ANTHROPOLOGIE • LVI/1 • pp. 39–52 • 2018

ANNA PANKOWSKÁ, MARTIN MONÍK, MAREK NECHVÁTAL

READING THE SILHOUETTES OF BURNT DEAD: USING ELEMENTAL ANALYSIS (PXRF) TO IDENTIFY LATE BRONZE AND EARLY IRON AGE URN CENOTAPHS

ABSTRACT: Deposition of empty urns or urns containing only non-representative amounts of bones is highly sophisticated and enigmatic symbolic act among prehistoric funeral practices. Low presence or absence of bones in burnt burials can be the result of intentional activity of past populations, or high fragmentation of bones, which are then likely to be lost. The aim of this study consists in applying analytical methods (pXRF) to determine whether cremation urn infills contained bone remains, as well as to approach their initial amount. For the purpose of the study we analysed urn infills, bones and surrounding subsoil (total of 35 samples). Discriminant analyses (DA) were carried out in order to identify the elements which best separate soil and the elements which separate infills on the basis of bone amount. Infills of urns without bones differed significantly from those with bones in amounts of P, Al, Ca, and Pb, and were similar to subsoil samples in some aspects. This indicates there have never been any bones in "empty" urns. In our study, we were able to distinguish urn cenotaphs from decomposed burnt bodies and showed that burnt bones chemically affected surrounding soil. The non-destructive pXRF showed itself to be an adequate technique for the analysis of elemental composition of soil and bone samples.

KEY WORDS: Burnt burials – Early Iron Age – Late Bronze Age – pXRF – Urn cenotaphs

INTRODUCTION

Burnt burials form a substantial component of different prehistoric archaeological periods within various socio-economical, environmental and religious conditions, and appear in diverse contexts (Schmidt, Symes 2015, Ubelaker 2009). They occur most frequently in subsurface contexts as secondary deposits in pits or urns. Such burials, in many cases, contain only non-representative amounts of bones or contain no bones

Received 17 March 2017; accepted 19 June 2017.

DOI: https://doi.org/10.26720/anthro.17.08.28.1

at all (McKinley 1993, McKinley 2004). Common explanations for the low presence or total absence of bones in burnt burials are: a) high fragmentation of fragile heat-altered bones and their susceptibility to be lost (Harvig *et al.* 2012); b) indelicate handling with bones during excavation (Pankowska *et al.* 2014) and c) purposeful activity of past populations. The amount of burnt bones deposited in urns and pits is an important variable for advanced social investigation of cremation rites. Poor and empty urns can thus represent both low status individuals and careless retrieval process (McKinley 1997), or instead, high status individuals represented by low amount of bones as a consequence of bone curation and keeping, or their circulation away from mortuary site (Cerezo-Román 2005). Stating possible explanations, however, is just the first step to interpretation. In this article, we are going to show how to distinguish between intentionally and accidentally empty burnt burials by analyzing burial contexts from the Late Bronze and Early Iron Ages in Bohemia (Czech Republic). Using chemical elements of soil samples and burnt bones, we identify the originally empty burnt burials.

Context and possible explanation of empty urns

Empty urns from the Late Bronze and Early Iron Ages are not uncommon in Central European territory (Nekvasil 1988). Similarly to other forms of secondary burials, burnt burials are consequences of multi-stage processes when bone absence or their small amounts in urns may be caused by deliberate selection of a few burnt individuals for burying, or by collecting just symbolic remains from each individual from the pyre. Also collection of a limited number of bones from older burial grounds has been evidenced (Smith, Brickley 2009). Contexts of empty urns are usually variable. There can be more of them within the pit, some upside down, other covered with a hollowed cup, where holes are frequently interpreted as soul-exits (Nekvasil 1988). Empty burial pits are known as cenotaphs. Limited amounts and scattering of bones is sometimes interpreted as deliberate secondary intrusion connected with ritual activities or looting. Similar activities are evidenced stratigraphically at some necropolises as well (Nekvasil 1988). Empty urns are also evidenced outside Central Europe. McKinley (1997) terms them *token* and (Stutz, Kuijt 2014) remark that such burials are evidence of the fact that many European Bronze and Iron Age urns are too small to contain whole adult human body. As for bone content in urns, Oestigaard (2013) estimates the average to be 10–20% of the adult skeletal weight. The absence of bones or their reduction seems to be a cultural marker evidenced across wide areas. Parts of burnt individuals might have been deposited at different places or scattered in water, air, and other hard-to-detect environments. The final archaeological record of burnt bones thus represents just residual amounts of bones from long-term and multi-stage burial processes.

An alternative explanation of small bone quantity is their high fragmentation. Larger fragments are less likely to be lost (Smith, Brickley 2009) whereas the presence of large fragments also correlates with a large amount of bones. Furthermore, the strong positive correlation between the weight of burials, fragment dimensions and detailed laboratory procedures (micro-excavation) became obvious in our previous study (Pankowska *et al.* 2014). Using micro-excavation, we eliminate methodological bias as a cause of the low preservation of burnt bones, and we are left with two possible explanations of empty urns: 1. taphonomic factor on one hand, i.e. the decomposition and loss of bones in the sediment, and 2. cultural bias, i.e. non-deposition of bones in the urn on the other. To distinguish which of these two explanations is valid for any empty burial is the basic problem in this study.

Unburnt body silhouettes and soil chemistry

When an empty grave is found and inhumation is suspected, phosphate analysis can be conducted in order to determine whether the body had decomposed leaving only silhouettes, or had never been interred (Ernée, Majer 2009, Holliday, Gartner 2007). Hudson (Hudson 1974) cit. in (Boddington *et al.* 1987) and Keeley et al. (Keeley *et al.* 1977) found that phosphate concentration in silhouettes is higher than in the surrounding soil and in some localized areas the disturbed soil contained more than ten times the amount of manganese compared to deposited skeleton (Mn). Hudson (Hudson 1974) further detected positive correlation of manganese (Mn) with copper (Cu) and recorded higher concentration of boron (B), magnesium (Mg), nickel (Ni) and zinc (Zn) in the silhouette compared to surrounding soil. Keeley et al. (Keeley *et al.* 1977) found that manganese (Mn) content was much higher in the silhouette than in fresh bone. In addition, traces of iron (Fe), aluminum (Al), sodium (Na), and potassium (K) are sometimes identified (Müller *et al.* 2011). Calcium concentrations are also frequently higher in the soil under the decomposed body (Neff 1999).

The reason for the specific minerals' accumulation and percolation in soil is their varied solubility, bone porosity, degree of bone mineral crystallinity, microbial activity, and soil characteristics (pH, soil texture, temperature, underground water etc.). All these mentioned factors must be considered when the processes of body decomposition in soil are studied. Pate and Hutton (Pate, Hutton 1988) suggested that bone diagenesis is better detected by exchangeable elements than by total elemental soil data. Only part of the total number of soil elements is available to interact with bone and therefore, when analyzing soil to study body decomposition, soluble minerals' concentration should be observed. According to Pate and Hutton's (Pate, Hutton 1988) research, major exchangeable elements are calcium (Ca), magnesium (Mg), potassium (K) and sodium (Na) ((Pate, Hutton 1988) in *Table 7*). Bones deposited in soils where environmental conditions are homogenous, pH neutral, and calcium (Ca) and phosphorous (P) concentrations relatively high can survive for a long time.

Microbial activity, bone porosity and bone crystanillity are other major factors that can influence the survival of bones. While neutral pH prevents decomposition of bones, it promotes microbial activity (Hedges 2002). Activity of microbes is highly affected by both environmental and pre-burial conditions. Hedges (Hedges 2002) declares that defleshed, cooked, or thermally processed bodies (bones) are more immune to microbial attack and are better preserved than skeletons buried under standard conditions. Also permanently waterlogged sites and sites with humic acids show few microbial attacks (Hedges 2002). Microbial attacks change elemental concentration in bones, change their histological structure, and in association with the type and density of bones, significantly influence the final preservation of bone tissue.

Burnt body silhouettes and soil chemistry

Decomposition of burnt bodies in soil is usually not expected (Herrmann *et al.* 1990). Perfectly calcined bones (cremated above circa 700 °C) are supposed to be more resistant to decomposition in soil because of their increased mechanical strength, increased crystal size, change to lattice defects and form of additional mineral phases of metamorphosed minerals, depletion of organic components and their transformation to whitlockite (Beckett *et al.* 2011, Thompson 2004, Ubelaker 2009). Burnt bones therefore survive more often than unburnt ones (McKinley 2016). This assumption, however, is valid only in the case of completely calcined bones. A number of prehistoric funeral pyres in Bohemia and Moravia did not achieve sufficiently high and stable temperatures, or regular oxygen enrichment of bones, during the burning process. Corpse and bone fragments were usually irregularly burnt according to body position, type of bones, and amount and distribution of soft tissue (Walker *et al.* 2008). Individual parts of a burial could be completely cremated above 600 °C, however, other parts of the same burial could be burned incompletely (Vitešníková *et al.* 2008). Completely and incompletely burnt bones are recognizable by their color (Devlin, Herrmann 2008), consistency, microstructure (Absolonova *et al.* 2012), and indirectly also by their Ca/P ratio which is around 2.15 in fresh bones and decreases through burning to 1.11–1.46 (Skinner 2013). However, the most fundamental factor for preservation of burnt bones is the presence of organic component. Only bones burnt above 450–600 °C lose their organic component (Schurr, Cook 2014) and can survive in unmodified form. Acidic soils, sandy gravels, and alluvial silty clays, however, can destroy even perfectly calcined bones, in concrete their trabecular parts (McKinley 2016). Assuming imperfect cremation and deposition of remains with organic content (even with residues of soft tissues), we can expect decomposition processes as in unburnt bodies. If the burnt bones had decomposed in soil, significant increase of phosphorous, potassium, calcium, manganese, magnesium, aluminum and iron would have occurred under the decomposed body (Müller *et al.* 2011).

Portable X-ray fluorescence (pXRF) in archaeology and forensic anthropology

Recently, non-destructive compositional analyses by portable X-ray fluorescence (pXRF) have become increasingly widespread in analyses of material culture in archaeology (Craig *et al.* 2007, Frahm, Doonan 2013). Modern pXRF spectrometers have better resolution than those of past decades though sometimes requiring more specialized knowledge (Byrnes, Bush 2016). Portable XRF is inexpensive and makes it easy to quantify chemical analysis of different materials (Hunt, Speakman 2015).

pXRF has been also used in non-human osteology (Buddhachat *et al.* 2016) and forensic science to distinguish human individuals (Gonzalez-Rodriguez, Fowler 2013, Perrone *et al.* 2014, Vodičková 2017), determine osseous and unknown materials (Gilpin, Christensen 2015, Christensen *et al.* 2012, Zimmerman *et al.* 2015) and detect post-mortem lead concentration in human bones (Rebocho *et al.* 2006). Soil discrimination by pXRF was carried out e.g. in Japan (Hiraoka 1994), where selected elements from soil samples determined nine types of soil. Further research regarding soil analysis and pXRF was conducted to locate archaeological sites and define human activity (Oonk *et al.* 2009, Wilson *et al.* 2008, Šmejda *et al.* 2017). The knowledge of soil and bone chemistry can give social and household archaeologists the ability to observe past population in action (Robin 2002). Regarding cremation, pXRF scans were performed to identify and quantify metals on the surface of bones in Tomb II at Aegae Point (Antikas, Wynn-Antikas 2016). XRF scans have detected traces of gold, iron and lead. Furthermore the utility of pXRF as an analytical tool for forensic odontology in cremated victim identification was demonstrated by (Bush *et al.* 2007). To our knowledge, no research using pXRF in association with body decay in soil or burnt burials has been conducted up to date.

AIM

The aim of this study is to explain the origin of empty urns using chemical content of their infills. The question is whether we can distinguish empty urns as consequences of intentional action from accidental postdepositional processes. If burnt bones do not decompose in the sediment, chemical composition of the infill and surroundings is assumed to be the same.

MATERIAL

We studied 35 bone and soil samples from 17 burnt burials from Ostrov u Stříbra site (Czech Republic). For chemical analysis, we collected: a) burnt bones (n = 10); b) infills directly from around the bones (n = 17) and c) several control samples from the surrounding subsoil (n = 8). Furthermore, we divided the infills into three categories based on the presence of bones and their weight: a) infill with no bones (n = 4); b) infill with bones weighing less than 50 g (n = 5); c) infill with bones weighing more than 51 g (n = 8) (*Figure 1*).

Site characterization

The multicultural site Ostrov u Stříbra is situated in West Bohemia (*Figure 2*) in the Czech Republic.

FIGURE 1: Examples of urn cremation burials represent: a) infill with bones weighing more than 51 g; b) infill with bones weighing less than 50 g (white arrow shows one of six bone fragments); c) infill with no bones.

Archaeological excavation took place there in 2014 under the leadership of K. Postránecká from *Západočeský institut pro ochranu a dokumentaci památek* (in Czech only) (Postránecká *et al.* 2015). This area has been settled continuously since Middle Bronze Age (1500 BC) up to today. Traces of both settlement and funerary activities were evidenced at the site. Funerary activities are represented by 39 graves dating to Late Bronze Age and Early Iron Age (1250–450 BC (Jiráň 2008)). The site belongs geomorphologically to Bohemian Highland (480 m a. s. l.), with luvic cambisol as the predominating soil type. The surface has been significantly influenced by agricultural activities here and many graves were damaged by tillage. Local geological subsoil is formed by metamorphosed Neo-Proterozoic sediments – phyllite slates and greywackes (Seifert, Vejlupek 1992) of Teplá-Barrandian Unit, their Carboniferous cover – mostly clastic sediments, and uncertainly dated porphyres and prophyrites of the Borský pluton. All these rocks had been intensively weathered, giving rise to bright to rusty brown clayey to silty soil with clay admixture which forms the infills of the graves. Subsoil pH is neutral here (7.5–8.0), rather poor in calcium (Ca) and phosphorous (P) but richer in arsenic (As), beryllium (Be), aluminum (Al), and cadmium (Cd).

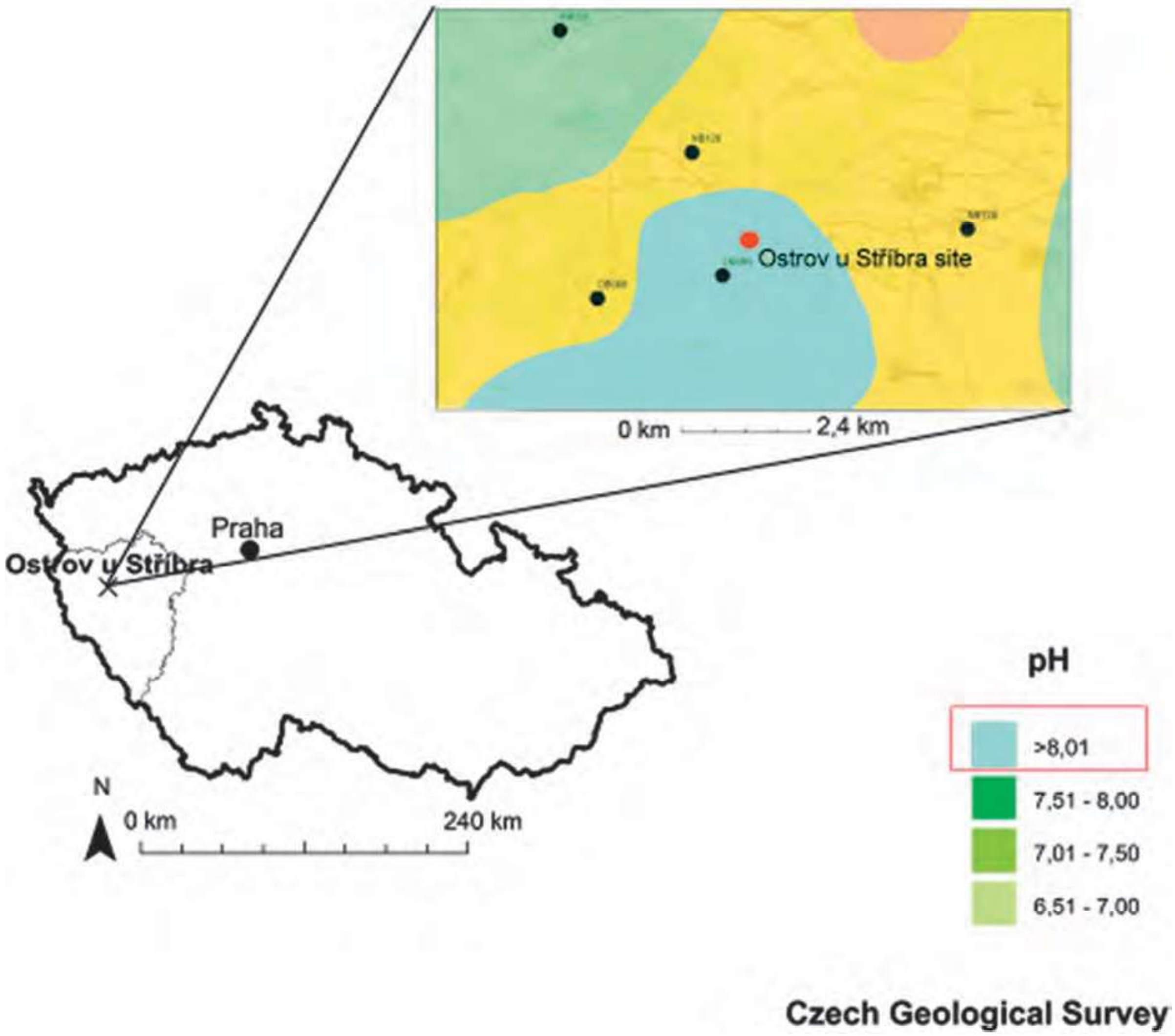

FIGURE 2: Map of the site Ostrov u Stříbra (Czech Republic).

METHOD

For the purpose of our research, we used X-ray fluorescence spectroscopy (pXRF), in concrete the Olympus Innov-X DELTA portable device. To minimize the error caused by large particles from out of the grave or soil, all samples were ground in an agate mortar prior to the measurement. They were then put in plastic cups and covered with a thin Mylar film. The measurements were then conducted in the GeoChem mode targeting an area of approximately 10 mm. Each sample was measured just once, using the voltage of 40 and 10 kV for 240 seconds in each case. Sixteen elements out of 39 tested were detected in the soil and bone samples (from 0.05 up to 15 weight %): P, Al, Si, K, Ca, Ti, V, Mn, Fe, Co, Cu, Zn, Rb, Sr, Zr, Pb. Their concentrations were calculated using fundamental parameters algorithms.

Prior to the measurement, the pXRF device was calibrated with a more robust method, the ICP-MS used at ACME laboratory in Vancouver (Canada). The specifics of the calibration are presented in (Nechvátal 2017) and are given here just briefly: 52 ground samples of soils, rocks and slags were analyzed with ICP-MS. The results were then compared with our pXRF results so that it was possible to use empirical calibration values for each element and modify the calibrations pre-defined in the pXRF device. All samples were then measured again (for 240 seconds) with the calibrated pXRF device; the correlation (regression) functions along with R^2 values are presented in Figure 3 and 4. Not all soil, rock and slag samples contained all tested elements so that the number of measurements for both calibration and final measurement differs accordingly (*Figure 3 and 4*). The elements presented in Table 1 were mostly measured as solid samples, the exception being P and Cu which were measured in solution. The only element which correlates poorly between pXRF and ICP-MS is vanadium. The reasons are explained below. The cases where just three samples for calibration were used (Figure 3 and 4) are those where the element was not present in sufficient amount in the 52 rock samples. In that case, three samples of known amount of given element were prepared in laboratory to calibrate the pXRF device (Nechvátal 2017).

Statistics

For each sample, the assumption of normality was tested by the Shapiro-Wilk test. ANOVA tests were computed to determine which elements are significantly associated with samples. We used the significance level of 0.05 (5%). Discriminant analyses (DA) were carried out in order to identify the elements which best separate soil samples from surroundings from samples from infills, and the elements which separate infills on the basis of bone amount. The power of DA is given by the Wilks' Lambda (McLachlan 1992) which ranges from 0 (perfect discrimination) to 1 (no discrimination at all). The posterior probability is the probability, for each

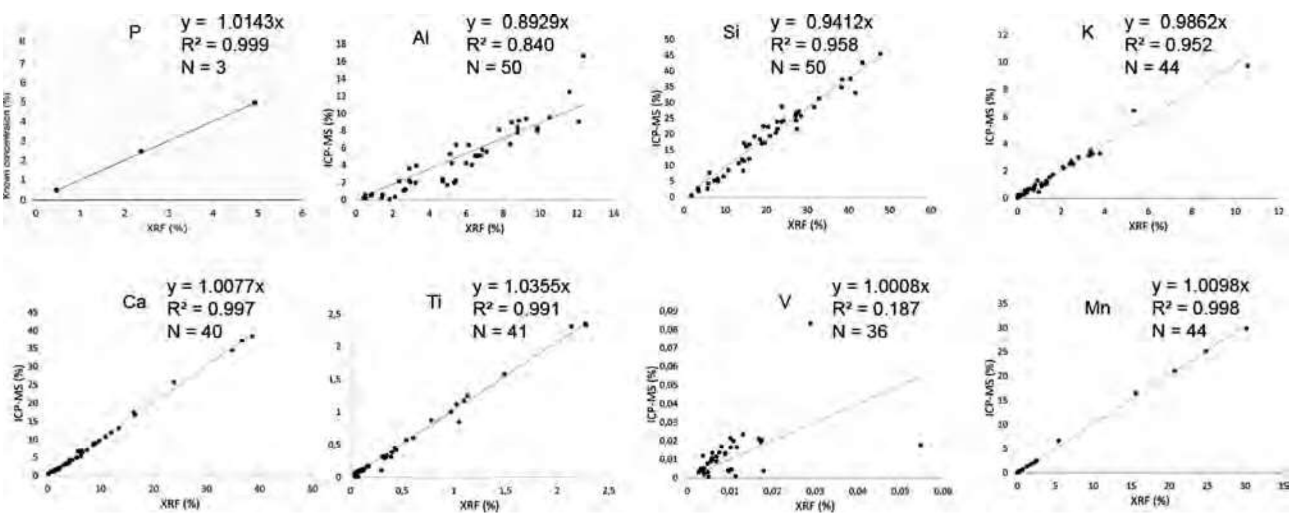

FIGURE 3: Calibration curves between ICP-MS and pXRF measurements after calibration of the pXRF device and, in the case of phosphorous, between known concentration of the element in prepared sample and pXRF measurement. Both precision and accuracy of the used pXRF device are good with the exception of vanadium measurements (see text).

sample, of belonging to one of the groups; it is calculated from the Mahalanobis' distance. For group determination, posterior probability equal or superior to 0.95 was considered to be the threshold. Therefore, DA was evaluated by two criteria: a) the percentage of samples which were correctly classified with $p \geq 0.95$, and b) the accuracy rate (percentage of specimens correctly determined). Descriptive statistics, explorative analyses, ANOVA tests and plot of measurements agreement were done in SPSS 22.

The methodological proceedings included several steps:

1) Testing of pXRF repeatability and reproducibility. We conducted an assessment of agreement between two measurements of soil samples originating from one urn. We tested two samples of one urn infill, from the two different levels. For this purpose we used t-test (at the 0.05 level).
2) Evaluation of Ca/P ratio in burnt bone samples. If the ratio is the same as in unburnt bones (approx. 2.15), it can be assumed that the temperature of burning was low and thus fresh bones with parts of soft tissue had been buried which later decomposed in the soil. Furthermore, we visually assessed the color and surface of bone fragments to estimate the degree of dehydration and oxidation.
3) Differences in soil chemistry depending on presence of bones. First we present a dataset of descriptive statistics and F test with elements which characterize specific soil samples. Furthermore, we used DA for classification of: a) control samples of subsoil vs. all urn infills independently on the amount of bones; b) three categories of infills (infill without bones, infill with bone amount less than 50 g and infill with bone amount more than 51 g); c) all soil samples with respect to the amount of bones in infills.

RESULTS

Testing of pXRF measurements

Agreement between the two measurements of a single urn infill was high. There weren't any significant differences between the first and second measurement (t-test = 0.843; p = 0.41).

Detection of Ca/P ratio in bone samples

The Ca/P ratio was relatively constant in all 10 samples of burnt bone. The mean ratio was 2.21 (*Table 1*). The ratio corresponds to fresh unburnt bones (Tzaphlidou, Zaichick 2003). We assume a low temperature of burning as other factors like diagenetic alteration resulting in increasing Ca/P ratio due to secondary calcium deposition or decreasing in acid soil can be excluded (see below). The color of bones corresponds to low oxidation and dehydration. Bones are yellow to light brown. The conclusion is that bones could have contained organic matrix and could have left chemical trace in the surrounding soil.

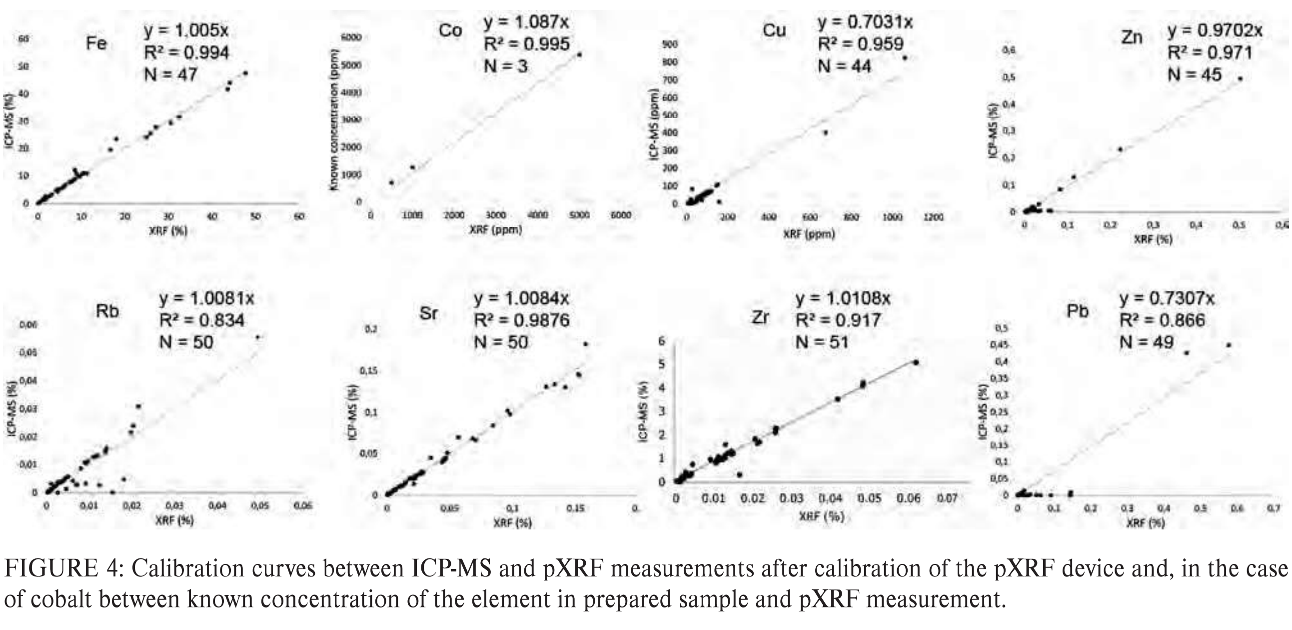

FIGURE 4: Calibration curves between ICP-MS and pXRF measurements after calibration of the pXRF device and, in the case of cobalt between known concentration of the element in prepared sample and pXRF measurement.

Differences in soil chemistry depending on presence of bones

In the first step, we evaluated the difference between subsoil samples and all urn infills. The elements that significantly differed at 0.05 level were P, Ca, Mn, and Sr (*Table 1*). Concentration of vanadium (V) was higher in infill samples at 0.055 significance level in the current data set. All these elements' concentrations increase in infills when compared to surrounding subsoil (*Figure 5a*). Only Si, Cu, Rb, Pb, and surprisingly Fe were less abundant in surrounding subsoil than in infill, the decrease, however, was not significant in any case. Other elements as Al, K, Ti, Zn, and Zr were represented in greater amounts in infills but again the differences were not significant (*Table 1*). From the total of 25 analyzed subsoil and infill samples, 94.1% of original cases were correctly classified. From the total, only 76.1% were correctly classified above or equal to 95% (*Table 2*). Only one case was erroneously classified (case 982 with 1 g of bones), and in cross-validation test one more case (an empty urn) was erroneously classified.

In the second step, we evaluated only three categories of infills according to weight of bones deposited in urns. From all detected elements P, Ca, Mn, V, Zn and Pb significantly differed at the 0.05 level (*Table 1*). Most of these elements' concentrations increase with weight of bones except for the concentration of Pb (*Figure 5a*). Concentrations of Si and Cu decrease with bones (*Figure 5b*) the decrease, however, is not significant. Other elements as Al, K, and Sr increase with bones but this trend was not significant (*Table 1*). Decreasing or increasing trends of remaining elements' concentrations (Ti, Fe, Co, Rb, Zr) couldn't be reliably compared between the three categories of infills. From the total of 17 analyzed urn infills, 94.1% of original cases were correctly classified. However, from the total of 17 samples, only 53.0% were correctly classified above or equal to 95% (*Table 3*)

In the third step, we put together all categories (subsoil samples, infills without bones, infills with bone amounts less than 50 g and infills with bone amounts more than 51 g). The discrimination was unsurprisingly low (only 84% of original grouped cases were correctly classified). The reason for this was close similarity of subsoil category and infills without bones (*Figure 6*). Only 48.9% of samples were correctly classified above or equal to 95%. This result positively discriminated subsoil samples and infills of empty urns from urn infills with bones.

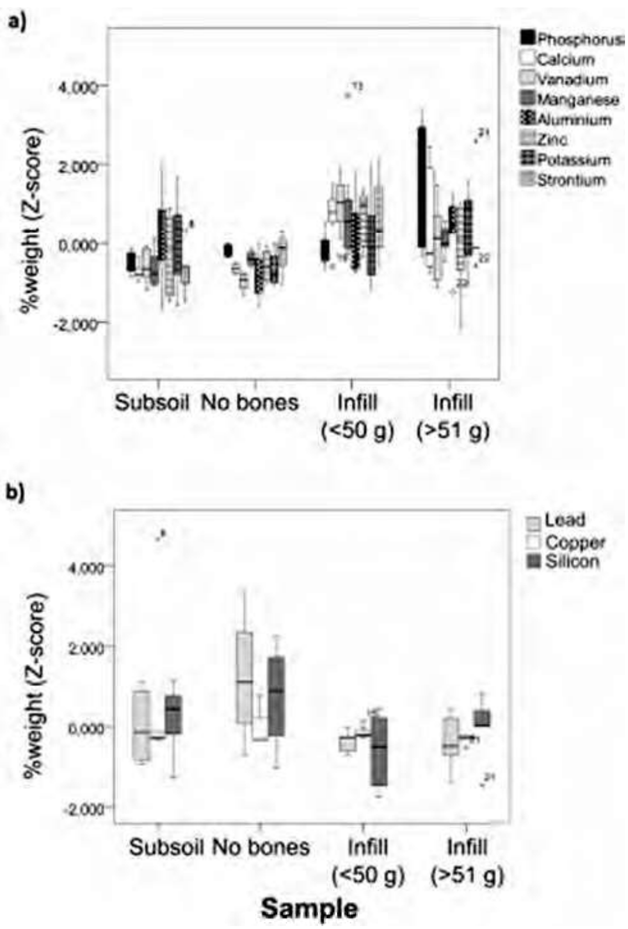

FIGURE 5: Boxplots of element concentrations with observable trends across the samples; a) increasing trend; b) decreasing trend.

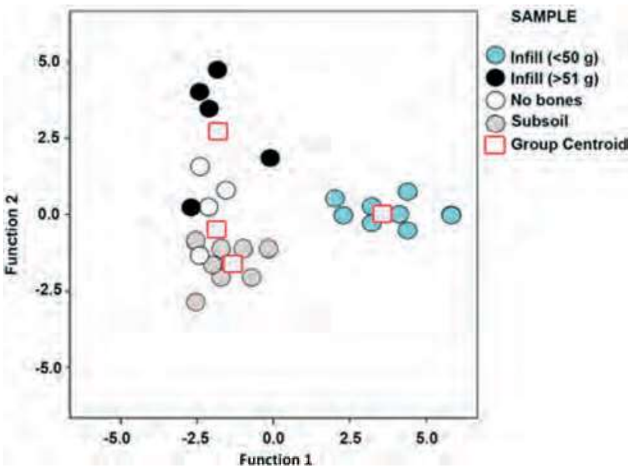

FIGURE 6: Canonical discriminant functions. First two function explain 90.8% of variance.

TABLE 1: Sum of element concentrations (weight %) in the samples with indication of elements increasing in grave infills or along with the presence of bones in graves. * Differences between subsoil and infill samples; ** differences among infills without bones, with bones up to 50 g and above 51 g.

Element		Bones (n = 10)	Subsoil (n = 8)	Infill (n = 17)	F	p value*	No bones (n = 4)	> 50 g (n = 5)	51 g > (n = 8)	F	p value**
P	mean	7.297	0.092	0.402	3.327	0.053	0.169	0.170	0.527	4.505	0.031
	SD	1.958	0.066	0.360			0.065	0.092	0.370		
Al	mean	4.407	6.953	7.365	0.100	0.754	6.125	6.888	7.106	2.270	0.140
	SD	1.215	0.924	0.885			2.066	0.725	2.214		
Si	mean	9.217	16.402	16.174	0.387	0.540	17.290	14.938	15.920	1.874	0.190
	SD	2.700	1.285	1.183			5.487	1.431	4.887		
K	mean	1.259	2.037	2.352	0.004	0.948	1.777	2.057	2.205	1.472	0.263
	SD	0.451	0.390	0.353			0.612	0.386	0.677		
Ca	mean	16.116	0.189	1.045	5.752	0.013	0.247	1.169	1.050	2.984	0.053
	SD	4.749	0.123	0.741			0.089	0.395	0.765		
Ti	mean	0.435	0.517	0.544	0.936	0.343	0.519	0.584	0.543	0.717	0.505
	SD	0.104	0.045	0.043			0.158	0.156	0.135		
V	mean	0.048	0.040	0.058	3.617	0.055	0.034	0.065	0.050	9.574	0.020
	SD	0.015	0.006	0.013			0.012	0.009	0.022		
Mn	mean	0.104	0.046	0.097	5.858	0.012	0.060	0.120	0.083	2.845	0.050
	SD	0.073	0.021	0.033			0.014	0.062	0.022		
Fe	mean	3.420	4.041	4.086	0.117	0.740	3.632	4.503	3.859	0.663	0.531
	SD	1.204	0.611	0.682			1.116	1.418	0.931		
Co	mean	0.000	0.002	0.002	1.807	0.184	0.002	0.002	0.002	1.235	0.321
	SD	0.000	0.000	0.000			0.001	0.000	0.001		
Cu	mean	0.005	0.018	0.006	1.656	0.205	0.010	0.008	0.004	1.039	0.380
	SD	0.002	0.033	0.001			0.032	0.003	0.002		
Zn	mean	0.018	0.017	0.021	0.981	0.332	0.015	0.023	0.017	4.650	0.028
	SD	0.005	0.006	0.004			0.005	0.004	0.008		
Rb	mean	0.007	0.013	0.015	0.380	0.549	0.011	0.013	0.012	0.275	0.763
	SD	0.002	0.002	0.002			0.004	0.003	0.005		
Sr	mean	0.012	0.005	0.006	5.378	0.017	0.005	0.008	0.007	0.810	0.464
	SD	0.002	0.001	0.000			0.002	0.002	0.003		
Zr	mean	0.010	0.021	0.023	0.020	0.891	0.025	0.020	0.019	1.339	0.294
	SD	0.004	0.002	0.002			0.008	0.003	0.008		
Pb	mean	0.004	0.006	0.005	0.001	0.979	0.011	0.005	0.004	4.850	0.025
	SD	0.002	0.004	0.001			0.006	0.001	0.003		
Ca/P	mean	2.21									

TABLE 2: Predicted group membership of subsoil and infill samples. * The percentage of samples which were correctly classified above or equal to p ≥ 0.95;** the accuracy rate (percentage of specimens correctly determined).

Samples			
	Subsoil	Infills	Total
Subsoil	8 (100%)	0 (0%)	8 (100%)
Infills	1 (5.9%)	16 (94.1%)	17 (100%)
Wilks' Lambda	0.350		
Correct classified	76.1%*		
Accuracy	94.1%**		
Cross-validated Accuracy	90.5%		

TABLE 3: Predicted group membership of infill samples. * The percentage of samples which were correctly classified above or equal p ≥ 0.95; **the accuracy rate (percentage of specimens correctly determined).

Samples of infills				
	No bones	< 50 g	> 51 g	Total
Without bones	4 (100%)	0	0	4 (100%)
51 g >	0	8 (100%)	0	8 (100%)
> 50 g	1 (20%)	0	4 (80%)	5 (100%)
Wilks´ Lambda	0.111			
Correctly classified	53.0%*			
Accuracy	94.1%**			
Cross-validated				
Accuracy	82.4%			

DISCUSSION

Our research has shown that infills of urns without bones differed significantly from those with bones in amounts of P, Ca, Mn, Zn, Pb and V, and were similar to subsoil samples in some aspects. Subsoil samples differed from all infill samples in amounts of P, Ca, Mn, Sr and V. Our results indicate there have never been any bones in "empty" urns. On the other hand, even minimal amounts of bones (below 50 g) caused increased values of the elements mentioned above, indicating deliberate deposition of few bone remains with organic component, and their gradual decomposition in soil. Soil properties cannot, in this case, account for the absence of burnt bones in empty burials.

Our results oppose the statement of (Herrmann *et al.* 1990) and (Strand *et al.* 2008) that burnt bones do not decay in soil. However, in the strict sense we can say that only incompletely burnt bones containing some organic component might have decayed in surrounding soil. Burials under this study had been burned at low temperatures. This is suggested by bone color, consistency, and unchanged Ca/P ratio in the bones. The Ca/P ratio serves as indirect evidence that fire temperature wasn't high enough for mineral transformation. An unchanged Ca/P ratio also serves as evidence of absence of mineral modification caused by diagenetic alteration resulting in increasing Ca/P ratio due to secondary calcite deposition (Zapata *et al.* 2006), or decreasing, for example in acid soil (López-Costas *et al.* 2016). Discrimination analysis has reliably categorized all samples in different categories, the reliability was slightly lower just when a 95% threshold was predetermined. The whole discrimination, however, is high as regards archaeological investigation.

Investigations focused on elemental changes of decomposing bodies confirm increased amounts of Ca, P, Mn, Cu, B, Na, Zn, Mg (Hudson 1974, Keeley *et al.* 1977) and also Al, Na and K (Müller *et al.* 2011) around the bodies. The reason of the changes is the substitution of given elements, their accumulation by microorganisms, and geochemical composition of soil. We have confirmed significantly higher amounts of P and Ca in relation with the presence of bones, and statistically non-significant increase of K and Sr. Lead (Pb) decreases significantly and is mostly present in surrounding subsoil. Especially the concentrations of Al, K and Mn have been shown, in previous studies, to be more abundant in buried individuals than in living ones (Lambert *et al.* 1985). These elements are those accumulated by microorganisms during body decomposition.

Increased values of vanadium (V) in our study remain problematic. Biological significance of vanadium hasn't been demonstrated so far, it is probable, however, it is not regulated by organisms, similarly to manganese (Darrah 2009). According to (Hunt, Speakman 2015), pXRF spectrometer cannot accurately quantify vanadium in archaeological sediment matrix at the concentrations in which they are typically present. Higher concentration of vanadium may be due to spectral interference of different elements (Ferret *et al.* 2003). Significant overlap of the spectra of Ti, V and Cr may result in vanadium data variation. After adjusting the pXRF with calibration factors, the standard deviation of elemental values remained high when compared to ICP-MS. As stated by (Bertin 1978), the precision and accuracy of vanadium XRF measurements depend also on titanium concentration in the sample as their spectral peaks (V Kβ = 4.931 KeV vs. Ti Kα = 4.952 KeV) may coincide due to their interference.

Symbolism of empty graves

On the basis of the analysed data, four of the empty urns can be classified as cenotaphs, i. e. intentionally empty graves without human remains. None of them contained any grave goods, just remnants of funeral pyre in the form of charcoal and pottery fragments. In one case, the empty grave was equipped with three cups, one of them with a hole in its bottom. Empty perforated urns were also discovered in other necropolises in Central Europe (Nekvasil 1988). The function of such vessels is unclear but the holes are often identified as soul-exits used by the soul at the moment of final transformation of an individual from peri-mortem to final post-mortem stage.

Cenotaphs are a common phenomenon throughout the world. They are symbolic graves with the body missing due to its loss, destruction, or death in distant lands. In prehistoric finds, the reasons might be similar, or there might occur distribution of body remains among members of a given community, dispersing of remains at different places etc. Burnt bones could be also removed from urns and redeposited, as well as reintegrated at different place. Analogies were evidenced in contemporary Bali where cemeteries serve as temporary repositories for cremated remains which are later exhumed and scattered (Downes 1999). Depositions of empty urns, as labor-intensive and complex processes, were probably carefully prepared and planned. Small deposits of bones and even empty urns provide evidence for complex post-pyre, long-term processing.

Although the absence of body in a cenotaph doesn't necessarily mean the absence of "personhood" (i. e. grave was made for a concrete individual) in the grave or urn (Chapman 2000), the question remains why some were more subject to fragmentation or circulation after death than others. This may be the result of one's individual position, gender division, and experience in Bronze Age system of kinship. For the Scandinavian Iron Age, (Frisberg 2005) suggests different primary function of empty graves, such as cult buildings, altars, or simply sites where religious rituals took place. The absence of grave goods could also be a product of a multistage process. Grave goods might be displayed alongside the corpse before burning but were not later deposited with burnt bones, or they might be passed down across generations rather than buried, similarly to body fragments.

CONCLUSION

Our study suggests that decomposing burnt remains can affect the surrounding environment. We were able to distinguish intentionally empty urns using chemical analyses of soil and burnt bones. We may conclude that urns without bones were deposited in this way deliberatedly. Post-depositional processes do not appear to account for this pattern. Individuals carrying out the funerals did not bury burnt remains in four of the thirteen urns explored by us. Our research has also amassed evidence that burnt, charred bones are decomposable in soil similarly to inhumations. Finally, we can confirm that pXRF, when properly calibrated, is a reliable method of elemental analysis of soil samples in forensic and archaeological contexts. Portable XRF is a nondestructive, easy to use tool with the possibility of repetitive measurements. Its drawback are relatively higher detection limits and inaccuracy in the quantification of some elements so that it can't be considered a full-fledged substitute for laboratory quantitative analysis in forensic science. However, we assume that pXRF is an appropriate analytical device in field forensic anthropology and archaeology.

ACKNOWLEDGEMENTS

We wish to extend our thanks to members of the Department of Anthropology of the University of West Bohemia for their financial support (SGS 016–028). We also thank P. Sulovský of the Department of Geology of the Palacky University in Olomouc for his help with pXR handling and calibration. We also thank to Petra Spěváčková, Hana Kašparová and Jiří Šneberger for their help with micro-excavation of burnt burials from Ostrov u Stříbra site.

REFERENCES

ABSOLONOVA K., DOBISIKOVA M., BERAN M., ZOCOVA J., VELEMINSKY P., 2012: The temperature of cremation and its effect on the microstructure of the human rib compact bone. *Anthropologischer Anzeiger; Bericht uber die biologisch-anthropologische Literatur* 69, 4: 439–60. doi: 10.1127/0003-5548/2012/0213.

ANTIKAS T. G., WYNN-ANTIKAS L. K., 2016: New Finds from the Cremains in Tomb II at Aegae Point to Philip II and a Scythian Princess. *International Journal of Osteoarchaeology* 26, 4: 682–692. doi: 10.1002/oa.2459.

BECKETT S., ROGERS K. D., CLEMENT J. G., 2011: Interspecies variation in bone mineral behavior upon heating. *Journal of forensic sciences* 56, 3: 571–579. doi: 10.1111/j.1556-4029.2010.01690.x.

BERTIN E. P., 1978: *Introduction to X-ray spectrometric analysis*. Plenum Press, New York (USA).

BODDINGTON A., GARLAND A. N., JANAWAY R. C., 1987: *Death, decay and reconstruction*. Manchester University Press, Manchester (UK).

BUDDHACHAT K., KLINHOM S., SIENGDEE P., BROWN J. L., NOMSIRI R., KAEWMONG P., THITARAM C., MAHAKKANUKRAUH P., NGANVONGPANIT K., 2016: Elemental Analysis of Bone, Teeth, Horn and Antler in Different Animal Species Using Non-Invasive Handheld X-Ray Fluorescence. *PLOS ONE* 11, 5: e0155458. doi: 10.1371/journal.pone.0155458

BUSH M. A., MILLER R. G., PRUTSMAN-PFEIFFER J., BUSH P. J., 2007: Identification through X-ray fluorescence analysis of dental restorative resin materials: a comprehensive study of noncremated, cremated, and processed-cremated individuals. *Journal of forensic sciences* 52, 1: 157–165. doi: 10.1111/j.1556-4029.2006.00308.x

BYRNES J. F., BUSH P. J., 2016: Practical Considerations in Trace Element Analysis of Bone by Portable X-ray Fluorescence. *Journal of forensic sciences* 61, 4: 1041–1045.

CEREZO-ROMÁN J., 2005: Unpacking personhood and funerary customs in the Hohokam area of southern Arizona. *American Antiquity* 80: 353–375. doi: 10.1111/1556-4029.13103.

CRAIG N., SPEAKMAN R. J., POPELKA-FILCOFF R. S., GLASCOCK M. D., ROBERTSON J. D., SHACKLEY M. S., ALDENDERFER M. S., 2007: Comparison of XRF and PXRF for analysis of archaeological obsidian from southern Perú. *Journal of Archaeological Science* 34, 12: 2012–2024. doi: 10.1016/j.jas.2007.01.015

DARRAH T. H., 2009: *Inorganic trace element composition of modern human bones: relation to bone pathology and geographical provenance*. Dissertation (Ph.D.). Department of Earth and Environmental Sciences, Rochester (UK), University of Rochester.

DEVLIN J. B., HERRMANN N. P., 2008: 6 – Bone Color as an interpretative tool of the depositional history of archaeological cremains. In: *The Analysis of Burned Human Remains*. Pp. 109–x. Academic Press, San Diego.

DOWNES J., 1999: Cremation: A spectale and a journey. In: A. M. Pollard, J. Downes (Eds.): *The loved body's corruption*. Pp. 19–31. Cruithne Press, Glasgow.

ERNÉE M., MAJER A., 2009: Uniformita, či rozmanitost pohřebního ritu? Interpretace výsledků fosfátové půdní analýzy na pohřebišti únětické kultury v Praze 9 - Miškovicích (Uniformity or variability of funerary customs? Interpretation of phosphate analysis of Unetice cemetery in Prague 9 - Miskovice). *Archeologické rozhledy* 61: 493–508.

FERRET F. F., HAMOUCHE H., BOISSONNEAULT Y., 2003: Spectral interference in X-ray fluorescence analysis of common materials. *Advances in X-ray Analysis* 46: 381–387.

FRAHM E., DOONAN R. C. P., 2013: The technological versus methodological revolution of portable XRF in archaeology. *Journal of Archaeological Science* 40, 2: 1425–1434. doi: doi.org/10.1016/j.jas.2012.10.013

FRISBERG K. H., 2005: Where are the dead? Empty graves from early Iron Age Uppland. In: T. Artelius, F. Svanberg (Eds.): *Dealing with the Dead. Archaeological Perspectives on Prehistoric Scandinavian Burial Ritual (Riksantikvarieämbetet arkeologiska undersökningar skrifter*. Pp. 143–158. The Swedish National Heritage Board – The Museum of National Antiquities in Sweden, Stockholm, Sweden.

GILPIN M., CHRISTENSEN A. M., 2015: Elemental Analysis of Variably Contaminated Cremains Using X-ray Fluorescence Spectrometry. *Journal of forensic sciences* 60, 4: 974–978. doi: 10.1111/1556-4029.12757

GONZALEZ-RODRIGUEZ J., FOWLER G., 2013: A study on the discrimination of human skeletons using X-ray fluorescence and chemometric tools in chemical anthropology. *Forensic Science International* 231, 1–3: 407.e1–407.e6. doi: 10.1016/j.forsciint.2013.04.035

HARVIG L., LYNNERUP N., EBSEN J. A., 2012: Computed tomography and computed radiography of late bronze age cremation urns from Denmark: An interdisciplinary attempt to develop methods applied in bioarchaeological cremation research. *Archaeometry* 54, 2: 369–387. doi: 10.1111/j.1475-4754.2011.00629.x

HEDGES R. E. M., 2002: Bone diagenesis: an overview of processes. *Archaeometry* 44, 3: 319–328. doi: 10.1111/1475-4754.00064

HERRMANN B., GRUPE G., HUMMEL S., PIEPENBRINK H., 1990: *Prähistorische Anthropologie. Leitfaden der Feld- und Labormethoden*. Springer Verlag, Berlin (GE).

HIRAOKA Y., 1994: A Possible Approach to Soil Discrimination Using X-ray Fluorescence Analysis. *Journal of Forensic Sciences* 39, 1381–1392. doi: 10.1520/JFS13727J

HOLLIDAY V. T., GARTNER W. G., 2007: Methods of soil P analysis in archaeology. *Journal of Archaeological Science* 34, 2: 301–333. doi: 10.1016/j.jas.2006.05.004

HUDSON C. E., 1974: *The determination of trace elements in Saxon human remains.* North-East London Polytechnic: London.

HUNT A. M. W., SPEAKMAN R. J., 2015: Portable XRF analysis of archaeological sediments and ceramics. *Journal of Archaeological Science* 53: 626–638. doi: 10.1016/j.jas.2014.11.031

CHAPMAN J., 2000: *Fragmentation in Archaeology: People, Places and Broken Objects in the Prehistory of South Eastern Europe*. Routledge, London (UK).

CHRISTENSEN A. M., SMITH M. A., THOMAS R. M., 2012: Validation of X-ray fluorescence spectrometry for determining osseous or dental origin of unknown material. *Journal of forensic sciences* 57, 1: 47–51. doi: 10.1111/j.1556-4029.2011.01941.x

JIRÁŇ L., 2008: *Archeologie pravěkých Čech/5: Doba bronzová* (Archaeology of Bohemia; Bronze Age). Archeologický ústav AV ČR, Praha (ČR).

KEELEY H. C. M., HUDSON G. E., EVANS J., 1977: Trace element contents of human bones in various states of preservation 1. The soil silhouette. *Journal of Archaeological Science* 4, 1: 19–24. doi: 10.1016/0305-4403(77)90109-1

LAMBERT J. B., SIMPSON S. V., WEINER S. G., BUIKSTRA J. E., 1985: Induced metal-ion exchange in excavated human bone. *Journal of Archaeological Science* 12, 2: 85–92. doi: 10.1016/0305-4403(85)90053-6

LÓPEZ-COSTAS O., LANTES-SUÁREZ Ó., MARTÍNEZ CORTIZAS A., 2016: Chemical compositional changes in archaeological human bones due to diagenesis: Type of bone vs soil environment. *Journal of Archaeological Science* 67: 43–51. doi: 10.1016/j.jas.2016.02.001

MCKINLEY J. I., 1993: Bone fragment size and weights of bone from modern British cremations and the implications for the interpretation of archaeological cremations. *International Journal of Osteoarchaeology* 3, 4: 283–287. doi: 10.1002/oa.1390030406

MCKINLEY J. I., 1997: Bronze Age 'Barrows' and Funerary Rites and Rituals of Cremation. *Proceedings of the Prehistoric Society* 63: 129–145. doi: 10.1017/S0079497X00002401

MCKINLEY J. I., 2004: Compiling a skeletal inventory: cremated human bone. In: M. Brickley, J. I. McKinely (Eds.): *Guidelines to the Standards for Recording Human Remains*. Pp. 9–13. IFA Paper No 7. BABAO, University of Southampton and the Institute of Field Archaeologists, Southampton (UK).

MCKINLEY J. I., 2016: Complexities of the Ancient Mortuary Rite of Cremation: An Osteoarchaeological Conundrum. In: G. Grupe, G. C. McGlynn (Eds.): *Isotopic Landscapes in Bioarchaeology*. Pp. 17–41. Springer, München.

MCLACHLAN G. J., 1992: *Discriminant Analysis and Statistical Pattern Recognition*. John Wiley and Sons, New York (USA).

MÜLLER K., CHADEFAUX C., THOMAS N., REICHE I., 2011: Microbial attack of archaeological bones versus high concentrations of heavy metals in the burial environment. A case study of animal bones from a mediaeval copper workshop in Paris. *Palaeogeography, Palaeoclimatology, Palaeoecology* 310, 1–2: 39–51. doi: 10.1016/j.palaeo.2011. 03.023

NEFF H., 1999: Traces of the Past: Unraveling the Secrets of Archaeology through Chemistry. *American Anthropologist* 101, 4: 849–850. doi: 10.1525/aa.1999.101.4.849

NECHVÁTAL M., 2017: *The usage of portable RTG-fluorescence spectrometer for analysis of rocks and solutions*. Dissertation. Department of Geology, Faculty of Science, Palacky University in Olomouc, Olomouc, Czech Republic.

NEKVASIL J., 1988: Konfrontace archeologických poznatků s antropologickými z hrobů lužické kultury (Confrontation of archaeological with anthropological records of Lusatian culture). In: M. Dočkalová (Ed.): *Antropofagie a pohřební ritus doby bronzové (Anthropophagy and Bronze Age funerary practices)*. Pp. 165–175. ČS společnost antropologická při ČSAV, Brno (MZM), ČR.

OESTIGAARD T., 2013: Cremations in culture and cosmology. In: S. Tarlow, L. S. Nilsson (Eds.): *The Oxford Handbook of the Archaeology of Death and Burial*. Pp. 497–509. Oxford University Press, Oxford (UK).

OONK S., SLOMP C. P., HUISMAN D. J., VRIEND S. P., 2009: Geochemical and mineralogical investigation of domestic archaeological soil features at the Tiel-Passewaaij site, The Netherlands. *Journal of Geochemical Exploration* 101, 2: 155–165. doi: 10.1016/j.gexplo.2008.06.004.

PANKOWSKA A., PRŮCHOVÁ E., MONÍK M., NOVÁKOVÁ M., 2014: Taphonomy of cremation burials: excavation and deposition bias in bone preservation. *Archäologische Arbeitsgemeinschaft Ostbayern/West- und Südböhmen/Oberösterreich. Fines Transire* 23: 223–231.

PATE F. D., HUTTON J. T., 1988: The use of soil chemistry data to address post-mortem diagenesis in bone mineral. *Journal of Archaeological Science* 15, 6: 729–739. doi: 10.1016/0305-4403(88)90062-3

PERRONE A., FINLAYSON J. E., BARTELINK E. J., DALTON K. D., 2014: Chapter 7 – Application of Portable X-ray Fluorescence (XRF) for Sorting Commingled Human Remains A2 – Adams, Bradley J. In: J. E. Byrd (Ed.): *Commingled Human Remains*. Pp. 145–165. Academic Press, San Diego.

POSTRÁNECKÁ K., JAVORČÍKOVÁ K., ZAVŘEL J., ŽÁČKOVÁ P., PANKOWSKÁ A., ŠNEBERGER J., SPĚVÁČKOVÁ P., KAŠPAROVÁ H., MAJER A., 2015: *Ostrov u Stříbra, ppč. 1952/1, 1952/2, 1950, 1949, 1947, 1946/1. Záchranný archeologický výzkum. Nálezová zpráva o záchranném archeologickém výzkumu při stavbě výrobní haly (35/15; 119/13)*. ZIP o.p.s. – Západočeský institut pro ochranu a dokumentaci památek, Plzeň.

REBOCHO J., CARVALHO M. L., MARQUES A. F., FERREIRA F. R., CHETTLE D. R., 2006: Lead post-mortem intake in human bones of ancient populations by (109)Cd-based X-ray fluorescence and EDXRF. *Talanta* 70, 5: 957–961. doi:10.1016/j.talanta.2006.05.062

ROBIN C., 2002: Outside of houses. *Journal of Social Archaeology* 2, 2: 245–268.

SEIFERT A., VEJLUPEK M., 1992: *Geologická mapa (geology map) ČR 1 : 50 000, list 11-44: Nýřany*. Czech Geological Survey, City.

SCHMIDT C. W., SYMES S. A. (Eds.), 2015: *The Analysis of Burned Human Remain*. San Diego.

SCHURR M. R., COOK D. C., 2014: The Temporal and Cultural Contexts of the Enigmatic Cremations from the Yokem Site, Illinois, USA. In: I. Kuijt, C. P. Quinn, G. Cooney (Eds.): *Transformation by Fire. The Archaeology* *of Cremation in Cultural Context*. Pp. 67–92. University of Arizona Press, Tucson, Arizona.

SKINNER H. C., 2013: Mineralogy of Bones. In: O. Selinus (Ed.): *Essentials of Medical Geology*. Pp. 665–687. Springer, Netherlands.

SMITH M., BRICKLEY M., 2009: *People of the Long Barrows*. The History Press, Gloucestershire.

STRAND R., SHIELDS F., SWIADER J., 2008: *Cremation ash as phosphorous source for soil additive or fertilize*r. Google Patents, City.

STUTZ L. N., KUIJT I., 2014: Perspectives–Reflections on the Visibility of Cremation as a Physical Event. In: I. Kuijt, C. P. Quinn, G. Cooney (Eds.): *Transformation by Fire. The Archaeology of Cremation in Cultural Context.* Pp. 143–148. University of Arizona Press, Tucson, Arizona.

ŠMEJDA L, HEJCMAN M, HORÁK J, and SHAI I. 2017. Multi-element mapping of anthropogenically modified soils and sediments at the Bronze to Iron Ages site of Tel Burna in the southern Levant. Quaternary International. doi.org/10.1016/j.quaint.2017.11.005

THOMPSON T. J., 2004: Recent advances in the study of burned bone and their implications for forensic anthropology. *Forensic science international* 146 Suppl: S203–5. doi: 0.1016/j.forsciint.2004.09.063

TZAPHLIDOU M., ZAICHICK V., 2003: Calcium, phosphorus, calcium-phosphorus ratio in rib bone of healthy humans. *Biological trace element research* 93, 1–3: 63–74. doi: 10.1385/BTER:93:1-3:63

UBELAKER D. H., 2009: The forensic evaluation of burned skeletal remains: a synthesis. *Forensic science international* 183, 1–3: 1–5. doi: 10.1016/j.forsciint.2008.09.019

VITEŠNÍKOVÁ A., PROKEŠ L., NÝVLTOVÁ FIŠÁKOVÁ M., DROZDOVÁ E., KOUŘIL P., STABRAVA P., GRYC J., 2008: Studium degradace kosterních pozůstatků pomocí infračervené spektrometrie. In: *Muzea, památky a konzervace. Brno: Technické muzeum v Brně*. Pp. 24–30, Brno.

VODIČKOVÁ N., 2017: *Druhové a individuální rozlišení spálených a nespálených kostí pomocí aplikace rentgenové fluorescence (XRF). Master Thesis.* Faculty of Philosophy and Arts, University of West Bohemia, Plzeň.

WALKER P. L., MILLER K. W. P., RICHMAN R., 2008: 7 – Time, temperature, and oxygen availability: an experimental study of the effects of environmental conditions on the color and organic content of cremated bone. In: *The Analysis of Burned Human Remains*. Pp. 129–xi. Academic Press, San Diego.

WILSON C. A., DAVIDSON D. A., CRESSER M. S., 2008: Multi-element soil analysis: an assessment of its potential as an aid to archaeological interpretation. *Journal of Archaeological Science* 35, 2: 412–424. doi: 10.1016/j.jas.2007.04.006

ZAPATA J., PÉREZ-SIRVENT C., MARTÍNEZ-SÁNCHEZ M. J., TOVAR P., 2006: Diagenesis, not biogenesis: Two late Roman skeletal examples. *Science of The Total Environment* 369, 1–3: 357–368. doi: 10.1016/j.scitotenv.2006.05.021

ZIMMERMAN H. A., SCHULTZ J. J., SIGMAN M. E., 2015: Preliminary Validation of Handheld X-Ray Fluorescence Spectrometry: Distinguishing Osseous and Dental Tissue from Nonbone Material of Similar Chemical Composition. *Journal of Forensic Sciences* 60, 2: 382–390. doi: 10.1111/1556-4029.12690

Anna Pankowská*
Department of Anthropology
Faculty of Arts
University of West Bohemia
Sedláčkova 15
30125 Plzeň
Czech Republic
E-mail: pankowsk@ksa.zcu.cz

Martin Moník
Marek Nechvátal
Department of Geology
Faculty of Science
Palacky University in Olomouc
17. listopadu 1192/12
771 46 Olomouc
Czech Republic
E-mail: martin.monik@gmail.com
E-mail: marek.nech@centrum.cz

* Corresponding author.