the South-Eastern Pre-Alpine region, which can often be seen among other elite female burials in Central Europe (Krausse et al. 2017; Metzner-Nebelsick 2018; Golec et al. 2023). Their tendency towards non-local $^{87}Sr/^{86}Sr$ ratios aligns well with the proposed higher mobility of elite women, possibly linked to matrimonial alliances (Dizdar 2020; Dizdar and Kapuran 2021; Frie 2021), as well as with signs of transalpine female ancestry in the DNA of the South-German Hallstatt period elites (Gretzinger et al. 2024). Coincidentally, in the Dolenjsko region of today's Slovenia, lavish burials adorned with gold and numerous cult items emerge during the 7th century BCE, which have been attributed to women likely fulfilling a religious role in society (Guštin and Preložnik 2005). In this region, textile production represented an important aspect of the economy, and included the production of high-quality textiles intended for elite networks of trade and diplomacy (Frie 2021). Admittedly, no direct isotopic connection between Modřice and Dolenjsko or the wider North Adriatic region can be made with the currently available data. The Modřice dataset is also clearly too small to be considered as irrefutable evidence for these implications concerning the whole of Central Europe. Nevertheless, as Mediterranean religious ideas managed to reach such distant regions as modern Poland (Józefowska et al. 2024), it is legitimate to ask whether some religious aspects of Early Iron Age societies might have originated in the Pre-Alpine region, and if it might be possible that female mobility might have been important in shaping the cultural identities of the Hallstatt period.

Conclusion

The isotopic analyses of the Hallstatt period cemetery at Modřice have shown that its division into burial districts likely reflects groups of people with different origins and dietary habits, who maintained their separation even in the burial space. It attests to a high interconnectedness within Hallstatt period

Europe, and suggests that the archaeologically visible movement of goods was likely accompanied by a notable mobility of people, with possible settlement by originally non-local elites and specialists from the Western Hallstatt culture in the centre of the Horákov group.

On top of that, burial district II stands out for its predominantly female occupancy, non-local origins and dietary structure, with likely imposed dietary restrictions. This limitation of the dietary intake of animal protein is particularly unexpected in the lavish burials of elite females with unusual attire, strong links to the South-Eastern Pre-Alpine area, and a presumed religious role in society. As it is clear that the intensive trade connections of the Hallstatt period transferred not only goods but also ideas, it may be appropriate to ask whether these elite females might have been the carriers of those ideas.

Declarations

Competing Interests:

The authors declare that they have no known conflict of interest.

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Author Contribution

The archaeological background and historical context was provided by PK. The osteological material was curated and sampled by ZT and SDK. Sample preparation and collagen extraction for dietary analysis were performed by SDK. Sample preparation for mobility analysis was performed by ZV. RS performed the FTIR analysis of the cremated bones and provided relevant figures. Isotopic data have been interpreted by ZV and futher refined by all authors. The first draft of the manuscript was written by ZV. All authors reviewed and commented on the manuscript.

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Data Availability

All measured data are available in the Supplementary Material of this article.

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Figures

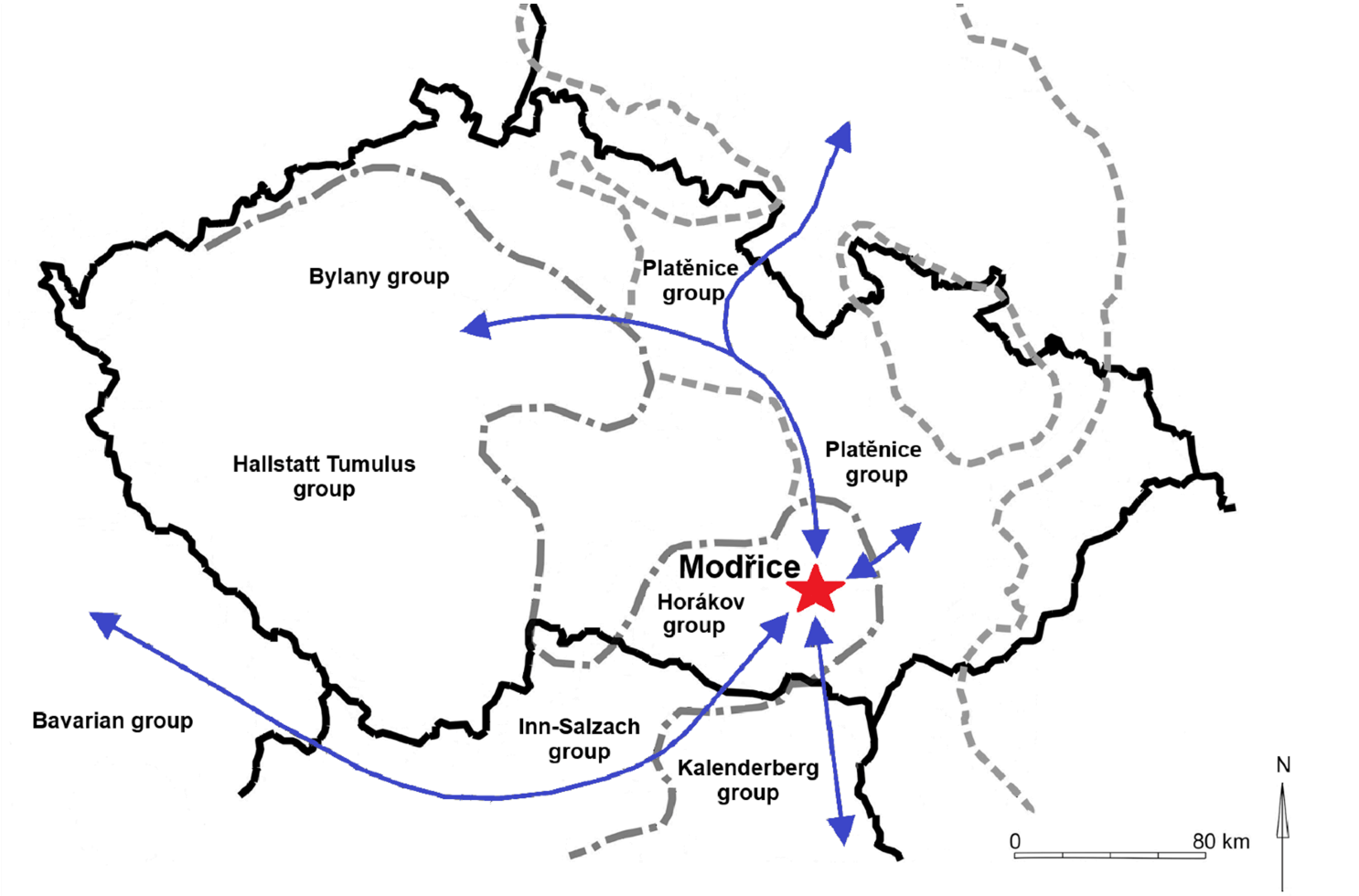


Figure 1

The location of the Horákov group and the Modřice site (CZ) among selected Central European Hallstatt culture groups with directions of documented supra-regional interactions. Map modified after Kos et al. (2022).

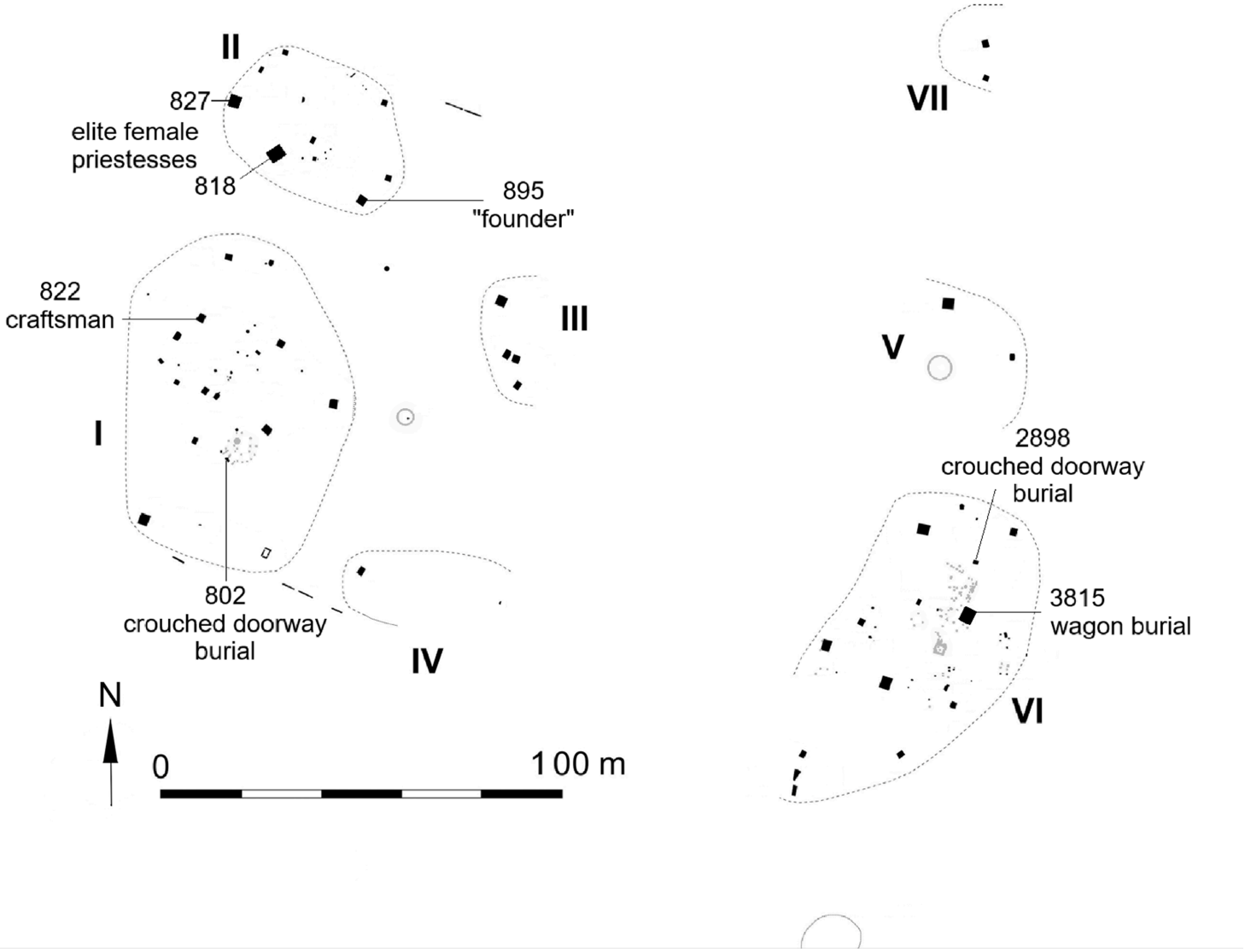


Figure 2

Map of the Hallstatt period cemetery at Modřice. Roman numerals denote burial districts. Structural elements of the above-ground constructions shown in grey, identified graves in black. Several noteworthy burials mentioned in the text are shown. Modified after Kos et al. (2022).

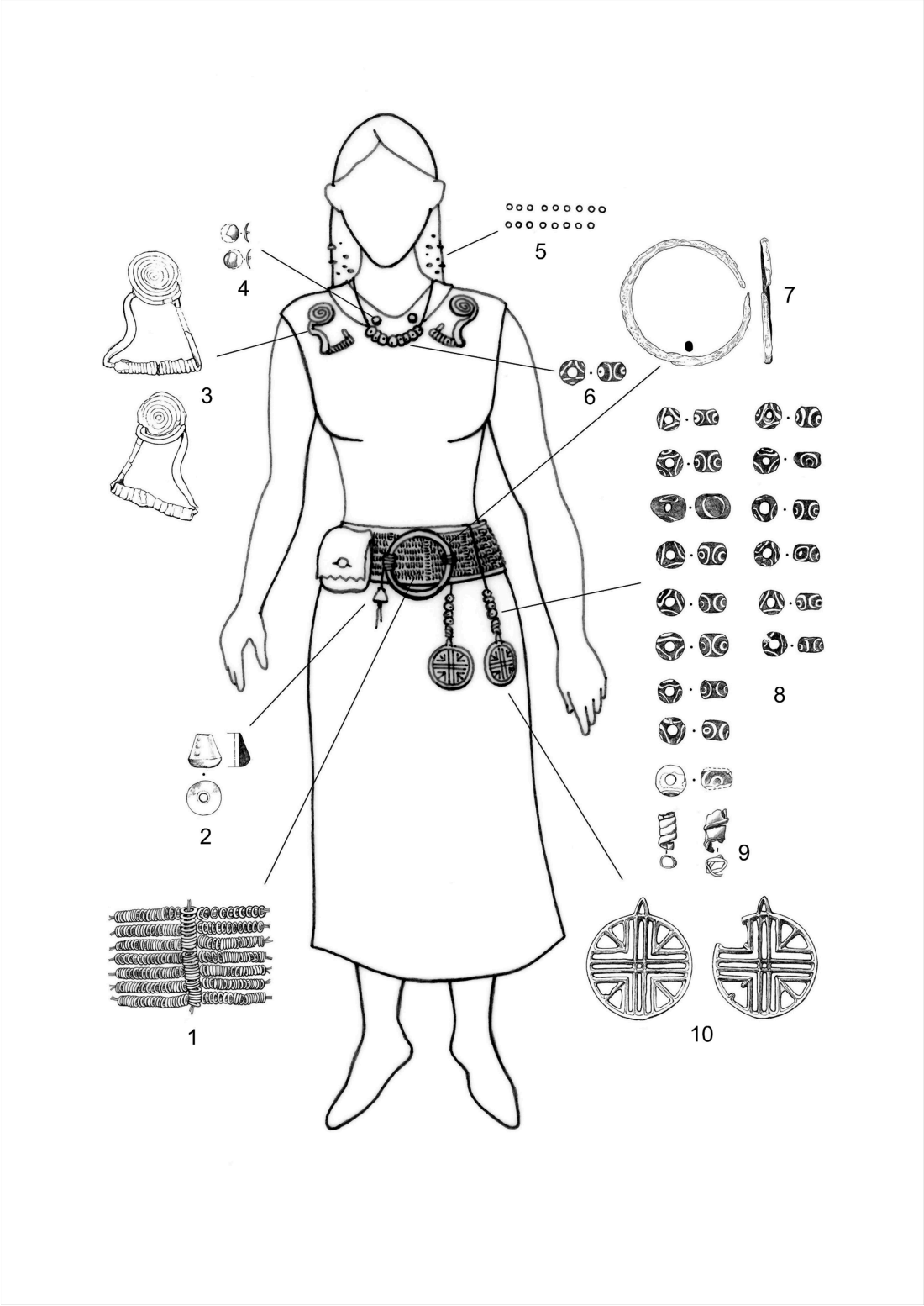


Figure 3

Funeral attire of the elite female from grave 818 at Modřice. 1 - composite ring belt, 2 - pottery spindle whorl/bead, 3 - iron fibulae, 4 - bronze buttons, 5 - necklace or hairstyle appliques made of small glass and bronze rings, 6 - necklace with glass beads, 7 - iron belt ring, 8 - hanging cords with glass beads, 9 - bronze spirals, 10 - bronze pendants. Image taken from Kos et al. (2022).

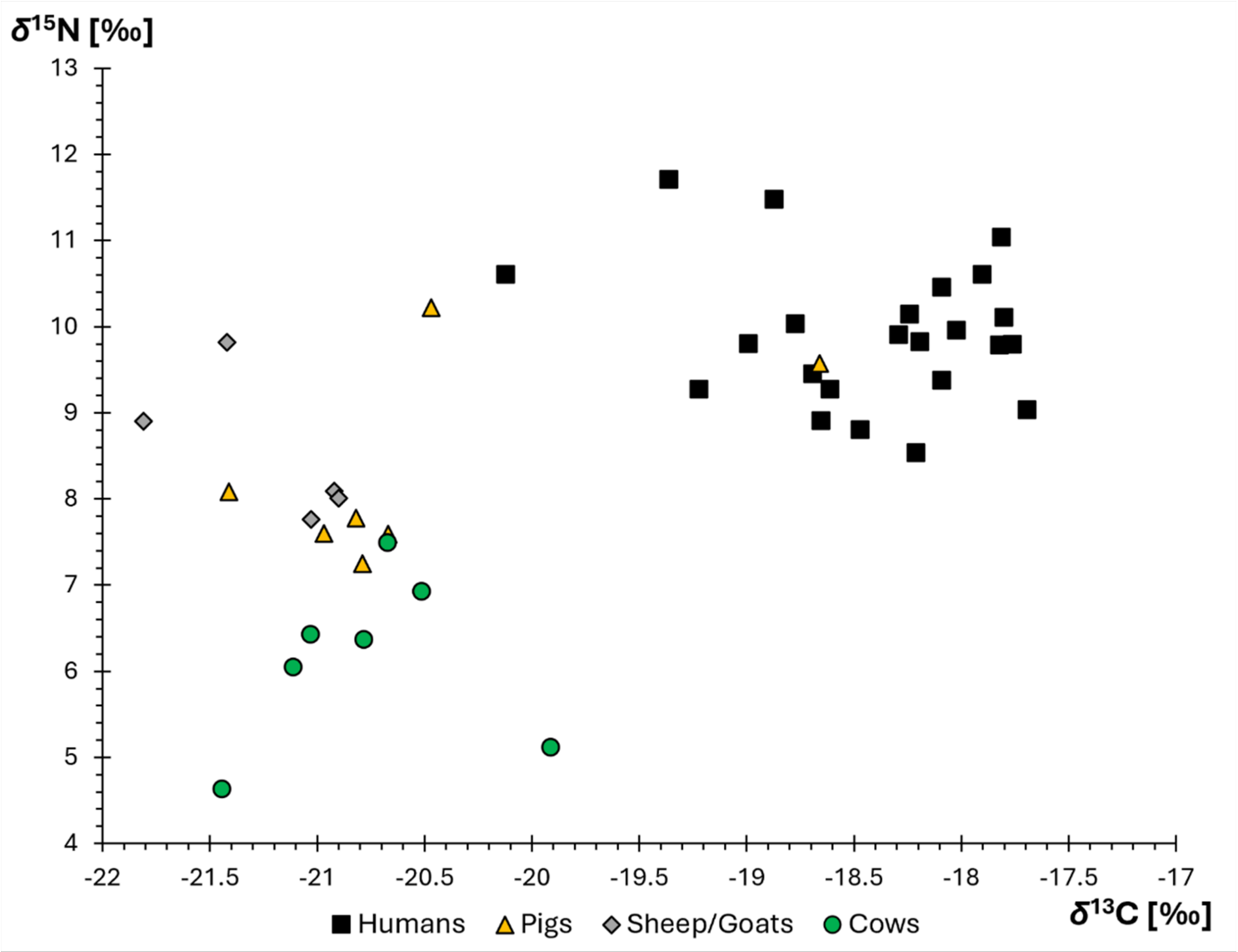


Figure 4

Measured $\delta^{13}C$ and $\delta^{15}N$ values from Modřice

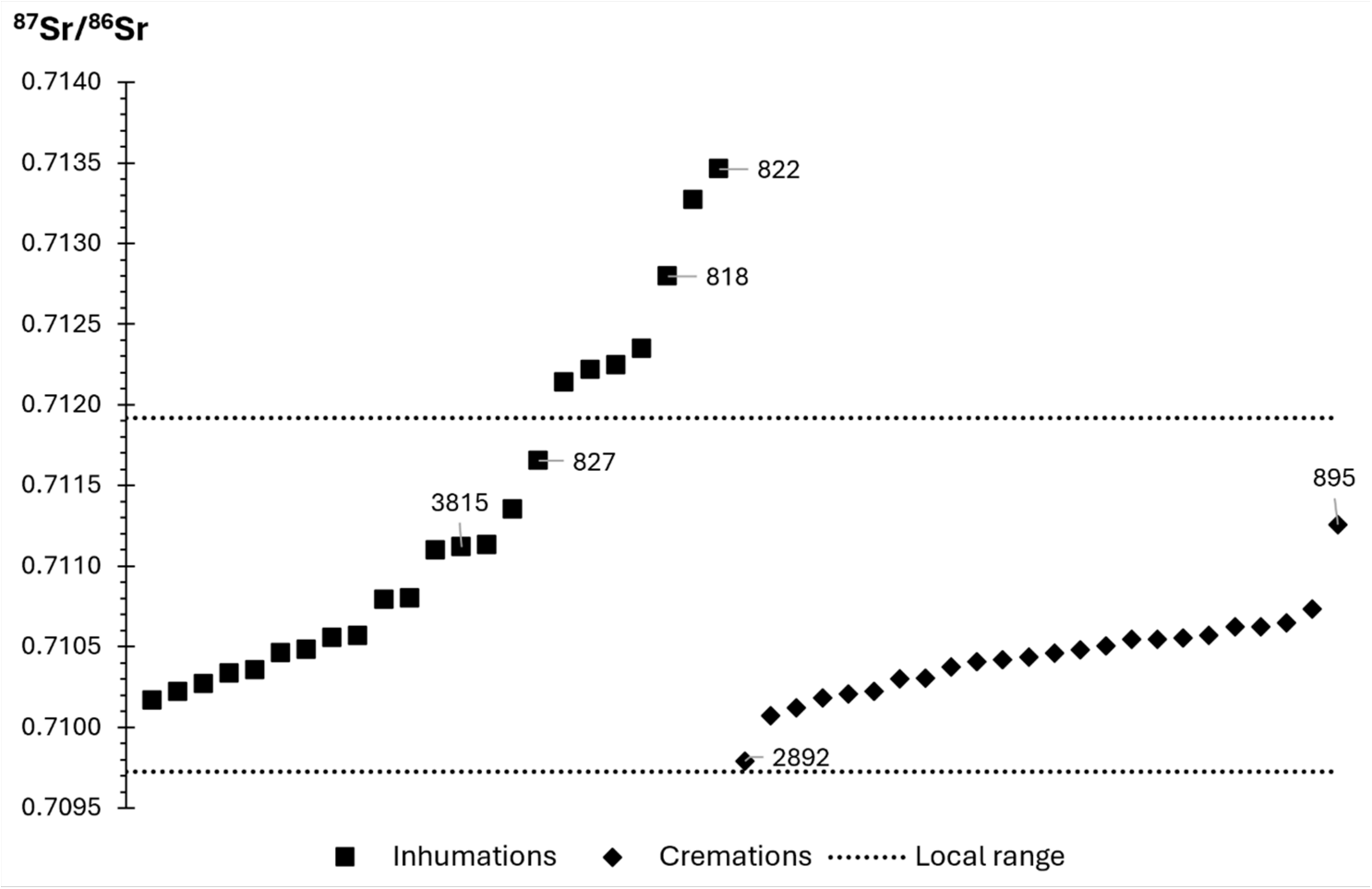


Figure 5

Measured $^{87}Sr/^{86}Sr$ ratios of human inhumations and cremations from Modřice. Several graves mentioned in the text are shown.

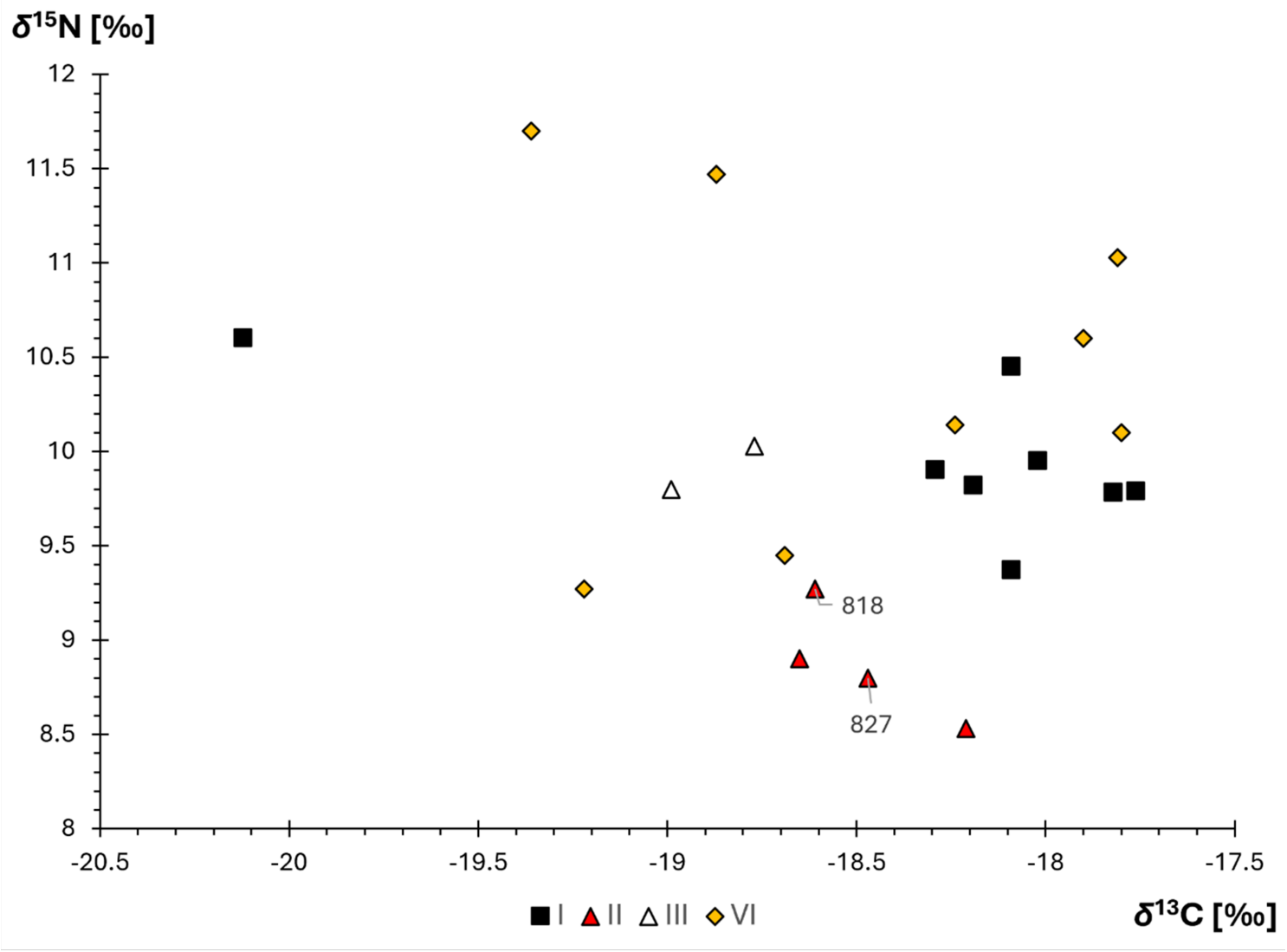


Figure 6

Measured $\delta^{13}C$ and $\delta^{15}N$ values from human inhumations at Modřice, separated by their burial districts. Elite “priestesses” with their respective grave numbers are shown.

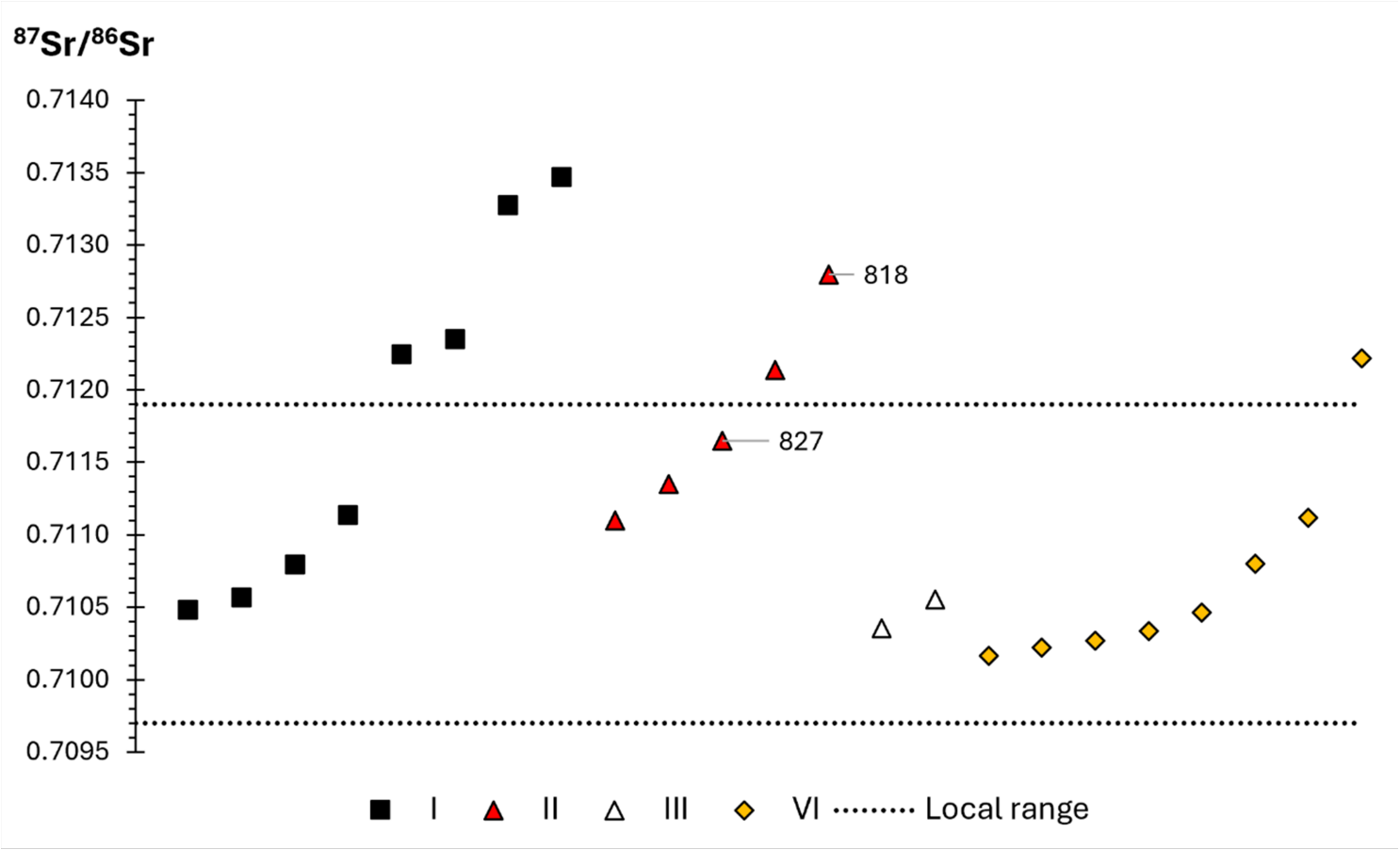


Figure 7

Measured $^{87}Sr/^{86}Sr$ ratios from human inhumations at Modřice, separated by their burial districts. Elite "priestesses" are shown.

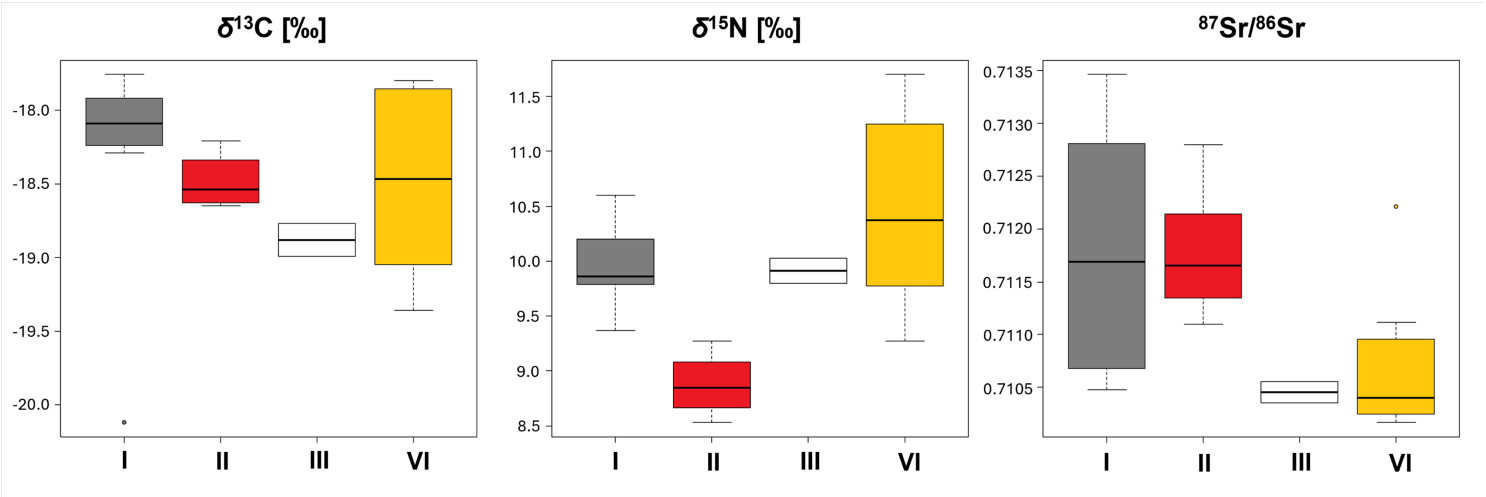


Figure 8

Boxplot comparison of the measured isotopic data from inhumations at Modřice, separated by burial districts.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- SupplementaryMaterialS1.docx
- SupplementaryMaterialS2.xlsx