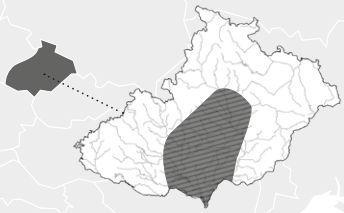
Přehled výzkumů 66/1, 2025 ● 153–167

Chemical composition of Moravian La Tène anklets and their fillings

Chemické složení moravských laténských nánožníků a jejich výplní

– *David Spáčil** –



KEYWORDS

La Tène – Iron Age – Moravia – jewellery – anklets – attire – chemical composition – analyses – XRF

ABSTRACT

This study examines the chemical composition of La Tène anklets and their fillings from Moravia, offering insights into technological advancements and crafting practices during the Late Iron Age. These anklets, integral to La Tène period attire and often worn in pairs, were categorised into eleven typological groups based on their design, such as wire anklets, rod-like anklets, caterpillar anklets, and anklets with hollow hemispheres. Up to seventy-one examples were analysed using X-ray fluorescence (XRF) and gas chromatography-mass spectrometry (GC-MS). The research identified a sudden increase in lead content within the copper alloys used for anklet production, reflecting broader Central European metallurgical trends during the LT B2/C1 periods. This shift may have been influenced by factors such as enhanced workability, aesthetic considerations, or production efficiency, but its exact purpose remains uncertain.

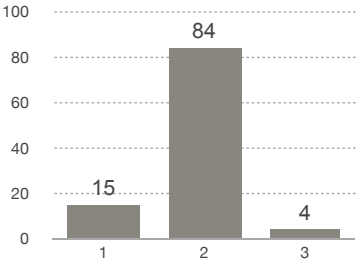
The study also investigates the origins and role of fillings found in hollow anklets, which included both dirt-like substances and textile remnants. Chemical analysis detected traces of pine resin; its presence could be linked to its use as an adhesive for textile stuffing (for structural support or comfort) or as a component in the lost-wax casting process of these artefacts.

1. Introduction

Anklets are a typical component of La Tène attire. The heyday of their popularity was in the Late Iron Age, when they gained favour among wealthier women (Waldhauser 1987, 38–45), although they appear more or less throughout the entire Iron Age. Chronologically, in the Late Iron Age, they belong to the 'flat cemetery' period dating from LT B to C1 (ca 410–175 BC in Central Europe; Venclová ed. 2008, 21). An anklet is a form of annular jewellery worn on the ankles. In Moravia, they were worn almost exclusively in pairs, and graves with more than two anklets are rare (e.g. grave 34 from Brno-Maloměřice with three anklets; Čižmářová 2005, 84), while those with only one anklet are a bit more common, though still non-standard (Graph 1).

Previous research on La Tène period anklets rarely focused on chemical analyses, and to the author's knowledge, there are no papers on the chemical analysis of the fillings found in some anklets. It is necessary to mention a few works dealing with the topic of anklets in general: of importance are certainly studies by P. Sankot (1981; 2002a; 2002b) about the decoration and spatial distribution of La Tène period anklets with a focus on Bohemia; a monumental work about annular jewellery in Slovakia by J. Bujna (2005); works of various authors on anklets in Slovakia and Hungary (Masse, Szabó 2005; Fábry 2012; Furman 2014), and Italy (Geschwind 2020); and one of the latest from the author of this paper (Spáčil 2023) on anklets with hollow hemispheres in Moravia.

A notable work on the chemical composition of Late Iron Age jewellery (not exclusively anklets) is a monograph focusing on the area of today's Bohemia (Frána et al. 1997). The authors used surface XRF (X-ray fluorescence) in combination with NAA (neutron activation analysis) to conclude that annular jewellery (anklets being the primary studied source) changes its composition throughout the La Tène period. According to them, the change happens in the LT B2 period with the emergence of anklets with hollow hemispheres, which tend to have a higher content of lead (Frána et al. 1997, 94–95). They also stated that the surface analyses represented a problem, since the corrosion



Graph 1. Histogram of graves with 1, 2, or 3 anklets. Data from Čižmářová 2005; 2009; 2011; 2013; 2017; 2019.

Graf 1. *Histogram hrobů podle počtu nánožníků – 1, 2, nebo 3 kusy v hrobě. Data převzata z Čižmářová 2005; 2009; 2011; 2013; 2017; 2019.*

* Corresponding author – E-mail address: david.spacil01@upol.cz

https://doi.org/10.47382/pv0661-03

Received 17 January 2025; received in revised form 31 March 2025.
Available online 9 June 2025.

Competing interests: The authors have declared that no competing interests exist.

layers of the anklets distort the results. Similar observations can be seen in a paper from Danielisová et al. (2021), which partially uses the data published in the previously mentioned publication (Frána et al. 1997). According to the paper, the first copper alloy artefacts with high (in this case more than 13%) lead concentrations appear in LT B2a, although they make up only about 10% of all studied artefacts from this subphase. Artefacts with high lead levels become standard only in the B2b and later subphases (over 50% of studied artefacts).

Although these types of publications are present in the surrounding regions, there are only a few works discussing the chemical composition of Late Iron Age artefacts in Moravia. For example, M. Kmošek's master's thesis deals with such analyses of prehistoric and protohistoric artefacts made of copper alloys; however, annular jewellery is of only marginal interest (Kmošek 2019). Also noteworthy are papers by Goláňová et al. (2020) and Danielisová et al. (2020), both of which focus on the chemical composition of artefacts (for example, belt parts, small figurines, amulets and pendants) from the Middle and Late La Tène period (more precisely from LT C–D; these sets chronologically overlap with the set of anklets studied in this paper only marginally) from – at least partially – Moravia. High lead levels (10–30, in extreme cases even up to 90% lead) can be observed in mentioned artefacts from this period in both publications.

In terms of anklet fillings, the research focused primarily on typically very well-preserved fillings of tubular/caterpillar anklets from the perspective of textile research. A few notable works cover anklets (or bracelets) and partially even those from Moravia. The textile fillings of two Moravian caterpillar bracelets (previously considered to be anklets; Salayová 2023, 534) from Mušov and anklets of the same type from Miroslav were covered by M. Kostelníková (2001), the textile research in the Czech and Slovak Republics was thoroughly described by T. Belanová-Štolcová (2012), although the La Tène period anklets make up only a part of this work.

This paper focuses on the two aforementioned matters: the first goal is to determine if the conclusions reached by Frána et al. (1997) about the 'chronological sensitivity' of the lead content in the La Tène period anklets apply also to the region of Moravia. The second goal is to hopefully trace the origin and significance of the dirt-like fillings from both caterpillar anklets and anklets with hollow hemispheres by means of an analysis of their chemical composition.

2. Materials

There are ca 310 anklets from the La Tène period in the region of Moravia (Filip 1956; Meduna 1980; Čižmářová 2005; 2009; 2011; 2013; 2017; 2019) and they come in various forms. These can be sorted into four main categories: wire anklets (a very thin body that usually meanders in loops; Fig. 1:4); anklets with a rod-like body (the body is composed of a rod with a circular cross-section and is always open, thus they have two terminals; some of these anklets are decorated; Fig. 1:2); caterpillar anklets (made from thin metal plate, which is curved inwards and makes up a hollow body of roughly a round cross-section with triplets of protrusions along it; Fig. 1:1); and anklets with hollow hemispheres (the largest kind with varying size, number of hemispheres, and decoration; Fig. 1:3; for further information about anklets with hollow hemispheres, see Spáčil 2023).

Of these anklets, 71 were selected for analysis (for the spatial distribution of the studied anklets, see Fig. 2). They were classified into eleven auxiliary categories, some defined specifically for this paper,[1] expanding the aforementioned types (Tab. 1). Although the original intention was to have the same or at least a similar number of anklets in each category, the scarcity of some anklet types prevented it. Anklets with hollow hemispheres and anklets with a rod-like body represent the majority (34 individuals [or 48%] and 27 individuals [or 38%], respectively) of all the anklets in the studied set. The remaining artefacts are eight caterpillar anklets (ca a third of all caterpillar anklets in Moravia) and two wire anklets (of a total of six potential[2] wire anklets in Moravia).

The majority of all Moravian anklets come from La Tène burial grounds or graves (around 280 individuals), while the remaining ca 30 anklets come either from settlements or their activity area cannot be determined. This can be partially explained by similarities between various annular ornaments: simply put, it is difficult to discern bracelets, armbands and anklets (Salayová 2023, 48) when presented with no context (the position of the annular ornament on the body), and thus a significant number of anklets from settlements or with no context might end up being broadly categorised as 'annular ornaments'.

Anklets from the La Tène period are typically made from copper alloys in Moravia. Of the aforementioned ca 310 anklets, less than 2% are made from iron, and there is no evidence of anklets being made from any other material (e.g. glass or sapropelite, materials from which bracelets and armbands are sometimes made), probably for practical reasons. Apart from being flexible enough to be put on ankles, jewellery from copper alloys allows the craftsman to produce more complex decorative elements than if they were produced from iron. The plastic style (Kruta 1975, 45–95, e.g. Fig. 44–48; Megaw, Megaw 2001, 135–144) is the best example of said complexity. The anklets with hollow hemispheres represent an extreme case of shape complexity even in their non-decorated form. This formal complexity may be connected to a higher level of lead content, as

Fig. 1. Four main categories of anklets. 1 – Caterpillar; 2 – with hollow hemispheres; 3 – with a rod-like body; 4 – wire. 1 – Vracov, inv. No. 70.441; 2 – Brno-Bohunice, inv. No. SAÚ 444/47; 3 – Holubice, inv. No. 107.215; 4 – Brno-Chrlice, inv. No. 314476. 1–3 – Moravian Museum (MZM); 4 – Brno City Museum (MMB). Photo by D. Spáčil.

Obr. 1. *Čtyři hlavní kategorie nánožníků. 1 – Housenkovité; 2 – puklicové; 3 – tyčinkovité; 4 – drátěné. 1 – Vracov, inv. č. 70.441, 2 – Brno-Bohunice, inv. č. SAÚ 444/47, 3 – Holubice, inv. č. 107.215, 4 – Brno-Chrlice, inv. č. 314476. 1–3 – Moravské zemské muzeum (MZM), 4 – Muzeum města Brna (MMB). Foto D. Spáčil.*

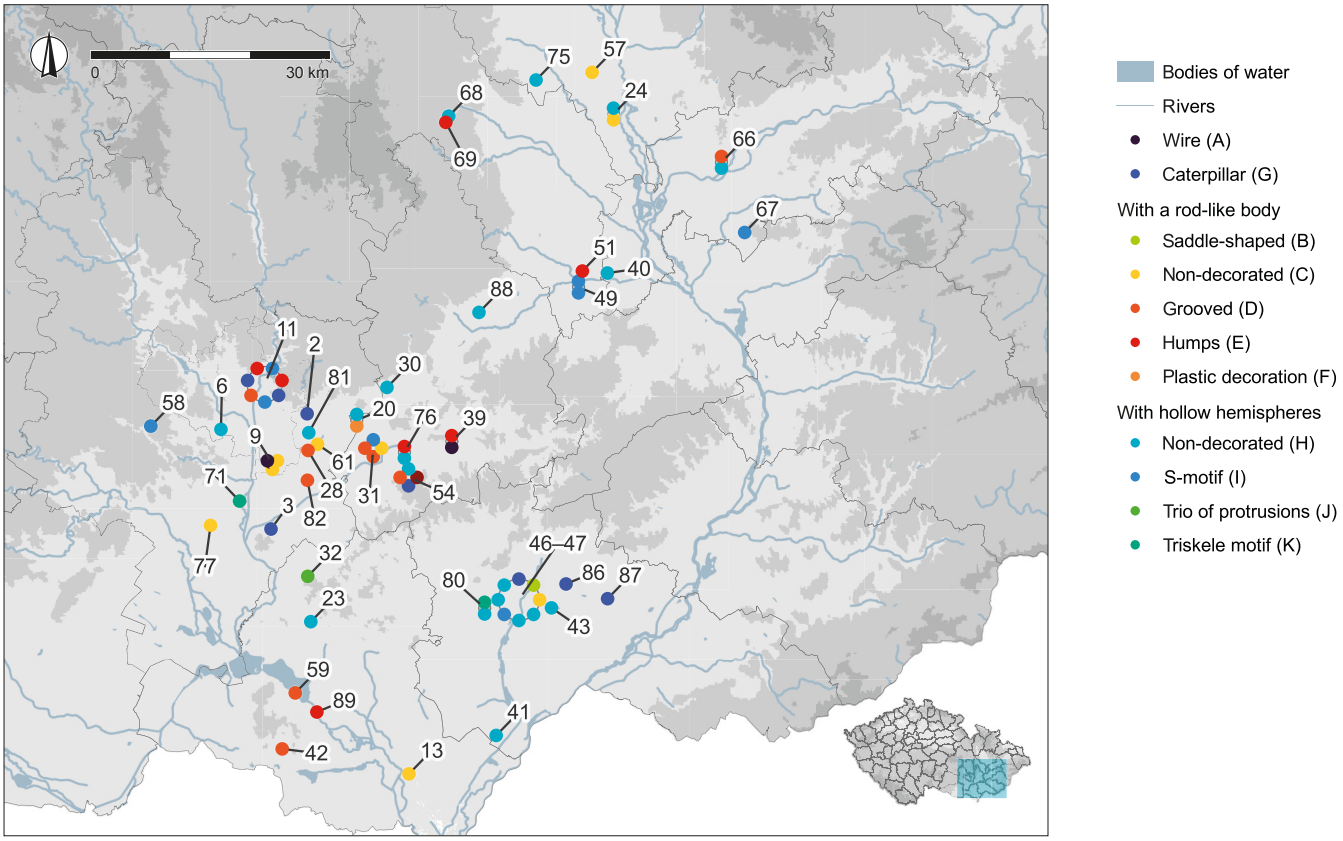


Fig. 2. The location of the studied anklets on the map of Moravia. 1 – Bedřichovice; 2 – Blučina; 3 – Brno-Bohunice; 4 – Brno-Chrlice; 5 – Brno-Maloměřice; 6 – Břeclav; 7 – Holubice; 8 – Hustopeče; 9 – Charváty; 10 – Kobylnice; 11 – Královopolské Vážany; 12 – Křenovice; 13 – Křepice; 14 – Marefy; 15 – Měrovice; 16 – Mikulčice; 17 – Mikulov; 18 – Milotice; 19 – Mistřín (both sites); 20 – Mořice; 21 – Němčice nad Hanou; 22 – Nížkovice; 23 – Olomouc-Slavonín; 24 – Omice; 25 – Pavlov; 26 – Ponětovice; 27 – Přerov-Předmostí; 28 – Přestavlky; 29 – Ptení – Mlýnisko; 30 – Ptení – Výmolův rybník; 31 – Rajhrad; 32 – Slatinice; 33 – Slavkov; 34 – Sobotovice; 35 – Šardice; 36 – Šlapanice; 37 – Telnice; 38 – Vlkoš; 39 – Vracov; 40 – Vyškov; 41 – Zaječí. Author D. Spáčil.

Obr. 2. *Lokace studovaných nánožníků na mapě Moravy. 1 – Bedřichovice; 2 – Blučina; 3 – Brno-Bohunice; 4 – Brno-Chrlice; 5 – Brno-Maloměřice; 6 – Břeclav; 7 – Holubice; 8 – Hustopeče; 9 – Charváty; 10 – Kobylnice; 11 – Královopolské Vážany; 12 – Křenovice; 13 – Křepice; 14 – Marefy; 15 – Měrovice; 16 – Mikulčice; 17 – Mikulov; 18 – Milotice; 19 – Mistřín (obě lokality); 20 – Mořice; 21 – Němčice nad Hanou; 22 – Nížkovice; 23 – Olomouc-Slavonín; 24 – Omice; 25 – Pavlov; 26 – Ponětovice; 27 – Přerov-Předmostí; 28 – Přestavlky; 29 – Ptení – Mlýnisko; 30 – Ptení – Výmolův rybník; 31 – Rajhrad; 32 – Slatinice; 33 – Slavkov; 34 – Sobotovice; 35 – Šardice; 36 – Šlapanice; 37 – Telnice; 38 – Vlkoš; 39 – Vracov; 40 – Vyškov; 41 – Zaječí. Autor D. Spáčil.*

some authors state that lead improves the properties of bronze (Bureš, Waldhauser 2005, 733). This very old statement dates back to Jan Erazim Wocel: 'Hotovitelé bronzových šperků této pozdější doby přidávali částky olova do kovoviny, aby tato tím snadněji tekutou se stala' [In this later period, bronze jewellery makers would add amounts of lead to the alloy so that it would become fluid more easily] (Wocel 1868, 196).

Fillings can sometimes be found in hollow anklets (categories G–K). They are either dirt-like (Fig. 3:3, 4) in consistency or appear as cloth (Fig. 3:1, 2). The cloth fillings in caterpillar anklets most likely serve as padding, since the sheet of metal used to create these anklets is very thin and fragile. Cloth stuffed inside like this adds almost no weight to the ring and, on the other hand, keeps the anklet from collapsing or otherwise damaging itself. The cloth is usually made from a plain-woven linen fabric (Kostelníková 2001; Belanová-Štolcová 2012; Štolcová 2019). In some cases, the cloth filling in caterpillar anklets is stiffened with some sort of glue (Kostelníková 2001). Fillings were preserved in three out of the eight studied caterpillar anklets (Tab. 1). On the other hand, the meaning and origin of

Symbol	Category	Count	With fillings
A	Wire	2	0
B	Saddle-shaped	1	0
C	With a rod-like body	9	0
D	With a grooved rod-like body	9	0
E	With a rod-like body and humps	7	0
F	With a rod-like body and plastic decoration	1	0
G	Caterpillar	8	3
H	With non-decorated hollow hemispheres	23	14
I	With hollow hemispheres decorated with an S-motif	8	3
J	With hollow hemispheres with a trio of protrusions	1	1
K	With hollow hemispheres decorated with a triskele motif	2	1

Tab. 1. Categories of anklets defined for this paper with their symbols used in the text, the count of individuals selected for the analyses, and the count of anklets with fillings from each category.

Tab. 1. *Kategorie nánožníků vytvořené pro tento článek a jejich symboly užité v textu, počet kusů studovaných nánožníků a počet nánožníků s výplněmi z každé kategorie.*

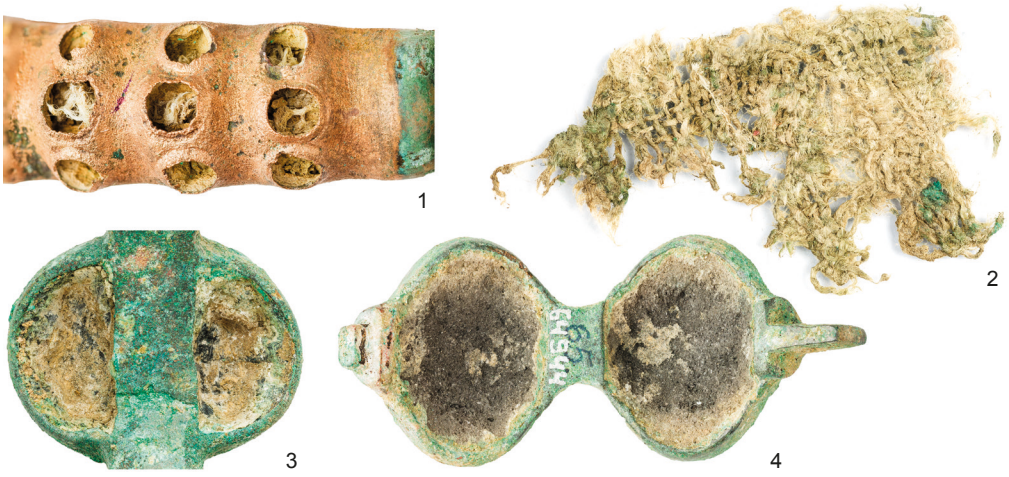


Fig. 3. Various examples of fillings in anklets. 1, 2 – Cloth filling; 3, 4 – dirt-like filling. 1 – Bedřichovice, inv. No. 156.834; 2 – Hustopeče, inv. No. 174.647; 3 – Brno-Bohunice, inv. No. SAÚ 444/47; 4 – Nížkovice, inv. No. 64.944. MZM. Not to scale. Photo by D. Spáčil.

Obr. 3. *Příklady výplní nánožníků. 1, 2 – Látková výplň; 3, 4 – hliněná výplň. 1 – Bedřichovice, inv. č. 156.834; 2 – Hustopeče, inv. č. 174.647; 3 – Brno-Bohunice, inv. č. SAÚ 444/47; 4 – Nížkovice, inv. č. 64.944. MZM. Bez měřítka. Foto D. Spáčil.*

dirt-like fillings are much less obvious. Concerning the anklets with hollow hemispheres, these fillings may originate simply from the dirt of the grave that got inside the hemispheres after the deposition. They could also be remnants from anklet production, e.g. from the clay mould. It might also be decomposed or petrified cloth padding (although no macroscopic traces of cloth have been identified in the studied set of anklets with hollow hemispheres), similar to the caterpillar anklets, although with a slightly shifted sense. Instead of supporting the anklet construction, the padding could protect the anklet wearer's ankles from bruising. Fillings were preserved in over 55% of the studied anklets with hollow hemispheres (Tab. 1).

All the studied anklets have been dated (if possible) according to the chronology of the La Tène graves in Bohemia (Waldhauser ed. 1978; Waldhauser 1987) and to a lesser extent also to the chronology of Moravian La Tène armbands and bracelets (Salayová 2023), based on the accompanying artefacts from their respective contexts.

3. Methodology and results

3.1 Analyses of metal composition

In the matter of finding the composition of the metal used to make the studied anklets, the surface XRF analysis was conducted in two main phases. Initially, 64 anklets were analysed using a portable Vanta XRF (pXRF) spectrometer (Olympus, MA, USA) in Analchem mode in the Department of Analytical Chemistry at Palacký University, Olomouc. For the evaluation of the results, Vanta data management software was used. In the second phase, another seven anklets were analysed using a Niton Xl3t 980 pXRF spectrometer in General Metals mode at the Institute of Archaeology of the Czech Academy of Sciences, Brno.

The surface XRF method was primarily chosen for its non-invasive nature, to avoid damaging the anklets by taking samples, and for the ease of use, so large quantities of samples could be measured in a relatively short time. The measured spots on the anklets were not polished for the same reason. Instead, the least corroded section of each anklet was selected (which is far from ideal) to lessen the distortion of the results. On every anklet, three different spots were measured, again, to minimise the error. In the first (Vanta) phase, each measurement took 30 seconds and was comprised of two internal sub-phases. The first sub-phase (with energy up to 8 keV) took 10 seconds, and the second one (up to 40 keV) took the remaining 20 seconds. The seven anklets analysed in the second phase with the Niton Xl3t 980 were also measured three times each, with each measurement lasting 60 seconds. The Vanta spectrometer has an elemental detection range of Mg–U, so it measures 80 elements, of which 32 were detected in a non-null quantity in at least one anklet. Apart from that, it measures for light elements, i.e. those with an atomic number of eleven or lower. In some cases, the raw results showed quite strong signals of these light elements (likely contamination of organic compounds), just as the signals of elements usually connected to soil (e.g. silicon, aluminium, calcium, phosphorus). Values of these elements were later filtered out and the results recalculated, so they would be closer to the actual composition of the metal and were not affected by the contamination. The values from the surface XRF can be found in Tab. 2 (Spáčil et al. 2025), although it shows only elements which make up at least 0.1% of at least one anklet.

Despite all efforts, the measurements were still very much affected by corrosion layers on the surface of the studied anklets. In some cases, the scatter of Cu and Sn went as high as 56%

Anklet No.	Group	Cu	Sn	Pb	Fe	Ti	Sb	Ag	Ni	Bi	Zn	Au	V	Cr	Pd	Sc
1	A	85.2%	10.8%	3.0%	0.3%	0.2%	0.3%	0.1%	0.2%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
		7.0%	*5.2%*	*1.4%*	*0.1%*	*0.1%*	*0.1%*	*0.0%*	*0.1%*	*0.1%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*
2	A	87.0%	10.1%	1.3%	0.9%	0.3%	0.1%	0.2%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%
		1.8%	*1.5%*	*0.2%*	*0.0%*	*0.1%*	*0.1%*	*0.2%*	*0.0%*	*0.0%*	*0.1%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*
3	B	91.4%	5.0%	2.9%	0.2%	0.0%	0.1%	0.0%	0.0%	0.0%	0.3%	0.0%	0.0%	0.0%	0.0%	0.0%
		4.3%	*3.5%*	*0.8%*	*0.1%*	*0.0%*	*0.1%*	*0.0%*	*0.0%*	*0.0%*	*0.2%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*
4	C	83.4%	16.0%	0.1%	0.2%	0.2%	0.1%	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%
		3.1%	*2.9%*	*0.0%*	*0.1%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.1%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*
5	C	78.6%	19.7%	0.2%	0.6%	0.3%	0.2%	0.0%	0.0%	0.0%	0.1%	0.1%	0.0%	0.0%	0.0%	0.0%
		7.3%	*6.9%*	*0.1%*	*0.2%*	*0.1%*	*0.1%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*
6	C	72.7%	20.7%	2.0%	0.1%	0.9%	0.3%	0.2%	1.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	2.0%
		7.4%	*8.7%*	*0.2%*	*0.0%*	*1.1%*	*0.3%*	*0.3%*	*1.1%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*2.8%*

Anklet No.	Group	Cu	Sn	Pb	Fe	Ti	Sb	Ag	Ni	Bi	Zn	Au	V	Cr	Pd	Sc
7	C	81.6%	14.0%	1.9%	2.0%	0.3%	0.1%	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%
		2.3%	*1.9%*	*0.3%*	*0.5%*	*0.1%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*
8	C	87.2%	10.5%	1.3%	0.4%	0.2%	0.1%	0.0%	0.0%	0.0%	0.3%	0.0%	0.0%	0.0%	0.0%	0.0%
		1.4%	*1.5%*	*0.2%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.4%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*
9	C	81.6%	14.8%	3.0%	0.2%	0.0%	0.1%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
		10.4%	*9.0%*	*1.0%*	*0.1%*	*0.0%*	*0.1%*	*0.1%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*
10	C	48.4%	48.8%	0.1%	1.9%	0.3%	0.4%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
		20.4%	*19.3%*	*0.0%*	*0.9%*	*0.1%*	*0.1%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*
11	C	78.3%	14.3%	4.7%	1.2%	1.1%	0.1%	0.0%	0.1%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
		5.1%	*3.2%*	*1.3%*	*0.3%*	*1.0%*	*0.1%*	*0.0%*	*0.1%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.1%*
12	C	69.6%	19.1%	7.6%	1.4%	0.3%	0.8%	0.4%	0.2%	0.2%	0.1%	0.1%	0.0%	0.0%	0.0%	0.0%
		12.5%	*7.7%*	*3.9%*	*0.6%*	*0.2%*	*0.3%*	*0.2%*	*0.0%*	*0.1%*	*0.1%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*
13	D	78.5%	12.5%	7.5%	0.3%	0.2%	0.4%	0.2%	0.2%	0.3%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%
		10.9%	*6.2%*	*4.0%*	*0.0%*	*0.2%*	*0.2%*	*0.1%*	*0.1%*	*0.2%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*
14	D	88.3%	10.4%	0.0%	0.6%	0.2%	0.3%	0.0%	0.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
		2.6%	*1.8%*	*0.0%*	*0.5%*	*0.2%*	*0.1%*	*0.0%*	*0.1%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*
15	D	85.2%	13.3%	0.8%	0.3%	0.2%	0.1%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
		0.6%	*0.6%*	*0.1%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*
16	D	81.1%	11.9%	5.1%	0.4%	0.5%	0.4%	0.1%	0.1%	0.1%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%
		13.1%	*7.4%*	*4.6%*	*0.2%*	*0.1%*	*0.3%*	*0.2%*	*0.1%*	*0.1%*	*0.1%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.1%*
17	D	85.6%	11.2%	1.9%	0.2%	0.4%	0.2%	0.2%	0.1%	0.0%	0.1%	0.1%	0.0%	0.0%	0.0%	0.0%
		2.7%	*2.1%*	*0.4%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.1%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*
18	D	69.5%	20.5%	8.4%	0.1%	0.2%	0.5%	0.2%	0.3%	0.1%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%
		7.8%	*5.1%*	*2.3%*	*0.1%*	*0.0%*	*0.2%*	*0.1%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*
19	D	88.7%	10.9%	0.1%	0.0%	0.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
		0.2%	*0.2%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*
20	D	74.0%	14.5%	8.3%	0.7%	0.8%	0.5%	0.3%	0.3%	0.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
		5.3%	*3.1%*	*1.8%*	*0.2%*	*1.7%*	*0.2%*	*0.2%*	*0.0%*	*0.1%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*
21	D	81.2%	10.0%	7.8%	0.1%	0.2%	0.3%	0.1%	0.1%	0.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
		1.7%	*0.8%*	*1.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*
22	E	74.7%	18.8%	4.2%	0.4%	0.2%	0.8%	0.4%	0.1%	0.1%	0.1%	0.1%	0.0%	0.0%	0.0%	0.0%
		11.8%	*8.2%*	*2.4%*	*0.2%*	*0.2%*	*0.3%*	*0.3%*	*0.1%*	*0.1%*	*0.1%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*
23	E	84.3%	11.4%	3.3%	0.2%	0.2%	0.0%	0.1%	0.0%	0.4%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%
		4.0%	*2.6%*	*1.2%*	*0.1%*	*0.1%*	*0.0%*	*0.0%*	*0.0%*	*0.1%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*
24	E	83.4%	14.6%	0.9%	0.8%	0.1%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
		1.1%	*1.0%*	*0.1%*	*0.1%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*
25	E	59.1%	31.2%	2.6%	6.1%	0.6%	0.2%	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%
		11.7%	*9.7%*	*0.4%*	*1.3%*	*0.4%*	*0.1%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*
26	E	85.8%	12.8%	0.6%	0.1%	0.3%	0.1%	0.0%	0.1%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%
		0.7%	*0.4%*	*0.3%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*
27	E	82.4%	12.5%	3.6%	0.5%	0.3%	0.2%	0.1%	0.2%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
		3.5%	*2.3%*	*0.9%*	*0.2%*	*0.2%*	*0.1%*	*0.1%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*
28	E	73.9%	22.2%	1.8%	0.4%	1.0%	0.1%	0.0%	0.0%	0.0%	0.1%	0.0%	0.2%	0.0%	0.0%	0.2%
		4.1%	*3.0%*	*0.3%*	*0.1%*	*0.5%*	*0.1%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.1%*	*0.0%*	*0.0%*	*0.3%*
29	F	83.6%	14.3%	1.4%	0.3%	0.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
		3.9%	*2.3%*	*1.6%*	*0.1%*	*0.0%*	*0.1%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*
30	G	91.0%	7.1%	0.7%	0.2%	0.1%	0.4%	0.2%	0.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
		0.1%	*0.1%*	*0.1%*	*0.1%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*
31	G	78.3%	17.5%	3.1%	0.4%	0.2%	0.3%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
		4.6%	*4.2%*	*0.6%*	*0.1%*	*0.1%*	*0.1%*	*0.1%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*
32	G	89.5%	8.0%	1.9%	0.2%	0.0%	0.1%	0.0%	0.1%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
		3.2%	*2.2%*	*0.8%*	*0.1%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*
33	G	86.5%	12.2%	0.6%	0.2%	0.1%	0.1%	0.0%	0.0%	0.0%	0.2%	0.0%	0.0%	0.0%	0.0%	0.0%
		2.3%	*2.3%*	*0.1%*	*0.1%*	*0.1%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.3%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*
34	G	85.7%	10.5%	3.0%	0.3%	0.1%	0.1%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
		1.0%	*1.1%*	*0.2%*	*0.1%*	*0.1%*	*0.1%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*
35	G	77.6%	17.9%	2.9%	0.4%	0.2%	0.2%	0.1%	0.1%	0.0%	0.1%	0.1%	0.0%	0.0%	0.0%	0.5%
		6.5%	*5.0%*	*0.8%*	*0.1%*	*0.1%*	*0.1%*	*0.1%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.7%*
36	G	77.2%	16.1%	5.1%	0.7%	0.1%	0.2%	0.1%	0.1%	0.1%	0.1%	0.1%	0.0%	0.0%	0.0%	0.0%
		5.8%	*3.6%*	*1.5%*	*0.4%*	*0.1%*	*0.1%*	*0.1%*	*0.0%*	*0.0%*	*0.1%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*
37	G	81.2%	14.7%	3.1%	0.3%	0.4%	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%	0.1%	0.0%	0.0%
		0.8%	*0.6%*	*0.1%*	*0.0%*	*0.1%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.1%*	*0.0%*	*0.0%*
38	H	59.6%	20.2%	18.9%	0.6%	0.1%	0.3%	0.1%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
		2.3%	*3.1%*	*2.4%*	*0.3%*	*0.0%*	*0.1%*	*0.0%*	*0.0%*	*0.1%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*
39	H	80.2%	14.0%	5.0%	0.4%	0.0%	0.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
		3.5%	*1.9%*	*1.8%*	*0.1%*	*0.0%*	*0.1%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*
40	H	70.4%	18.7%	9.3%	1.0%	0.0%	0.2%	0.0%	0.0%	0.1%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%
		2.8%	*3.5%*	*1.5%*	*0.1%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*

Anklet No.	Group	Cu	Sn	Pb	Fe	Ti	Sb	Ag	Ni	Bi	Zn	Au	V	Cr	Pd	Sc
41	H	39.3%	10.2%	49.4%	0.8%	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
		16.7%	*0.4%*	*16.5%*	*0.2%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.1%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*
42	H	45.8%	18.3%	34.0%	1.0%	0.2%	0.3%	0.1%	0.0%	0.1%	0.1%	0.1%	0.0%	0.0%	0.0%	0.0%
		8.9%	*2.9%*	*5.7%*	*0.2%*	*0.0%*	*0.1%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*
43	H	34.3%	14.8%	46.0%	4.4%	0.0%	0.2%	0.0%	0.0%	0.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
		2.8%	*0.9%*	*1.8%*	*1.6%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*
44	H	69.9%	14.6%	14.3%	0.2%	0.0%	0.2%	0.1%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
		5.5%	*1.7%*	*3.6%*	*0.0%*	*0.0%*	*0.0%*	*0.1%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*
45	H	84.8%	12.0%	2.3%	0.4%	0.1%	0.2%	0.1%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%
		3.3%	*2.8%*	*0.4%*	*0.2%*	*0.0%*	*0.1%*	*0.0%*	*0.0%*	*0.0%*	*0.1%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*
46	H	43.1%	10.1%	45.5%	1.0%	0.0%	0.1%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
		19.1%	*2.8%*	*21.8%*	*0.4%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*
47	H	50.8%	11.6%	35.2%	1.9%	0.1%	0.1%	0.1%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
		10.2%	*2.7%*	*9.3%*	*0.9%*	*0.1%*	*0.1%*	*0.1%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*
48	H	54.5%	13.8%	30.6%	0.4%	0.3%	0.1%	0.0%	0.0%	0.1%	0.1%	0.0%	0.1%	0.0%	0.0%	0.0%
		11.4%	*1.1%*	*11.6%*	*0.3%*	*0.2%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.1%*	*0.0%*	*0.0%*	*0.0%*
49	H	51.8%	21.0%	26.0%	0.7%	0.0%	0.2%	0.1%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
		5.9%	*3.7%*	*9.3%*	*0.3%*	*0.0%*	*0.0%*	*0.1%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*
50	H	75.2%	5.9%	17.9%	0.1%	0.0%	0.2%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
		8.3%	*1.3%*	*7.4%*	*0.1%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*
51	H	49.1%	13.9%	36.4%	0.4%	0.0%	0.1%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
		8.4%	*5.8%*	*10.4%*	*0.3%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*
52	H	21.2%	10.3%	67.9%	0.3%	0.0%	0.1%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
		4.3%	*3.6%*	*7.9%*	*0.1%*	*0.0%*	*0.0%*	*0.1%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*
53	H	42.0%	9.8%	47.4%	0.2%	0.0%	0.2%	0.2%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
		21.9%	*4.9%*	*27.1%*	*0.1%*	*0.0%*	*0.1%*	*0.1%*	*0.0%*	*0.1%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*
54	H	25.9%	22.5%	49.9%	0.9%	0.0%	0.4%	0.2%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
		5.3%	*0.6%*	*6.1%*	*0.3%*	*0.0%*	*0.1%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*
55	H	73.4%	15.9%	9.0%	1.2%	0.1%	0.2%	0.1%	0.0%	0.1%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%
		2.1%	*1.4%*	*1.7%*	*0.4%*	*0.1%*	*0.0%*	*0.1%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*
56	H	70.4%	12.5%	4.7%	11.8%	0.0%	0.2%	0.3%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
		4.7%	*2.3%*	*1.7%*	*5.3%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*
57	H	70.7%	13.4%	12.3%	2.0%	1.2%	0.1%	0.1%	0.0%	0.1%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%
		3.5%	*0.2%*	*4.2%*	*0.1%*	*0.4%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.1%*	*0.0%*	*0.0%*	*0.0%*
58	H	20.4%	13.7%	65.0%	0.3%	0.1%	0.2%	0.1%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
		14.1%	*7.5%*	*20.8%*	*0.2%*	*0.1%*	*0.1%*	*0.1%*	*0.0%*	*0.1%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*
59	H	73.5%	11.8%	14.1%	0.2%	0.1%	0.1%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
		3.8%	*0.9%*	*4.4%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*
60	H	21.9%	13.4%	63.9%	0.2%	0.0%	0.1%	0.1%	0.0%	0.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
		7.7%	*5.0%*	*9.8%*	*0.1%*	*0.1%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*
61	I	59.5%	21.2%	18.5%	0.3%	0.1%	0.1%	0.1%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
		25.8%	*17.4%*	*8.8%*	*0.3%*	*0.1%*	*0.1%*	*0.1%*	*0.0%*	*0.1%*	*0.1%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*
62	I	85.3%	13.5%	0.2%	0.3%	0.1%	0.2%	0.1%	0.2%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%
		1.6%	*1.7%*	*0.0%*	*0.2%*	*0.0%*	*0.0%*	*0.0%*	*0.1%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*
63	I	58.2%	9.2%	31.3%	0.9%	0.1%	0.1%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
		20.6%	*2.1%*	*18.4%*	*0.2%*	*0.0%*	*0.0%*	*0.1%*	*0.0%*	*0.1%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*
64	I	71.9%	15.5%	6.4%	5.7%	0.0%	0.1%	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%
		3.8%	*2.3%*	*2.6%*	*1.2%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*
65	I	47.0%	18.4%	33.6%	0.4%	0.2%	0.2%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
		0.0%	*4.6%*	*5.0%*	*0.1%*	*0.1%*	*0.0%*	*0.1%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*
66	I	42.9%	8.8%	47.0%	1.0%	0.0%	0.1%	0.1%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
		11.0%	*1.2%*	*12.4%*	*0.3%*	*0.0%*	*0.0%*	*0.1%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*
67	I	34.1%	51.2%	13.6%	0.3%	0.1%	0.3%	0.1%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
		4.4%	*8.5%*	*4.7%*	*0.0%*	*0.1%*	*0.0%*	*0.1%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*
68	I	56.4%	13.5%	27.9%	1.6%	0.3%	0.1%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
		7.2%	*0.3%*	*7.4%*	*0.3%*	*0.1%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*
69	J	71.3%	12.6%	13.0%	1.5%	0.5%	0.3%	0.2%	0.0%	0.0%	0.1%	0.1%	0.2%	0.0%	0.0%	0.0%
		11.6%	*2.7%*	*8.5%*	*0.3%*	*0.2%*	*0.1%*	*0.1%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.1%*	*0.0%*	*0.0%*	*0.0%*
70	K	59.6%	18.8%	19.6%	0.9%	0.1%	0.4%	0.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.1%	0.0%
		11.8%	*13.7%*	*7.5%*	*0.5%*	*0.1%*	*0.4%*	*0.3%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.1%*	*0.1%*	*0.0%*
71	K	47.8%	7.9%	43.1%	0.7%	0.1%	0.1%	0.0%	0.0%	0.1%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%
		4.3%	*0.3%*	*4.6%*	*0.6%*	*0.2%*	*0.0%*	*0.0%*	*0.0%*	*0.1%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*

Tab. 2. Composition of studied anklets according to surface XRF. Numbers in the first column correspond to anklet numbers in the catalogue. Each anklet record consists of two rows: the first row represents the mean values of individual measurements, and the second represents standard deviations calculated from these values. Only elements which make up at least 0.1% of at least one anklet are shown.

Tab. 2. *Složení studovaných nánožníků podle povrchové XRF analýzy. Čísla v prvním sloupci odpovídají číslům v katalogu. Záznam každého nánožníku sestává ze dvou řádků: první řádek představuje průměrné hodnoty jednotlivých měření téhož nánožníku, druhý pak směrodatnou odchylku získanou z těchto měření. Byly zahrnuty pouze prvky, které tvoří alespoň 0,1 % minimálně jednoho z nánožníků.*

	Surface XRF			Subsurface XRF			ICP-MS/ICP-OES		
Anklet No.	**Cu**	**Sn**	**Pb**	**Cu**	**Sn**	**Pb**	**Cu**	**Sn**	**Pb**
15	85.2%	13.3%	0.8%	92.7%	6.1%	0.8%	–	–	–
19	88.7%	10.9%	0.1%	94.8%	4.5%	0.3%	–	–	–
20	74.0%	14.5%	8.3%	89.3%	4.5%	5.0%	–	–	–
39	80.2%	14.0%	5.0%	91.2%	6.0%	2.1%	–	–	–
49	51.8%	21.0%	26.0%	82.3%	6.4%	10.8%	–	–	–
52	21.2%	10.3%	67.9%	88.4%	4.7%	6.9%	–	–	–
60	21.9%	13.4%	63.9%	87.9%	4.0%	8.0%	–	–	–
61	59.5%	21.2%	18.5%	–	–	–	84.4%	9.8%	5.4%
62	85.3%	13.5%	0.2%	–	–	–	88.1%	10.0%	1.4%

Tab. 3. The values of subsequent analyses made from drilled samples of seven anklets and the values for two anklets covered by this paper (Danielisová et al. in preparation), both in contrast with the surface XRF values. Anklet numbers correspond to the numbering in the catalogue.

Tab. 3. *Hodnoty z následných analýz provedených na odvrtaných vzorcích sedmi nánožníků a hodnoty získané pro další dva nánožníky probírané v tomto článku (Danielisová et al. v přípravě). Pro porovnání se v tabulce nachází i hodnoty z povrchové XRF analýzy. Čísla nánožníků odpovídají číslům v katalogu.*

throughout the three measurements taken on a single (!) anklet. The highest scatter in one anklet was even worse, with a Cu to Pb ratio of 65%. This is due to the chemical characteristics of these elements, the corrosion layer (as stated above) and the XRF spectrometer's way of operation. The spectrometer is not capable of taking measurements from the artefact's core; in fact, it is limited to only tens of micrometres (Kučera et al. 2021, 34). Copper, tin and lead also mix only to a limited degree; for example, it is presumed that during the solidification of the artefact, tin is pushed towards the surface, because it solidifies later than copper. On the other hand, lead forms 'islands' and layers around the copper crystal (Frána et al. 1997, 46), making the alloy less homogenous, and thus lead values can differ significantly between individual measurements (Kmošek 2019, 11). To conclude, results from the surface XRF are to be viewed very critically and as semi-quantitative.

To verify and possibly correct the error of the surface XRF, seven already damaged anklets were selected and samples were taken from the damaged spots with a drill. These anklets (Tab. 3; Fig. 4:1–7) are from categories D and H. First, a bit of material was removed by drill to eliminate the corrosion layers, and then the sample itself was taken (the samples were very small – under 5 mg in weight). The samples were analysed once more using the XRF method. A benchtop ED-XRF (energy dispersive X-ray fluorescence) spectrometer ElvaX Pro at the Institute of Archaeology of the Czech Academy of Sciences in Brno was used this time due to its capability to measure small samples more accurately than the portable model. Each sample was measured for five minutes with an energy up to 45 keV. This follow-up analysis (Tab. 3) yielded more plausible results when compared to the pXRF values. Two things are apparent when comparing the two methods: (1) there is a quite stable margin between the two sets of Sn values, which are about 9±4% lower in the samples taken from the artefact core, and (2) when there is a higher than negligible amount of Pb, it seems to be disproportionately more pronounced in the surface readings at the expense of Cu. Although finding number two does not apply unconditionally, because of the lead-induced inhomogeneities

Fig. 4. The anklets selected for reference analyses. 1 – Křenovice inv. No. 111.050; 2 – Pavlov, inv. No. 175.741; 3 – Přerov-Předmostí, inv. No. 66.140; 4 – Nížkovice, inv. No. 64.944; 5 – Vyškov, inv. No. 112.090; 6 – Mistřín, inv. No. 65.411; 7 – Holubice, inv. No. 64.850; 8 – Brno-Maloměřice, inv. No. 107.570; 9 – Brno-Maloměřice, inv. No. 107.508. MZM. Photo by D. Spáčil.

Obr. 4. *Nánožníky vybrané pro srovnávací analýzy. 1 – Křenovice, inv. č. 111.050; 2 – Pavlov, inv. č. 175.741; 3 – Přerov-Předmostí, inv. č. 66.140; 4 – Nížkovice, inv. č. 64.944; 5 – Vyškov, inv. č. 112.090; 6 – Mistřín, inv. č. 65.411; 7 – Holubice, inv. č. 64.850; 8 – Brno-Maloměřice, inv. č. 107.570, 9 – Brno-Maloměřice, inv. č. 107.508. MZM. Foto D. Spáčil.*

discussed above. Two other anklets covered by this paper (anklet No. 61 and 62;[3] Fig. 4: 8, 9) were recently analysed by a team of researchers, and values of Cu, Sn and Pb for these two anklets were measured via ICP-MS (inductively coupled plasma mass spectrometry) and/or ICP OES (inductively coupled plasma atomic emission spectroscopy; Danielisová et al. in preparation) was used with the permission of their authors as a reference. The measured values were very close in the surface XRF and the ICP-MS (mean difference of 2.5% in all three main compounds), in the case of anklet No. 62 (Fig. 4:8) with a heavily cleaned surface (the corrosion layer was probably removed during some phase of conservation). The difference in the second anklet (No. 61) was more pronounced (mean difference of 16.5% in Cu, Sn and Pb combined) since the corrosion layer was still in place.

3.2 Filling analysis

For the filling analysis, samples from thirteen anklets were used (Tab. 4; Fig. 5). Only groups G–K (hollow anklets) could be used, since the anklets from previous groups do not have cavities for fillings. Samples of fillings were taken for a GC/MS (gas chromatography with mass spectrometry) analysis with a drill from multiple spots for maximum possible homogeneity. They were extracted with a 10 ml mixture of acetone: CH_3Cl (1 : 1, v/v) afterwards, centrifuged, blown with a fine stream of nitrogen gas, and silanized with a mixture of pyridine (Lachner, 10 µl) and N,O-Bis(trimethylsilyl)trifluoroacetamide (Merck, 10 µl). The samples were then analysed with a gas chromatograph with a triple quadrupole Agilent 7010 running Mass Hunter software (Agilent Technologies). Separation was carried out in two (5%-phenyl)-methylpolysiloxane capillary columns connected in series with a constant flow rate of 1.0 and 1.2 ml^{-1}. The temperature program was set at 50 °C and was held for five minutes. With a rate of 6°C per minute, the temperature was raised to 300°C and was held at this level for 10 minutes, after which it was gradually raised again by 20°C for a minute and held at 320°C for another five minutes. The sample injection was carried out using the splitless injection method (injection volume was 1 µl). The detected chemicals can be seen in Tab. 4.

4. Discussion

4.1 Metal composition

The surface XRF analysis results appear to show a pattern in the copper, tin, and lead content. Starting from the middle, tin shows the highest stability of all three major elements throughout all categories A–K (Graph 2**:** top left). The categories with the lowest number of individuals (A, B, F, J) are the most stable, of course, although the values are really scattered only in categories C, I and K (standard deviation over 10%). The mean value lies between 10% and 20% in most categories (except for B, where it is only 5%). Until category G, the contents of Sn and Cu correlate, since almost no other elements are present (apart from some outliers in categories C, D and E, with Pb contents around 10%), mean values of Cu in categories A–G are between 76% and 91%.

A significant change occurs with category H (and the following categories) regarding Pb and Cu levels. Lead seems to be radically higher in anklets with hollow hemispheres (cat. H–K) than in others. It is noteworthy that the change is not apparent in the tin levels, as stated above. The sudden 'disbalance' involves only copper and lead. The mean content of lead in the aforementioned categories fluctuates between 13% and 31% (the values of copper, tin, and lead from surface XRF analysis can also be seen in Graph 2: bottom).

Compound	36	37	38	41	45	46	47	51	54	56	61	63	65
Pimaric acid				×							×		
Isopimaric acid				×		×	×	×			×		
Dehydroabietic acid	×	×	×	×		×	×	×			×	×	×
Piceatannol											×		
Resveratrol				×			×	×			×		
Nonanoic acid	×	×	×	×	×	×	×	×	×	×	×		×
Tridecanoic acid		×	×				×			×			
Myristic acid	×	×	×	×	×	×	×	×	×	×	×	×	×
Nonadecanoic acid	×	×	×	×	×	×	×	×	×	×	×	×	×
Palmitic acid	×	×	×	×	×	×	×	×	×	×	×	×	×
9-Octadecanoic acid	×	×		×		×	×				×		×
Stearic acid	×	×	×	×	×	×	×	×	×	×	×	×	×
1-Monomyristin	×	×	×	×		×	×		×	×	×		×
2-Palmitoylglycerol	×	×	×	×	×	×	×		×	×	×		×
1-Monopalmitin	×	×	×	×	×	×	×	×	×	×	×	×	×
2-Monostearin	×	×	×	×	×	×	×		×	×	×		×
1-Monostearin	×	×	×	×	×	×	×	×	×	×	×		×
Lignoceric acid													×
1-Octadecanol	×	×	×	×	×	×	×	×	×	×	×		×
1-Tetradecanol		×	×				×			×			
Tetracosanol		×	×	×						×		×	
1-Octacosanol	×	×		×			×	×				×	×
Cholesterol derivative		×										×	
Stigmastatrienol		×	×	×						×	×	×	×
2-Dodecanol	×	×	×	×							×		×
Phthalate-2	×	×	×	×							×	×	×
Phthalate	×	×	×	×	×	×	×	×	×	×	×		×
Dibutyl phthalate	×	×	×	×	×	×	×	×	×	×	×	×	×
Monobutyl phthalate		×	×										
Alkane-1	×	×	×	×	×	×	×	×	×	×	×	×	×
Alkane-2	×	×	×	×	×	×	×	×	×	×	×	×	×
Alkane-3	×	×	×	×	×	×	×	×	×	×	×	×	×
Alkane-4	×		×	×	×	×	×		×	×	×		×
Alkane-5	×		×	×	×		×	×	×	×	×		×
Alkane-6		×	×	×	×					×	×	×	×
Alkane-7	×	×	×	×	×	×	×	×	×	×	×	×	×
Alkane-8	×	×	×	×	×	×	×	×	×	×	×	×	×
Alkane-9			×		×				×	×			
Alkane-10	×	×	×	×	×	×	×	×	×	×	×	×	×
Alkane-12	×	×	×	×	×	×	×		×	×	×	×	×
Alkane-14			×		×					×			×

Tab. 4. Organic compounds found in the sampled fillings. × – the compound is present in the sample.

Tab. 4. *Organické sloučeniny ve vzorkovaných výplních.* × *– sloučenina je přítomna ve vzorku.*

The shape of the curves of copper, tin and lead levels looks very similar when viewed from the perspective of relative chronology (Graph 2: top right): low values of Pb on the left side of the chart, high values on the right side, and vice versa for Cu. The content of lead starts to rise in the B2b sub-phase of the La Tène period, although it does not really rise until the C1a sub-phase.[4] Until the B2b period, the mean lead value remains relatively stable and low (around 3.5%), then rises to 8% and 27% in B2b and C1a, respectively. Copper levels change according to those of lead in B2b–C1a, while tin remains around 14% throughout the entire timeline.

Since very low levels of copper, just like very high levels of lead and a high standard deviation in some extreme cases[5] lower the credibility of the results substantially, the surface data were compared to those from the core of the artefacts. The reference set of anklets could be divided into two abstract parts: anklets with a very low standard deviation[6] and those with a very high

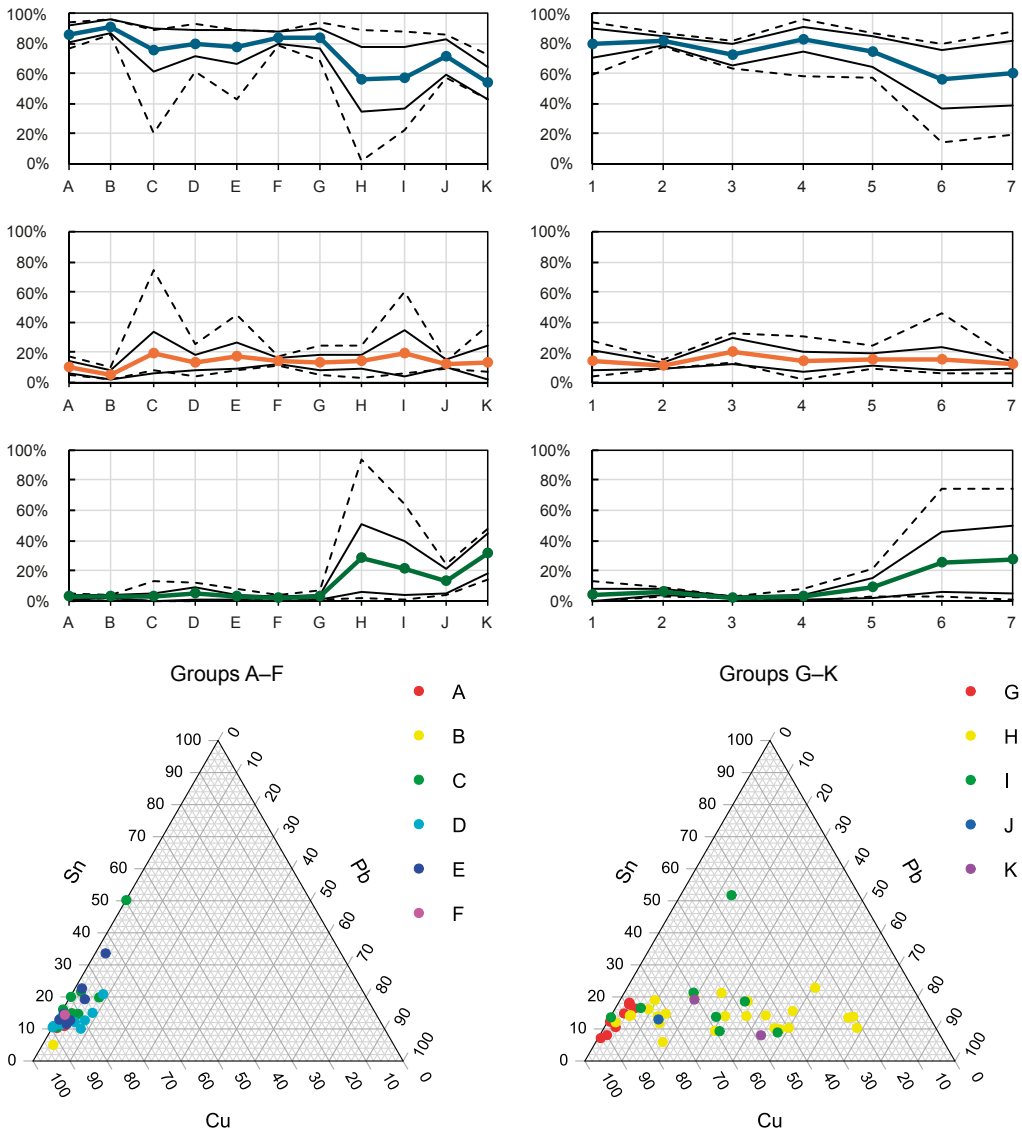
Fig. 5. Anklets with fillings subjected to GC/MS analysis.
1 – Vlkoš, inv. No. P 242b;
2 – Vracov, inv. No. 70.441;
3 – Brno-Bohunice, inv. No. SAÚ 444/47;
4 – Milotice, inv. No. 157.531;
5 – Mistřín, inv. No. P 301/8;
6, 7 – Nížkovice, inv. No. 64.944, inv. No. 64.924;
8 – Slavkov u Brna, inv. No. 64.910;
9 – Vyškov, inv. No. 112.090;
10 – Šardice, inv. No. P 55;
11 – Omice, inv. No. 66.115;
12 – Křepice, inv. No. SAÚ 881;
13 – Brno-Maloměřice, inv. No. 107.570.
1, 5, 10 – MMH; 2–4, 6–9, 11–13 – MZM. Photo by D. Spáčil.

Obr. 5. *Nánožníky s výplněmi podrobené GC/MS analyse.*
1 – Vlkoš, inv. č. P 242b;
2 – Vracov, inv. č. 70.441;
3 – Brno-Bohunice, inv. č. SAÚ 444/47;
4 – Milotice, inv. č. 157.531;
5 – Mistřín, inv. č. P 301/8;
6, 7 – Nížkovice, inv. č. 64.944, inv. č. 64.924;
8 – Slavkov u Brna, inv. č. 64.910;
9 – Vyškov, inv. č. 112.090;
10 – Šardice, inv. č. P 55;
11 – Omice, inv. č. 66.115;
12 – Křepice, inv. č. SAÚ 881;
13 – Brno-Maloměřice, inv. č. 107.570.
1, 5, 10 – MMH; 2–4, 6–9, 11–13 – MZM. Foto D. Spáčil.

standard deviation[7] (Graph 3). The comparison outcome was quite clear. Very high lead levels in anklet No. 52 and 60 were not confirmed at all by the reference analyses. In fact, in all nine verification samples, none of the main elements showed 'unexpected behaviour', i.e. a sudden radical change between anklet categories. Copper oscillated between 82.3% and 94.8%, tin between 4% and 10%, and lead was also quite stable, ranging from 0.3% to 10.8%, contrary to the surface XRF analysis.

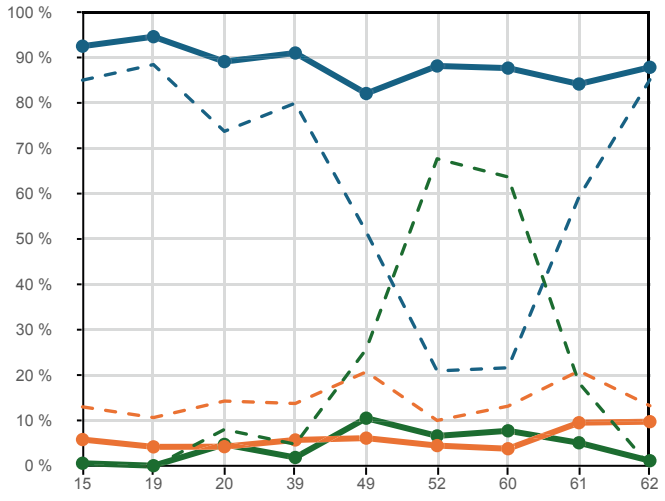
The surface XRF values of anklets No. 49, 52, 60 and 61 (Fig. 4:4–6, 9) deviated substantially from the follow-up analyses (up to 67%!). On the other hand, anklet No. 15, 19, and 62 (Fig. 4:1, 2, 8) showed the opposite tendency. Differences in mean values of the main elements from the surface XRF and reference analyses do not rise higher than 7.5% (Cu value in anklet No. 15) in these anklets. The standard deviation in none of these anklets (using the values from both the initial and follow-up analyses) does not exceed 3.3% (Cu value in anklet No. 15 again). Values from all three of these anklets have a relatively low standard deviation, and especially in values of Pb (σ under 0.5%). The correlation concerning the aforementioned issue is evident when looking at their pictures: the absence (Fig. 4:2, 8) or presence (Fig. 4:4, 5, 9) of the corrosion layer plays a major role in the surface XRF analysis.

Returning to the lead content from the perspective of the artefact core, although the Pb levels in the reference set are much lower than those from the surface XRF in anklets with hollow hemispheres, there is still a large difference compared to the anklets with a rod-like body (especially anklet No. 19). On the other hand, the core analysis indicates a low lead representation (below 8% in most cases) in comparison to that what seems to be standard in surrounding regions during LT B2 and C, although this might be partly due to the small sample size.



Graph 2. Graphic expression of surface XRF data. Top left: mean values of Cu, Sn, and Pb content in anklet groups A–K. Top right: mean values of Cu, Sn, and Pb in various periods of the Late Iron Age. 1 – B1b–c; 2 – B1b–B2a; 3 – B1c/B2a; 4 – B2a; 5 – B2b; 6 – B2b–C1a; 7 – C1a. Blue – Cu; orange – Sn; green – Pb; solid black line – ± 1 σ, dashed line – minimum and maximum values. Bottom: ternary plots of Cu, Sn, and Pb concentration in the studied anklets. Data taken from Table 2.

Graf 2. *Vyobrazení dat z povrchové XRF analýzy. Vlevo nahoře: průměrné hodnoty obsahu mědi, cínu a olova v kategoriích nánožníků A–K. Vpravo nahoře: průměrné hodnoty obsahu mědi, cínu a olova v jednotlivých úsecích doby laténské. 1 – B1b–c; 2 – B1b–B2a; 3 – B1c/B2a; 4 – B2a; 5 – B2b; 6 – B2b–C1a; 7 – C1a. Modrá – měď; oranžová – cín; zelená – olovo; plná černá čára – ± 1 σ, čárkovaná čára – minimální a maximální hodnoty. Dole: ternární diagramy koncentrace mědi, cínu a olova ve studovaných nánožnících. Data převzata z tabulky 2.*



Graph 3. A comparison of surface XRF data (dashed lines) with benchtop XRF or ICP-MS/ICP-OES data (solid line). Blue – Cu; orange – Sn; green – Pb. Data taken from Table 3.

Graf 3. *Srovnání dat z povrchové XRF analýzy (čárkovaná čára) s daty ze stolního XRF nebo ICP-MS-ICP-OES (plná čára). Modrá – Cu; oranžová – Sn; zelená – Pb. Data převzata z tabulky 3.*

4.2 Composition of fillings

The GC/MS analysis produced qualitative data about organic compounds present in the filling samples. Those compounds could be grouped based on their relevance to the matter: first, there was a group of aliphatic hydrocarbons (shown as 'alkane', plus a chain length, e.g. 'Alkane-1' in Tab. 4), which could represent contamination from conservation agents. These compounds were present more or less in every sample. Likewise, a group of fatty acids, fatty alcohols and sterols, suggesting a fat and wax content, was present in every sample. Although this could mean they were originally present in the anklet fillings, they could also be present in the agents used with the anklets during the conservation process. A group of phthalates was also detected in all the studied anklet fillings. They are probably also contamination from plastics, in which they serve as plasticisers.

In ten out of thirteen samples (anklet No. 36, 37, 38, 45, 52, 53, 57, 67, 69 and 71; Fig. 5:1–4, 6–8, 10–12), traces of acids usually connected to conifer resin were found, specifically pimaric, isopimaric and dehydroabietic acid, which are viewed as markers of pine resin (Bednář, Kurka 2021, 58, 70; Slavíková 2024, 10). The most common substance was dehydroabietic acid, which is a degradation product of abietic acid (Slavíková 2024, 10); it was present in all of the samples mentioned above. Traces of isopimaric and pimaric acids, which are also usually present in pine resin, were discovered in five and two samples, respectively.

Finally, resveratrol was present in the samples from anklet No. 45, 53, 57 and in the one from anklet No. 67, there was resveratrol along with its structural analogue – piceatannol. The former can be found, for example, in wine and grapes (*Vitis vinifera*), peanuts (*Arachis hypogaea*) and a wide range of berries (Jarošová et al. 2020, 1). Piceatannol can also be found in grapes and wine, although in a concentration roughly four times lower than resveratrol, in passion fruit (*Passiflora edulis*), Japanese knotweed (*Polygonum cuspidatum*) and *Picea abies*, the Norway spruce (Jarošová et al. 2019, 2). Although the presence of these two compounds is undoubtedly interesting, it remains unexplained. However, it could still originate from a mixture of oils used as a conservation agent.

5. Conclusion

From the evidence set forth above, it seems that the inference of the change in the bronze composition of annular jewellery in LT B2 made by Frána, Jiráň, Moucha and Sankot (1997) and also observed by Danielisová et al. (2021) holds in Moravian conditions as well. However, contrary to these publications, it seems that the change occurred a subphase later in Moravia. Truly high levels of lead do not appear in anklets fully until subphase LT C1a (although this statement should be verified on a larger and, most importantly, more varied set of artefacts in the future). This phenomenon could be caused by the transfer of the technologies connected to the metallurgy of copper alloys from Bohemia to Moravia or the relative chronology error in artefacts with a long 'lifespan'.

At this point, it should be emphasised that the surface XRF method did not prove reliable enough for copper alloy artefacts with a corroded surface (i.e. most prehistoric and protohistoric artefacts, unless the corrosion was mechanically removed), and especially those with higher amounts of lead or tin. Surface changes in the tin and lead content, at the expense of copper, are caused by corrosion processes. The preferential corrosion of copper leads to an overrepresentation of tin and lead on the surface (Kmošek 2019, 20). Although it is possible for leaded bronze to contain up to 40% lead, the surface XRF analysis in this study should be considered semi-quantitative, and the measured values should not be interpreted as absolute. On the other hand, the reference analyses (measuring the artefacts' cores) confirmed the tendency of adding more lead to the alloy, only on a much smaller scale: lead content was over 10% in only one out of six anklets, which *should* have had higher lead content compared to the situation in Bohemia.

But why was lead added to bronze anklets in higher amounts in the LT B2/C1 periods? The common explanation is that it allows the liquid bronze to flow more easily into the more complex moulds.[8] However, today's leaded bronzes are not used in artistic casting because of their inferior (!) properties in this respect (Jelínek 2024, 26). The reasons for the use of lead are therefore to be looked for elsewhere. Potential options could be, e.g. better workability[9] (Roučka 2004, 128), a change of colour, or maybe the lowering of production costs, possibilities that require further research.

Concerning the anklet fillings, presenting a clear conclusion based on the chemical analysis is difficult. All of the anklets from which the samples were taken come from quite old excavations and were subjected to conservation procedures, possibly even multiple times. All of the samples were thus contaminated with unidentified chemicals. Various detected compounds connected to fats and waxes are probably an outcome of this conservation. Multiple phthalates are also probably contaminants from an unknown (plastic) source. It is hard to explain piceatannol and resveratrol being present in some samples, as interesting as it might be. These two compounds both appear in grapes and wine and their connection to anklet fillings is unknown.

The presence of diterpenes (pimaric, isopimaric and dehydroabietic acid) might be much more significant. These three compounds are components of conifer resin (specifically in that of the genus *Pinus* – pine). Naturally occurring resin was used as a glue in the past (e.g. Langejans et al. 2022), which could explain its occurrence here. The traces of resin were detected in both analysed caterpillar anklets and in eight out of eleven studied anklets with hollow hemispheres. In caterpillar anklets, this is directly connected to the aforementioned findings of the preserved cloth filling appearing to be stiffened with a glue-like matter (Kostelníková 2001). On the other hand, the fillings of the two analysed anklets of this kind did not resemble a textile. They were, similar to those in anklets with hollow hemispheres, dirt-like in appearance, and no macroscopic fibre evidence could be observed in any of the anklets subjected to GC/MS analysis. In the case of the caterpillar anklets, it is probably safe to assume that the dirt-like fillings are in fact petrified cloth stuffing. Resin traces in anklets with hollow hemispheres could be an indication of glued stuffing preventing the anklet from bruising its wearer's ankle; however, the direct evidence for this premise is missing. On the other hand, resin was also added to wax when forming the model for lost-wax casting (which is the presumed method for the production of anklets with hollow hemispheres). Also, some of the fillings are black in colour, which could be caused by the wax model burning during the process.[10] These two thoughts suggest that the fillings of anklets with hollow hemispheres are actually remnants of a mould left from the lost-wax casting process, though this will have to be confirmed by future research.

6. Catalogue

The catalogue is structured as follows: site name, grave ID (or N/A if uncertain), type of anklet (and boss count combination if known – only concerns anklets with hollow hemispheres), archaeological dating (according to Waldhauser ed. 1978; Waldhauser 1987; and Salayová 2023), inventory number, depositing institution, and sources. ACO – Archeological Center Olomouc, MGP – Prostějov Museum and Gallery, MKP – Comenius Museum in Přerov, MMB – Brno City Museum, MMH – Masaryk Museum in Hodonín, MZM – Moravian Museum in Brno, VMO – Regional Museum in Olomouc.

ID	Site	Grave	Type of anklet	Dating	Inventory number	Depositing institution	Sources	Portable XRF	Invasive XRF	GC/MS
1	Brno-Chrlice – Přední roviny	10	A	B1b–c	314475	MMB	Čižmářová 2011, 82–86	✓		
2	Marefy – U Lišek	20	A	B1b–c	111.424	MZM	Čižmářová 2013, 143–151	✓		
3	Mistřín – Trávníky za kostelem	VII	B	B2a	P 307/6	MMH	Čižmářová 2017, 92–109	✓		
4	Brno-Chrlice – Přední roviny	7	C	B1b–c	314453	MMB	Čižmářová 2011, 82–86	✓		
5	Brno-Chrlice – Přední roviny	8	C	B1b–c	314461	MMB	Čižmářová 2011, 82–86	✓		

ID	Site	Grave	Type of anklet	Dating	Inventory number	Depositing institution	Sources	Portable XRF	Invasive XRF	GC/MS
6	Břeclav – Zvolence	gr. from year 1928	C	B1c/B2a	113.583	MZM	Čižmářová 2019, 133–135	✓		
7	Charváty – U sv. Jana	N/A	C	N/A	865, 866 (673/64)	VMO	Čižmářová 2017, 142–144	✓		
8	Křenovice – Přední díly	31	C	B1b–c	111.099	MZM	Čižmářová 2009	✓		
9	Mistřín – Trávníky za kostelem	VII	C	B2a	P 307/5	MMH	Čižmářová 2017, 92–109	✓		
10	Olomouc-Slavonín – U hvězdárny	4	C	B2	2/2000-804-4	ACO	Čižmářová 2017, 149–151	✓		
11	Ponětovice – Podíly	30	C	B1b–c	111.514 (Pa 243/36-119)	MZM	Čižmářová 2011, 124–147	✓		
12	Sobotovice	N/A	C	B1b–c	66.163	MZM	Čižmářová 2011, 150–151	✓		
13	Brno-Maloměřice – Plíže	10	D	B1b–c	107.476	MZM	Čižmářová 2005	✓		
14	Kobylnice – Nad Bezděkovem	8	D	N/A	112.042	MZM	Čižmářová 2011, 112–115	✓		
15	Křenovice – Přední díly	7	D	B1b–c	111.050	MZM	Čižmářová 2009	✓	✓	
16	Křenovice – Přední díly	30	D	B1b–c	111.091	MZM	Čižmářová 2009	✓		
17	Mikulov – Na rybníkách	N/A	D	N/A	157.526	MZM	Čižmářová 2019, 171–172	✓		
18	Nížkovice – Záhumenice	13	D	B1b–c	64.956	MZM	Čižmářová 2013, 154–162	✓		
19	Pavlov – Dolní pole I	H 48	D	B2a	175.741	MZM	Čižmářová 2019, 184–185	✓	✓	
20	Přerov-Předmostí – brick pit	N/A	D	N/A	66.140	MZM	Čižmářová 2017, 189–190	✓	✓	
21	Telnice – brick pit	1	D	B1b–B2a	66.161	MZM	Čižmářová 2011, 158–159	✓		
22	Brno-Maloměřice – Plíže	17	E	B2a	107.488	MZM	Čižmářová 2005	✓		
23	Brno-Maloměřice – Plíže	34	E	B2	107.517	MZM	Čižmářová 2005	✓		
24	Marefy – U Lišek	4	E	B2a	111.369	MZM	Čižmářová 2013, 143–151	✓		
25	Němčice nad Hanou – Za hájem	N/A	E	N/A	66.340	MZM	Čižmářová 2017, 178	✓		
26	Ptení – Výmolův rybník	N/A	E	N/A	38654	MGP	Čižmářová 2017, 183	✓		
27	Slavkov u Brna – Povětrníky	1	E	B1b–B2a	64.914	MZM	Čižmářová 2013, 174–179	✓		
28	Zaječí – gravel pit (Babeschhölzel)	10	E	B2	174.548	MZM	Čižmářová 2019, 208–211	✓		
29	Holubice – Dílce	27	F	B2a	107.215 (Pa 2643/38)	MZM	Čižmářová 2009	✓		
30	Bedřichovice – Malé pole	10/80	G	N/A	156.834 (00138-55/80)	MZM	Čižmářová 2011, 95–97	✓		
31	Blučina – Konopné zahrádky	20	G	B2a	55-107/63	MZM	Čižmářová 2011, 99–107	✓		
32	Brno-Maloměřice – Plíže	48	G	B2a	107.558	MZM	Čižmářová 2005	✓		
33	Brno-Maloměřice – Plíže	67	G	B2a	111.013	MZM	Čižmářová 2005	✓		
34	Mistřín – Trávníky za kostelem	XIV	G	B2b	P 316/6a	MMH	Čižmářová 2017, 92–109	✓		
35	Nížkovice – Záhumenice	4	G	B2a	64.919	MZM	Čižmářová 2013, 154–162	✓		
36	Vlkoš 2 – village area	N/A	G	B2a	P 242b	MMH	Čižmářová 2017, 122–123	✓		✓
37	Vracov – Na Babí sandpit	1	G	B2b	70.441	MZM	Čižmářová 2017, 123–125	✓		✓
38	Brno-Bohunice – Žlíbek	1	H (4+4 b.)	B2b	SAÚ 444/47	MZM	Čižmářová 2011, 74–75	✓		✓
39	Holubice – Dílce	4	H (6+5 b.)	B2	64.850	MZM	Čižmářová 2009	✓	✓	
40	Hustopeče – Šibenky	K 838	H (7+6 b.)	B2b–C1a	174.780	MZM	Čižmářová 2019, 139–159	✓		
41	Charváty – U sv. Jana	N/A	H	N/A	P 673/74	VMO	Čižmářová 2017, 142–144	✓		
42	Královopolské Vážany – Višňovce	N/A	H	N/A	66.184	MZM	Procházka 1937, 60; Anonym 1945	✓		
43	Měrovice – Před Gervízem	N/A	H	N/A	179.532	MZM	Čižmář et al. 2013	✓		
44	Mikulčice – Pískovna	N/A	H	N/A	A 2411	MMH	Ludikovský 1962	✓		
45	Milotice – state-owned farm	1/1962	H (7+6 b.)	B2–C1	157.531	MZM	Čižmářová 2017, 91	✓		✓
46	Mistřín – Trávníky za kostelem	I	H	C1a	P 301/8a	MMH	Čižmářová 2017, 92–109	✓		
47	Mistřín – Trávníky za kostelem	VIII	H	B2b–C1a	P 302/4c	MMH	Čižmářová 2017, 92–109	✓		
48	Mistřín – Trávníky za kostelem	I	H (5+2 b.)	C1a	P 301/8	MMH	Čižmářová 2017, 92–109	✓		✓
49	Mistřín – Trávníky, Rolka	N/A	H	N/A	65.411	MZM	Meduna 1980, 182–190	✓	✓	
50	N/A	N/A	H (3+3 b.)	N/A	N/A	MZM	unpublished	✓		
51	N/A	N/A	H	N/A	N/A	MZM	unpublished	✓		
52	Nížkovice – Záhumenice	7	H	N/A	64.944	MZM	Čižmářová 2013, 154–162	✓	✓	✓
53	Nížkovice – Záhumenice	1	H (5+5 b.)	B2	64.924	MZM	Čižmářová 2013, 154–162	✓		✓
54	Přerov-Předmostí – brick pit	N/A	H	N/A	65.047–65.049, 65.057–65.059, 70.451	MZM	Čižmářová 2017, 189–190	✓		
55	Ptení – Mlýnisko (Ptinky)	N/A	H (4+4 b.)	B2b	P 686/64	VMO	Čižmářová 2017, 182–183	✓		
56	Slatinice – railway construction site	from year 1882	H	N/A	A137383	VMO	Hlava 2014	✓		
57	Slavkov u Brna – Povětrníky	4	H (4+4 b.)	B2–C1	64.910	MZM	Čižmářová 2013, 174–179	✓		✓
58	Šardice – Kopec	N/A	H (4+2 b.)	N/A	3958 (698/64)	VMO	Čižmářová 2017, 119–121	✓		
59	Šlapanice – south end of village area	4	H (3+3 b.)	B2–C1	66.228	MZM	Čižmářová 2011, 156–158	✓		
60	Vyškov (Pustiměřské Prusy) – airport	2	H (6+6 b.)	B2b–C1a	112.090 (Pa 10904/39)	MZM	Čižmářová 2013, 163–170	✓	✓	✓
61	Brno-Maloměřice – Plíže	31	I (4+4 b.)	B2b–C1a	107.508	MZM	Čižmářová 2005	✓		
62	Brno-Maloměřice – Plíže	52	I (5+4 b.)	C1a	107.570	MZM	Čižmářová 2005	✓		✓
63	Křenovice – Přední díly	16	I (4+4 b.)	C1a	107.224	MZM	Čižmářová 2009	✓		
64	Mistřín – Trávníky za kostelem	VIII	I (5+2 b.)	B2b–C1a	P 302/4a-b	MMH	Čižmářová 2017, 92–109	✓		
65	Mořice – U můstku	N/A	I	N/A	170.663	MZM	Čižmář 2021	✓		
66	Mořice – U můstku	N/A	I	N/A	170.664	MZM	Čižmář 2021	✓		
67	Omice	N/A	I (?+2 b.)	N/A	66.115	MZM	Čižmářová 2011, 121	✓		✓
68	Přestavlky – Dvorský	N/A	I (5+2 b.)	B2b–C1a	348/65/2	MKP	Čižmářová 2017, 190–191	✓		
69	Křepice 1 – village area (Záhumenice)	N/A	J (3+3 b.)	N/A	SAÚ 881	MZM	Čižmářová 2019, 161	✓		✓
70	Rajhrad	N/A	K (4+3 b.)	N/A	66.224	MZM	Čižmářová 2011, 147–148	✓		
71	Šardice – Kopec	N/A	K	N/A	P55	MMH	Čižmářová 2017, 119–121	✓		✓

Acknowledgements

The funding for the present research paper was provided by the Czech Ministry of Education, Youth and Sports for specific research (IGA_FF_2024_003). Data from the large research infrastructure Archaeological Information System of the Czech Republic (AIS CR) have been used in this research paper. Available from: https://www.aiscr.cz/.

In the first place, I would like to thank Mgr. Matěj Kmošek, DiS., for his active help with chemical analyses – it would not be possible without him. My thanks also belong to doc. RNDr. Lukáš Kučera, Ph.D., for helping me with the technical aspects of this paper, and Mgr. Miloš Hlava, Ph.D., for his advice on choosing the topic. I am also grateful to all the collection curators who kindly lent anklets for my study, namely Mgr. Hana Čižmářová, Ph.D., PhDr. Jana Čižmářová, Mgr. Aleš Drechsler, PhDr. Lukáš Hlubek, Mgr. Zuzana Holubová, Mgr. František Kostrouch, Mgr. Blanka Veselá, and Bc. Barbora Zapletalová. And finally, I would like to thank Mgr. Alžběta Danielisová, Ph.D., for providing data on the two aforementioned anklets, and doc. Mgr. Martin Golec, Ph.D. and Mgr. Tomáš Mangel, Ph.D. for very fruitful consultations.

Notes

1. This applies to the categories of anklets with a rod-like body; the anklets with hollow hemispheres were further categorised based on the author's bachelor's thesis (Spáčil 2023, 40–42). The categories of wire and caterpillar anklets were not divided further.
2. The determination of some of these anklets is uncertain. For example, an 'anklet' from Hustopeče – Šibenky (inventory No. 174.725, MZM) comes from an empty grave (the skeleton was probably completely decomposed) and is very small. With a diameter of 3.5 cm, it is small even for a bracelet. But it also comes from the bottom part of a very small grave (only 135 × 60 cm; Kos 2005), which might suggest it was a child's anklet.
3. The anklets numbers in the text correspond to those in the catalogue.
4. The lead values are also higher in a broader timespan of B2b–C1a, which in reality contains anklets mixed from those two sub-phases, but for the lack of data they cannot be sorted any further.
5. E.g. anklet No. 53 with a mean Pb value of 47.4% (σ = 27.1%), 46 with a Pb value of 45.5% (σ = 21.8%).
6. Three anklets from category D (15, 19, 20) and one from category I (62).
7. Two from category H (52, 60) and one from category I (61).
8. E.g. 'alloying bronze with lead in order to facilitate casting' (Kysela 2020, 258).
9. Working is the next step after casting, which involves manually removing the imperfections left from casting.
10. Thanks to Matěj Kmošek for insights concerning lost-wax casting.

References

Anonym 1945: *Vážany K. (s. o. Slavkov)*. Manuscript of the excavation report, M-TX-194500352 [Accessed 2024-12-03]. Stored in: Archive of the Institute of Archaeology of the Czech Academy of Sciences, Brno. DOI: 10.60585/M-TX-194500352. Available also from: Digital Archive of the AMCR https://digiarchiv.aiscr.cz/id/M-TX-194500352.

Bednář, P., Kurka, O. 2021: Metody separační a spojené techniky. In: P. Bednář, L. Kučera (eds.): *Moderní chemická analýza v archeologii. I. díl*. Olomouc: Univerzita Palackého v Olomouci, 57–121.

Belanová-Štolcová, T. 2012: Slovak and Czech Republics. In: M. Gleba, U. Mannering (eds.): *Textiles and Textile Production in Europe from Prehistory to AD 400*. Ancient textiles 11. Oxford: Oxbow Books, 306–331.

Bujna, J. 2005: *Kruhový šperk z laténských ženských hrobov na Slovensku*. Nitra: Univerzita Konštantína Filozofa, Archeologický ústav SAV.

Bureš, M., Waldhauser, J. 2005: Mladší doba železná – Keltové na území Prahy. In: M. Lutovský, L. Smejtek (eds.): *Pravěká Praha*. Praha: Libri, 716–776.

Čižmář, I. 2021: *Mořice 2020. 'Za humny', 'U můstku'. Nález keltských nánožníků*. Manuscript of the fieldwork report, M-TX-202100428 [Accessed 2024-12-03]. Stored in: Archive of the Institute of Archaeology of the Czech Academy of Siences, Brno. DOI: 10.60585/M-TX-202100428. Available also from: Digital Archive of the AMCR https://digiarchiv.aiscr.cz/id/M-TX-202100428.

Čižmář, M., Čižmářová, J., Kejzlar, M., Kolníková, E. 2013: Detektorová prospekce archeologických lokalit na Moravě v roce 2011. *Přehled výzkumů* 54(2), 298–303.

Čižmářová, J. 2005: *Keltské pohřebiště v Brně-Maloměřicích*. Pravěk, Supplementum 14. Brno: Ústav archeologické památkové péče Brno.

Čižmářová, J. 2009: *Keltská pohřebiště z Holubic a Křenovic*. Pravěk, Supplementum 19. Brno: Ústav archeologické památkové péče Brno.

Čižmářová, J. 2011: *Keltská pohřebiště na Moravě. Okresy Brno-město a Brno-venkov*. Brno: Moravské zemské muzeum.

Čižmářová, J. 2013: *Keltská pohřebiště na Moravě. Okresy Blansko a Vyškov*. Brno: Moravské zemské muzeum.

Čižmářová, J. 2017: *Keltská pohřebiště na Moravě. Okresy Hodonín, Kroměříž, Olomouc, Opava, Prostějov, Přerov, Uherské Hradiště a Zlín*. Brno: Moravské zemské muzeum.

Čižmářová, J. 2019: *Keltská pohřebiště na Moravě. Okresy Břeclav a Znojmo*. Brno: Moravské zemské muzeum.

Danielisová, A., Bursák, D., Kertes, S., Rose, T., Čižmář, I., Čižmářová, H., Čižmářová, J., Militký, J., Mangel, T., Strnad, L., Trubač, J. in preparation: Iron Age communities in the contact zone – technological advances in the 3rd century BC along the Amber Road.

Danielisová, A., Bursák, D., Strnad, L., Trubač, J., Čižmářová, H., Daněček, D., Smíšek, K. 2020: Rituals, Hoards and Travellers? Archaeometry of the Iron Age Bronze Wheel Amulets. *Interdisciplinaria Archaeologica. Natural Sciences in Archaeology* XI(1), 33–45. DOI: 10.24916/iansa.2020.1.3. Available also from: https://www.iansa.eu/papers/IANSA-2020-01-danielisova.pdf.

Danielisová, A., Bursák, D., Strnad, L., Trubač, J., Fikrle, M. 2021: Life cycles of metals in the Iron Age (4th - 1st century BC). Sourcing and recycling of copper based alloys. In: B. Török, A. R. Giumlia-Mair (eds.): *Proceedings of the 5th International Conference 'Archaeometallurgy in Europe', 19-21 June 2019 - Miskolc, Hungary*. Monographies instrumentum 73. Drémil-Lafage: Éditions Mergoil, 273–288.

Fábry, N. B. 2012: Les anneaux à oves creux de la nécropole laténienne de Ludas. In: M. Szabó et al.: *La nécropole celtique à Ludas – Varjú-Dűlő*. Budapest: L'Harmattan, 181–187.

Filip, J. 1956: *Keltové ve střední Evropě*. Moumenta archaeologica V. Praha: Nakladatelství Československé akademie věd. Available also from: https://1url.cz/4JMEu.

Frána, J., Jiráň, L., Moucha, V., Sankot, P. 1997: *Artifacts of copper and copper alloys in prehistoric Bohemia from the viewpoint of analyses of element composition II*. Památky archeologické, Supplementum 8. Praha: Archeologický ústav AV ČR.

Furman, M. 2014: A Central European Form of La Tène Ornament. Rings with Three and Four Large Hollow Knobs from Slovakia. In: S. Berecki (ed.): *Iron Age Crafts and Craftsmen in the Carpathian Basin. Proceedings of the International Colloquium from Târgu Mureş. 10–13 October 2013*. Bibliotheca mvsei Marisiensis, Seria archaeologica VII. Târgu Mureş: MEGA, 183–190.

Geschwind, H. 2020: Auf der Suche nach den Keltinnen in Italien. Die Hohlbuckelringe aus Marzabotto (prov. Bologna/I). *Studia Hercynia* XXIV(2), 78–97. DOI: 20.500.11956/123729. Available also from: http://hdl.handle.net/20.500.11956/123729.

Goláňová, P., Komoróczy, B., Kmošek, M., Kolníková, E., Vlach, M., Zelíková, M. 2020: New metal and glass finds from the Late Iron Age in South Moravia (CZ). The contribution of citizen science to knowledge of the La Tene settlement structure in the Břeclav Region. *Přehled výzkumů* 61(2), 9–41. DOI: 10.47382/pv0612-05. Available also from: https://www.arub.cz/wp-content/uploads/61_2_01_final.pdf.

Hlava, M. 2014: Laténské pohřebiště v Čelechovicích na Hané (okr. Prostějov). In: J. Čižmářová et al. (eds.): *Moravské křižovatky. Střední Podunají mezi pravěkem a historií*. Brno: Moravské zemské muzeum, 527–561.

Jarošová, V., Veselý, O., Doskočil, I., Tomišová, K., Maršík, P., Jaimes, J. D., Šmejkal, K., Klouček, P., Havlík, J. 2020: Metabolism of cis- and trans-Resveratrol and Dihydroresveratrol in an Intestinal Epithelial Model. *Nutrients* 12(3). DOI: 10.3390/nu12030595. Available also from: https://pmc.ncbi.nlm.nih.gov/articles/PMC7146108/.

Jarošová, V., Veselý, O., Maršík, P., Jaimes, J. D., Šmejkal, K., Klouček, P., Havlík, J. 2019: Metabolism of Stilbenoids by Human Faecal Microbiota [online]. *Molecules* 24(6), 1155. DOI: 10.3390/molecules24061155. [Accessed 2024-12-03]. Available from: https://pmc.ncbi.nlm.nih.gov/articles/PMC6471231/.

Jelínek, V. 2024: *Slévárenské slitiny mědi pro umělecké lití* [online]. Manuscript of the thesis. Brno University of Technology. Faculty of Mechanical Engineering. Institute of Manufacturing Technology. Stored in: Theses.cz [Accessed 2024-12-03]. Available also from: https://theses.cz/id/zu34r8/.

Kmošek, M. 2019: *Měď a její slitiny jako surovina kovové industrie v pravěku a protohistorii na území jižní Moravy* [online]. Manuscript of the thesis. Masaryk University. Faculty of Arts. Department of Archaeology and Museology. Stored in: Archive of Thesis of Masaryk University [Accessed 2024-12-03]. Available from: https://is.muni.cz/th/ml8ni/.

Kos, P. 2005: *Hustopeče 2004*. Manuscript of the fieldwork report, M-TX-201701314 [Accessed 2024-12-09]. Stored in: Archive of the Institute of Archaeology of the Czech Academy of Sciences, Brno. DOI: 10.60585/ M-TX-201701314. Available also from: https://digiarchiv.aiscr.cz/id/M-TX-201701314.

Kostelníková, M. 2001: Laténské nánožníky s textilní výplní z Miroslavi (okr. Znojmo) a Mušova (okr. Břeclav). *Přehled výzkumů* 43, 325–326. Available also from: https://arub.cz/wp-content/uploads/pv_43_2001_specialni_metody.pdf.

Kruta, V. 1975: *L'Art celtique en Bohême. Les parures métalliques du Ve au IIe siècle avant notre ère*. Bibliothèque de l'Ecole des Hautes Études. IV. section, Sciences historiques et philologiques 324. Paris: Librairie Honoré Champion.

Kysela, J. 2020: *Things and Thoughts. Central Europe and the Mediterranean in the 4th-1st centuries BC*. Studia Hercynia, monographs 1. Praha: Charles University, Faculty of Arts. DOI: 20.500.11956/171021. Available also from: http://hdl.handle.net/20.500.11956/171021.

Langejans, G., Aleo, A., Fajardo, S., Kozowyk, P. 2022: Archaeological Adhesives [online]. In: *Oxford Research Encyclopedia of Anthropology*. 23 March 2022. DOI: 10.1093/acrefore/9780190854584.013.198. [Accessed 2024-12-03]. Available from: https://research.tudelft.nl/en/publications/archaeological-adhesives.

Ludikovský, K. 1962: Ploché keltské pohřebiště v Mikulčicích u Hodonína. In: R. Tichý (ed.): *Sborník Československé společnosti archeologické při ČSAV 2*. Brno: Krajské nakladatelství, 257–278. Available also from: https://www.digitalniknihovna.cz/mzk/uuid/uuid:fd09c5d0-b1d6-11e2-8c63-5ef3fc9ae867.

Masse, A., Szabó, M. 2005: La parure annulaire en bronze à oves creux de la période laténienne dans le bassin des Karpates. *Communicationes Archaeologicae Hungariae* 2005, 213–225. DOI: 10.54640/CAH.2005.213. Available also from: https://ojs.elte.hu/comarchhung/article/view/9323.

Meduna, J. 1980: *Die Latènezeitlichen Siedlungen und Gräberfelder in Mähren* (*Katalog*). Fontes Archaeologiae Moravicae XI. Brno: Archeologický ústav ČSAV v Brně. Available also from: https://arub.cz/wp-content/uploads/2020/11/Die_Latenezeitlichen_Siedlungen_und_Graberfelder_in_Mahren.pdf.

Megaw, J. V. S., Megaw, R. 2001: *Celtic Art. From its Beginnings to the Book of Kells*. Revised and expanded Edition. London: Thames & Hudson.

Procházka, A. 1937: *Gallská kultura na Vyškovsku* (*La tène středomoravský*). *1. Část archeologická*. Vlastivědný sborník okresu Vyškovského IV. Slavkov u Brna: Nákladem vlastním.

Roučka, J. 2004: *Metalurgie neželezných slitin*. Učební texty vysokých škol. Brno: Akademické nakladatelství CERM. Available also from: https://1url.cz/VJMpQ.

Salayová, I. 2023: *Kovové náramky a nápažníky na Moravě od 8. do 3. století př. n. l.* [online]. Manuscript of the thesis. Palacký University Olomouc. Faculty of Arts. Department of History. Stored in: These.cz [Accessed 2024-12-03]. Available from: https://theses.cz/id/t7tuaj/.

Sankot, P. 1981: Dva puklicové nánožníky z Kralup nad Vltavou. In: M. Buchvaldek, J. Sláma (eds.): *Varia archeologica 2* (*Sborník k poctě 80. narozenin akademika Jana Filipa*). Praehistorica VIII. Praha: Univerzita Karlova, 187–190.

Sankot, P. 2002a: Poznámky k laténskému nánožníku ze sbírky Městského muzea ve Vodňanech. *Archeologické výzkumy v jižních Čechách* 15, 89–94.

Sankot, P. 2002b: Zur Problematik des Kunsthandwerkes und der Werkstattbeziehungen in Böhmen während der Früh- bis Mittellatènezeit. In: C. Dobiat et al. (Hrsg.): *Dürrnberg und Manching. Wirtschaftsarchäologie im ostkeltischen Raum. Akten des internationalen Kolloquiums in Hallein / Bad Dürrnberg vom 7. bis 11. Oktober 1998*. Kolloquien zur Vor- und Frühgeschichte 7. Bonn: Dr. Rudolf Habelt GmbH, 331–348.

Slavíková, K. 2024: *Hmotnostní spektrometrie v analýze kulturního dědictví* [online]. Manuscript of the dissertation. Palacký University Olomouc. Faculty of Science. Department of Analytical Chemistry. Stored in: Theses.cz [Accessed 2024-12-03]. Available from: https://theses.cz/id/g9cxv4/.

Spáčil, D. 2023: *Laténské puklicové nánožníky z území Moravy* [online]. Manuscript of the thesis. Palacký University Olomouc. Faculty of Arts. Department of History. Stored in: Theses.cz [Accessed 2024-12-03]. DOI: 10.13140/RG.2.2.12795.28967. Available from: https://theses.cz/id/4bvw78/.

Spáčil, D., Kučera, L., Kmošek, M. 2025: *Chemical analyses and documentation of moravian anklets from La Tène Period* [Data set]. DOI: 10.5281/zenodo.15504038. Available from: https://zenodo.org/records/15504038.

Štolcová, T. 2019: Analýza zvyškov textilu z laténskych hrobov v okrese Břeclav a Znojmo. In: J. Čižmářová: *Keltská pohřebiště na Moravě. Okresy Břeclav a Znojmo*. Brno: Moravské zemské muzeum, 109–120.

Venclová, N. (ed.) 2008: *Archeologie pravěkých Čech 7. Doba laténská*. Praha: Archeologický ústav AV ČR, Praha, v. v. i. Available also from: https://www.arup.cas.cz/wp-content/uploads/2020/05/07_Laten_n.pdf.

Waldhauser, J. (ed.) 1978: *Das keltische Gräberfeld bei Jenišův Újezd in Böhmen. II. Band – Auswertung*. Archeologický výzkum v severních Čechách 6–7. Teplice: Krajské muzeum Teplice. Available also from: https://1url.cz/TJMp5.

Waldhauser, J. 1987: Keltische Gräberfelder in Böhmen. Dobrá Voda und Letky sowie Radovesice, Stránce und Tuchomyšl. *Bericht der Römisch-Germanischen Kommission* 68, 25–179.

Wocel, J. E. 1868: *Pravěk země České.* Praha: Královská společnost nauk.

Resumé

Nánožníky představují charakteristický prvek doby laténské, kdy se staly oblíbeným šperkem, zejména mezi bohatšími ženami. I když byly rozšířeny v celé době železné, jejich vrchol popularity spadá právě do její mladší fáze. Tyto kruhové šperky byly nošeny nejčastěji v páru, po jednom nad každým kotníkem. Hroby s více než dvěma nánožníky jsou velmi vzácné (graf 1). Zatímco výzkumy laténských nánožníků se většinou soustředily na jejich tvarové a typologické rozdělení, případně rozšíření (např. Bujna 2005; Fábry 2012; Furman 2014; Geschwind 2020; Masse, Szabó 2005; Sankot 1981; 2002a; 2002b; Spáčil 2023), dosud téměř nebylo podrobně zkoumáno jejich chemické složení. Tento článek si klade za cíl prověřit platnost závěrů Frány et al. (1997) a Danielisové et al. (2021) ohledně chronologické citlivosti přítomnosti olova v nánožnících a zjistit původ a význam hliněných výplní housenkovitých a puklicových nánožníků.

Na Moravě bylo identifikováno okolo 310 nánožníků, které lze rozdělit do čtyř hlavních skupin, pro potřeby toho článku ale byly rozčleněny do 11 jemnějších kategorií (tab. 1). Nejpočetnější jsou tyčinkové, a především puklicové nánožníky. Nánožníky obecně byly vyráběny převážně z měděných slitin. Pouze malé procento nánožníků je vyrobeno ze železa. Výrobní preference bronzu pravděpodobně souvisí s jeho lepší tvarovatelností, což mohlo usnadňovat výrobu složitějších dekorativních prvků, jako je tomu převážně u puklicových nánožníků. U dutých typů nánožníků se vyskytují výplně, které mohou být hliněné nebo látkové (obr. 3). Látkové výplně sloužily především jako podpůrná struktura pro křehké kovové části, zatímco hliněné výplně mohou být pozůstatky hrobového zásypu nebo hliněné formy použité při výrobě šperků. Výplně v puklicových nánožnících by mohly představovat i pozůstatky látkového polstrování, které sloužilo k ochraně nositelky před zraněním.

Pro zkoumání složení 71 nánožníků byla použita metoda povrchového XRF, která umožňuje rychlé a neinvazivní zjištění chemického složení (tab. 2). Tato metoda však vykazuje vysokou míru chybovosti kvůli vlivu korozní vrstvy na povrchu artefaktů. Výsledky XRF analýz ukázaly, že obsah cínu, mědi a olova se u jednotlivých typů nánožníků výrazně liší. Zatímco cín je poměrně stabilní, olovo vykazuje vzestupný trend, přičemž v pozdějších úsecích sledovaného období dosahuje významného podílu (graf 2). Pro ověření výsledků byly vybrány poškozené nánožníky, z nichž byly odebrány vzorky pro analýzu provedenou tentokrát stolním XRF spektrometrem (obr. 4). Tato metoda poskytla přesnější výsledky, které v omezené míře potvrzují, že vyšší obsah olova je skutečně přítomen u mladších nánožníků (tab. 3; graf 3). Z výsledků výzkumu vyplývá, že závěry Frány et al. (1997) o změnách ve složení bronzu platí i pro moravské nánožníky, avšak lze zde změnu pozorovat až o subfázi později. Zatímco v Čechách se obsah olova začal zvyšovat ve fázi LT B2, na Moravě se tento trend projevuje plně až v LT C1a. Tento rozdíl může být snad způsoben transferem technologických postupů mezi Čechami a Moravou. Zároveň se ukazuje, že povrchová XRF analýza není ideální metodou pro artefakty s korodovaným povrchem, jelikož při ní dochází ke zkreslení výsledků a je potřeba ji korigovat.

Co se týče výplní nánožníků, byly analyzovány vzorky ze 13 exemplářů (tab. 4; obr. 5), přičemž většina zjištěných látek byla pravděpodobně kontaminací z okolního prostředí, a to především z aplikovaných konzervačních postupů. Kromě nich byly zjištěny stopy resveratrolu a piceatannolu, což jsou látky běžně obsažené ve víně. Kromě toho byly ve většině vzorků nalezeny pryskyřičné kyseliny (kyselina pimarová, isopimarová a dehydroabietová), které naznačují přítomnost borovicových pryskyřic snad použitých jako lepidlo k uchycení látkových výplní sloužících jako polstrování, aby nedošlo k poranění kotníků nositelky. Nelze vyloučit ani možnost, že výplně puklicových nánožníků jsou pozůstatkem po výrobě.

Contact

David Spáčil
Faculty of Arts, Palacký University Olomouc
Křížkovského 10
CZ-771 80 Olomouc
david.spacil01@upol.cz
ORCID: 0009-0002-8856-2501