

Analysis of Bronze Fragments from the Late Bronze Age Hillfort Podmolí-Šobes, Czech Republic. Chronological Implications of Elemental Composition

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Abstract

This article focuses on the hillfort ‘Šobes’, a multilayered site in Southern Moravia, Czech Republic, with archaeological evidence of largely undisturbed human activity from the Late Neolithic to the present. The most prominent occupation phase is a Late and Final Bronze Age hillfort, notable for extraregional contacts and a rich artefact assemblage. The aim of the research was to analyse a unique bronze collection acquired without metal detecting, using typo-chronological methods and elemental composition analysis to assist in dating. The chosen approach was informed by prior research on dated Moravian bronze artefacts. During analysis, a distinct group of small tools – identified as awls and chisels – was examined for use-wear traces to assess their function. The results reflect the entire bronze assemblage from the site, revealing a largely homogeneous Late and Final Bronze Age tin-bronze group with a few younger items. Importantly, the first evidence for bronze production at the site using fahlore-based copper imported from other regions was identified.

Keywords

Bronze Age, metallurgy, hillfort, pXRF, use-wear analysis

Zusammenfassung – *Analyse der Bronzefragmente aus der spät-bronzezeitlichen Höhensiedlung Podmolí-Šobes, Tschechische Republik. Zur chronologischen Bedeutung der Elementzusammensetzung* Dieser Artikel untersucht die Höhensiedlung Šobes, eine mehrphasige Fundstelle in Südmähren, Tschechische Republik, deren archäologische Kontexte auf eine weitgehend ungestörte menschliche Präsenz vom Spätneolithikum bis heute hinweisen. Der dominanteste Besiedlungshorizont wird durch eine spät- und endbronzezeitliche Höhensiedlung mit überregionalen Kontakten und einem reichen Fundspektrum repräsentiert. Ziel der Forschung war die Analyse einer einzigartigen, ohne Metalldetektoren gesammelten Bronzeansammlung. Zur Untersuchung der meist stark fragmentierten Stücke wurden eine typo-chronologische Bestimmung und eine Analyse der Elementzusammensetzung auf Basis früherer Arbeiten zu mährischem Bronzematerial durchgeführt, um die Datierung zu präzisieren. Eine Untergruppe von Artefakten wurde als Ahlen und Meißel identifiziert und auf Gebrauchsspuren untersucht, um ihre Funktion

zu klären. Die Ergebnisse zeigen eine homogene spät- und endbronzezeitliche Zinnbronzegruppe, ergänzt durch jüngere Objekte, die zur allgemeinen Datierung der Fundstelle passen. Bemerkenswert ist, dass an dieser Fundstelle erstmals Hinweise auf die Verwendung von importiertem Kupfer auf Fahlerz-Basis für die Bronzeherstellung gefunden wurden.

Schlüsselbegriffe

Bronzezeit, Metallurgie, Höhensiedlung, pXRF, Gebrauchsspurenanalyse

1. Introduction: Characteristics and Current

State of Research on Podmolí-Šobes

The archaeological site Podmolí-Šobes lies on a prominent granite promontory, in southwestern Moravia, Czech Republic. It is located close to the present-day national border with Austria, with the closest large cities being Znojmo on the Czech side and Retz on the Austrian side (Fig. 1). An area known as ‘Šobes’ first appears in military mappings from the 18th century as agricultural land. The surface of the promontory is a slope with a north-south orientation; the accessible area measures approx. 15 ha. Its highest point lies 338 m above sea level, on a relatively flat upper plateau with an area of 3.5 ha (Fig. 2). The northern edge is collapsing into an extremely steep rocky slope, ending directly in the river Thaya, with a mean elevation of 95 m. The eastern and western edges are not as steep as those to the north, but they are still exceptionally inaccessible with an elevation ranging between 20 to 80 m. The southern slope slowly descends into the embankment plateau, located on alluvial sediments (sand and gravel) with an area of approx. 8.7 ha. The promontory is accessible only through a 20-metre-wide isthmus

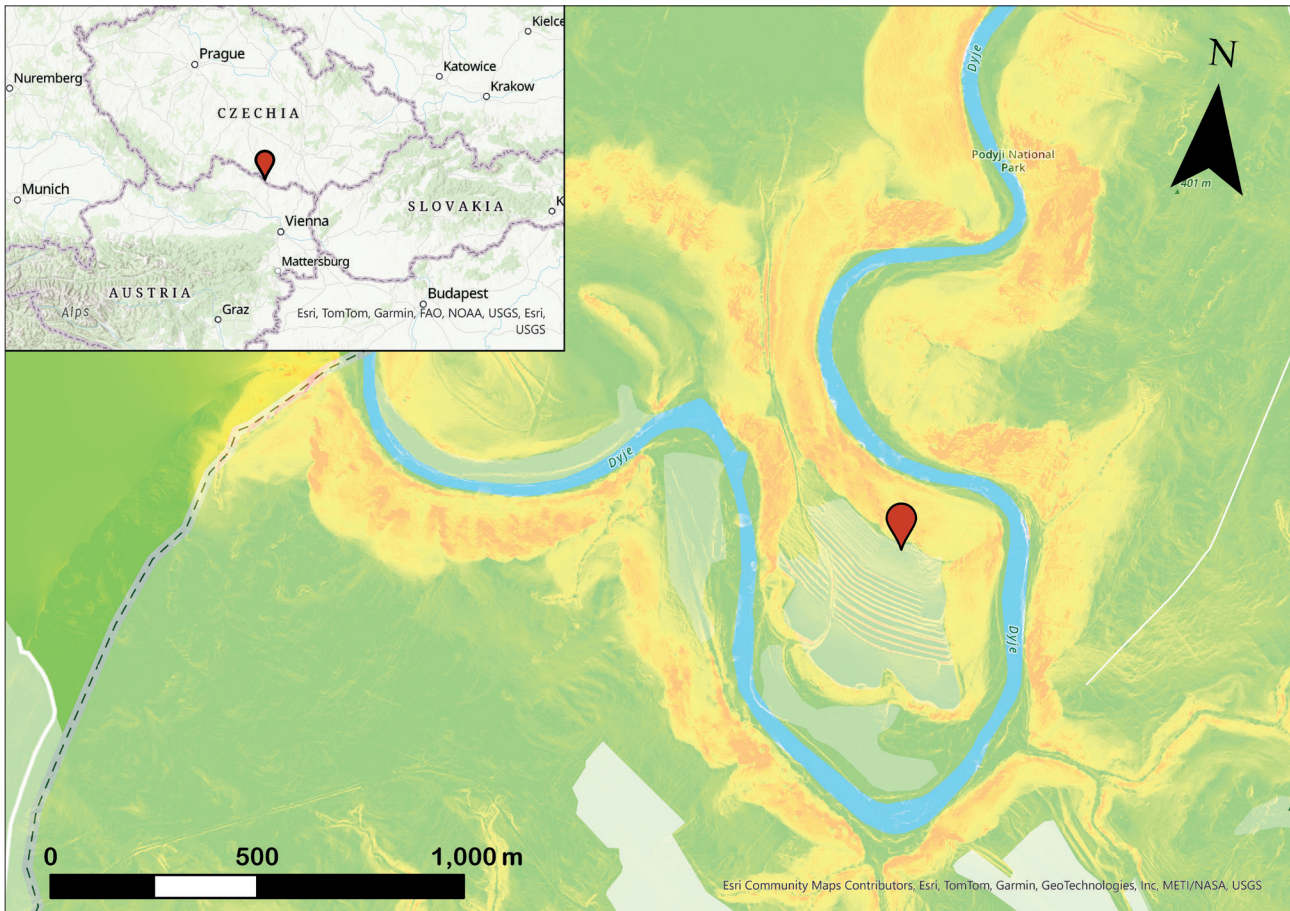


Fig. 1. Map of the site and its rough location in Central Europe. Note steep slopes circumventing the site (M. Valent).



Fig. 2. Aerial photo of the site as seen from the west. Photo taken during the 2015 excavations (Rožnovský 2015).

located in the north-northwest whose sides are also collapsing into the steep slopes towards the river, creating a perfectly defensible choke point. The river Thaya functions as a natural obstacle, source of water and possibly as a communication route. The land surrounding the settlement is exceptionally well preserved. Since at least the beginning of the 19th century, the immediate areas to the north, west and, most importantly, northwest were preserved as a royal forest.¹ Nowadays, this area is protected as Podyjí National Park which helps greatly with preservation of possible archaeological remnants. In the 1970s most of the promontory was terraformed with heavy machinery into a terraced vineyard, which is still used today. Based on available short reports (Říhorský 1974; Kovárník 1993; Čižmář 2001; Svoboda 2015), excavation reports (Čižmář 2000; Rožnovský 2015; Rožnovský 2016) and the author's previous research (Valent 2023), it can be concluded that human activities were already taking place at the site in the Late Neolithic and Early Eneolithic, were absent during the Early and Middle Bronze Age, and then resumed in the Late and Final Bronze Age, continuing until today.

All previous excavations and prospections provided valuable data about the site and a large assemblage of archaeological material. Based on these reports, the site reached the apex of its existence in the Late and Final Bronze Age as a large, fortified settlement of extraregional significance (Říhorský 1974; Kovárník 1993; Čižmář 2001). While any remains of perimeter defences are yet to be found, remains of a large rampart and rock-hewn ditch, separating the promontory from the rest of the land, were archaeologically studied and dated to the Middle-Danube Urnfield period (Čižmář 2001). The last two excavations, conducted in 2015 and 2016 by David Rožnovský for the South Moravian Museum in Znojmo, provided a substantial amount of Middle-Danube Urnfield material. Archaeological features, discovered during the 2015 excavation, were very well preserved under thick layers of soil in the southwestern part of the slope, above the alluvial embankment. The excavations uncovered several extraordinary situations, like the remains of an above-ground housing structure with a possible fire-related destruction horizon, a large waste pit or remnants of a possible Bronze Age wall with a fireplace in close proximity (Rožnovský 2015; Valent 2023). This is not the only residential structure found at the site, for the 2001 excavations managed to uncover a large prehistoric residential structure with remains of an oven (Čižmář 2000). The

slope area was probably terraced for the construction of buildings, as is evidenced by two excavated and dated walls (Čižmář 2000; Valent 2023). Extensive human activities in the Late Bronze Age are attested by an excessive amount of pottery, which includes storage vessels, cooking and utility pots and even fine tableware. Some of them were found in situ, like a small, distinctively decorated Velatice-phase cup, which was found lying on what may be the floor of a house. The majority of the features can be dated to the Middle-Danube Urnfield period (Čižmář 2000; Rožnovský 2015; Rožnovský 2016; Valent 2023), which supports the current hypothesis. A separate episode in the research on the site consists of surface prospections conducted independently by the amateur archaeologist Dan Svoboda in 2015. These were basic prospections, carried out on recently ploughed areas. Given the vast amount of material and data gathered, a 'mosaic-style' approach was chosen, segmenting the complete dataset into smaller studies with different focuses. This paper presents one part of the overall picture, specifically the analysis of a metal assemblage. The goal of this paper is to use advanced analytical methods to discern the typology and refine the dating of the site based on the heavily fragmented bronze assemblage found during surface prospections.

2. Methods

2.1. Description of the Material

The studied assemblage was borrowed from the South Moravian Museum in Znojmo, where it forms part of the collection. It consists of 163 metal objects and weighs 1259.6 g. All archaeologically significant bronze items were separated, totalling 93 specimens, of which 71 originate from surface prospections undertaken by the local enthusiast and unschooled archaeologist Dan Svoboda (Svoboda 2015); the remaining 12 items were obtained during field excavations (Čižmář 2000; Rožnovský 2015; Rožnovský 2016). These 93 objects weigh 335.2 g, with the average weight for the studied objects amounting to 3.6 g. These studied objects have an average length of 3.03 cm and an average width of 0.79 cm. It should once again be emphasised that all surface prospections (Svoboda 2015) were undertaken without the use of a metal detector, which directly impacts the ability to discuss their spatial distribution. Only two artefacts from field excavations can be associated with documented objects; the rest were found in the uppermost layers. Spatial data cannot be relied on, for two main reasons: the site is both a slope and a cultivated area. Settlement layers in the southern part of the site are filled with finds, especially pottery, which are most probably related to gravitational pull and the movement of soil downslope (Valent 2023). Agricultural activities included aggressive terraforming using

¹ As is noted in the cadastre sketches from 1824 and 1875 (<https://www.mza.cz/indikacniskici/skica/detail/95>, <https://www.mza.cz/indikacniskici/skica/detail/96>, last access 4.5.2026).

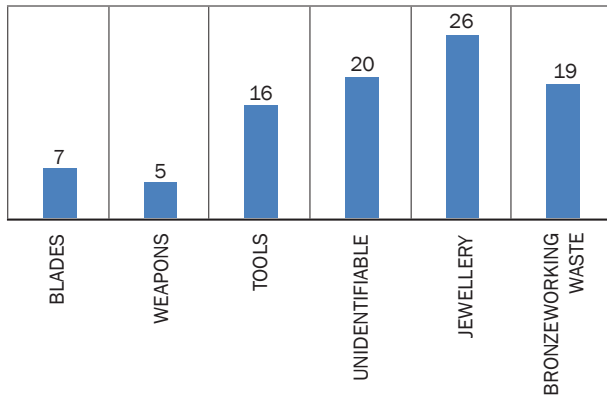


Fig. 3. Frequency of different types of artefacts identified (M. Valent).

explosives (to blast off the rocky base protruding onto the surface) and bulldozers (Říhový 1974) in the 70s, which can also be considered a major influence in disrupting the spatial distribution of artefacts. Most of the items also lack a precise GPS location. There are some items, however, whose spatial information can be of value. For example, two arrowheads were found on the eastern edge, where a simple form of perimeter defence might have stood. This could be related to a wartime event, as a similar observation was made at a different Late Bronze Age hillfort, Stolvá Hora in the Pálava Hills, approximately 48 km to the east (Navrátil et al. 2024). Another consideration is the state of preservation. Most of the objects are present only as a fragment, with few items being preserved whole. Despite extensive damage (either pre- or post-depositional) several types of artefacts can be distinguished, based on the typological classification established by Milan Salaš for Moravian Middle and Late Bronze Age metal hoards (Fig. 3; Salaš 2005a). Unfortunately, the grouping cannot be followed precisely. Some items could be identified unambiguously, and some could only be allocated to less specific groups. The simple ‘Tool’ attribute is used for items which probably represented a fragment of a tool. The defining characteristic is the assumed function, which relates to work activities. The ‘Jewellery’ group comprises every item which could possibly have been a part of a human decorative accessory, including parts of belts, pins, fibulae, etc. Some fragments could be identified as part of a blade, but since bladed artefacts could fall into two different categories, weapons and tools, a decision to employ the simplified group ‘Blades’ was made. Surface prospections yielded a substantial amount of metallurgical waste, iron and copper/bronze. Since the focus is on bronze items, only copper/bronze metallurgical waste is considered here, hence the group ‘Bronzeworking waste’. This terminology was deemed sufficient, due to the inability to determine from which part of the production process the fragments

originated. Any fragments which could not be securely identified are allocated to the ‘Unidentified’ category.

2.2. Awl/Chisel Subcollection and the Possibility of Use-Wear Analysis

The most common tools in the assemblage are small rod-shaped awls and chisels. They create an interesting subcollection in the material, which deserves attention. Several analogies can be found in Moravian and Czech assemblages (Kytlicová 1961; Furmánek 1973; Říhový 1992; Salaš 2005b), but their identification is based solely on the morphology. There are a few interesting aspects relating to these tools: some were made by reutilising jewellery (Kytlicová 1961, 239, Fig. 44), they were most probably shafted in an organic handle (Furmánek 1973, 87, 90, Figs. 44, 46) and there is an assumption that they were used to decorate bronze products (Kytlicová 1961). While a morphological similarity suggests their use in woodworking and textile production, no experimental studies have confirmed this. Nevertheless, use-wear methodology (Dolfini, Crellin 2016) was applied to determine whether any observable traces could aid in identifying these items. Use-wear analysis was conducted at the Department of Archaeology and Museology, Masaryk University in Brno. Twelve objects were deemed suitable. The chosen objects were first studied under a binocular magnifier with a side light source and then further observed under larger magnification with a trinocular microscope at 50–200x magnification. Observations were photographically documented, and these photos form part of the supplementary material (Appendix 1).

2.3. XRF-Based Chronology

As previously mentioned, the primary characteristic of the present collection is its fragmentary nature, which precludes the possibility of precise chronological classification based solely on typology, apart from the more chronologically sensitive artefacts that have been identified. Based on their morphology, most of the artefacts are chronologically irrelevant; however, this assemblage still represents certain chronological horizons, directly and authentically linked to day-to-day human activities at the site. Since these horizons cannot be determined solely through the artefact typology, an alternative approach had to be employed: dating based on elemental composition. Certain horizons can be identified based on elemental composition, which can be linked to the chronological development of bronze metallurgy. For the basis of the analysis, two studies that trace the elemental composition of typologically dated bronze artefacts were chosen. The Czech-Moravian material from the Middle Bronze Age to the Late Bronze Age was studied by the team of Jaroslav Frána (Frána, Moucha, Sankot 1997). A more

extensive chronological range was covered in the master's thesis of Matěj Kmošek (Kmošek 2020), which analysed a set of copper and bronze artefacts originating from Moravia, dated from the Eneolithic to the Early Middle Ages. The analytical methods employed in these studies are consistent, and the findings of Kmošek's work delineate particular metallurgical phases characterised by distinct trends in elemental composition. These phases mirror broader developmental trends observed in Eurasian material (Tylecote 1992; Kienlin 2013), though with unique chronological boundaries influenced by regional factors. The Moravian metallurgical phases appear to be a suitable point of comparison, given the geographical location of the site under investigation. It has to be recognised that the elemental composition of bronze, that can currently be measured, is influenced by a number of factors (Bray, Pollard 2012), such as the composition of the original ore, the preparation and smelting process (Tylecote 1992) and the casting process; recycling also needs to be considered (Bray et al. 2015). During the evaluation of the analyses, the aforementioned phenomena have been taken into account.

The first Moravian metallurgical phase encompasses artefacts dated to the Eneolithic and Early Bronze Age (EBA). Artefacts from this phase are made either of pure copper or of copper with small amounts of impurities. The most common impurities are arsenic, antimony or silver, with average values of 0.55 % (Kmošek 2020). For the Eneolithic and the EBA they tend to have roughly the same ratios of measured impurities, but the values increase drastically. It is not uncommon for tin or lead to be among them. Of particular interest are the increasing concentrations of arsenic and antimony, which likely improved the functional properties of the final products (Tylecote 1992; Junk 2003). Both elements are present in 'fahlores' or 'fahlerz' ores – especially the sulfosalts tetrahedrite $(\text{Cu}, \text{Fe})_{12}\text{Sb}_4\text{S}_{13}$ and tennantite $(\text{Cu}, \text{Fe})_{12}\text{As}_4\text{S}_{13}$. Substantial fahlore deposits can be found in nearby attested mining regions – deposits were mined in the Lower Inn Valley around Schwaz-Brixlegg (Grutsch et al. 2019; Staudt et al. 2019), while smaller deposits were accessed in the Eastern Alps (Lutz, Pernicka 2019) and fahlores are present in the Slovak Ore Mountains and Czech-German Erzgebirge (Zachar, Salaš 2018). While provenience study would be beneficial, it is not viable within the current scope of research. However, the fahlore triad is important for the analysis, as will be explained in the next paragraphs. A significant development in bronze metallurgy came with intentional alloying using tin. In Moravia, tin bronzes appear around the end of the 3rd millennium. Their values are not consistent and only a small fraction of measured artefacts contain more than 0.3 % tin (Kmošek 2020, 36). Some authors advise using a threshold of around 2–3 %

to discern the intentionality of alloying through the external addition of tin (Tylecote 1992; Kienlin 2013). Primary alloys should contain around 10 % tin in order to fully exploit the positive effect of tin on copper (Frána, Moucha, Sankot 1997; Kienlin 2013; Bray et al. 2015). Such high values of tin are considered to indicate intentional alloying, which is assumed to be standard in younger phases of the Bronze Age.

The second Moravian metallurgical phase is dated to the Middle Bronze Age (MBA), Late Bronze Age (LBA) and Early Iron Age. Earlier fahlore bronzes were slowly disappearing with the rise of tin bronzes – MBA artefacts have an average tin content of 5 %, higher amounts of nickel and show an almost total absence of arsenic and antimony. Tin values fluctuate initially, then slowly stabilise at around 8–12 %. It seems that, while at the beginning of this phase metallurgy was quite non-standardised, later (LBA) tin-bronzes contain a larger amount of tin on average. The amount of tin seems to correlate with the desired function (Trampuž Orel 1996; Frána, Moucha, Sankot 1997; Kienlin 2013; Orfanou et al. 2024). This composition can be traced from the MBA to the early stages of the LBA in Moravia, Czechia and the Eastern Alpine regions – impurities can yield different values, but major elements follow the rule. Studies from Austria hint at a massive change from fahlore deposits to chalcopyrite deposits from the Mitterberg region and frequent alloying with tin (Lutz, Pernicka 2019; Staudt et al. 2019). However, two distinct phenomena with a relatively sensitive chronological footprint occur in Moravian and Czech LBA material. First, older LBA artefacts have an elemental composition closely resembling that of MBA artefacts and are relatively standardised across a wide typological range. By contrast, younger LBA artefacts show more diverse elemental compositions, with significant differences between the raw materials and the products (Frána, Moucha, Sankot 1997). The second phenomenon observed concerns the ore used – fahlores reappear in the elemental composition. This was observed in Moravian, Bohemian (Frána, Moucha, Sankot 1997; Zachar, Salaš 2018; Kmošek 2020), Austrian (Grutsch et al. 2019; Lutz, Pernicka 2019; Staudt et al. 2019) and even Slovenian (Trampuž Orel 1996; Trampuž Orel, Heath, Orel 2016) material. Chalcopyrite and tin remained in use, but were often used interchangeably with fahlores, which gave them a distinct elemental composition, dubbed by some authors 'diluted fahlore copper' (Grutsch et al. 2019). Moravian artefacts from younger phases of the LBA on average comprise 3–6 % tin and almost 2 % arsenic and antimony, distinguishing them from earlier LBA and MBA artefacts, which tend to have negligible arsenic and antimony values (Kmošek 2020). Concerning neighbouring Austria, studies showed an interesting chronological occurrence – tinless metal with an arsenic,

antimony and silver signature dominates the EBA, then disappears in the MBA and is replaced by tin bronzes with chalcopyrite-based copper from the Mitterberg region. At the end of the LBA, the fahlore signature reappears and is used interchangeably with chalcopyrite and tin (Haubner 2021; Haubner, Strobl 2023).

The third Moravian metallurgical phase is defined by the introduction of lead as an alloying agent. This was observed in Bohemian Late Iron Age jewellery and dated to LT B2 (Frána, Moucha, Sankot 1997). Moravian material dated to the LBA contains negligible amounts of lead; however it is from the Late Iron Age that lead values increased enough to be considered an intentional addition. Tin is still present in bronze artefacts, average values hover around 7 % (Kmošek 2020). Lead, however, shows drastically oscillating values, from 0 % to almost 34 %. Used dating will work with dual tin-lead alloying – Moravian and Bohemian dual tin-lead alloys appear as early as the LBA; however, a larger amount of lead seems to be chronologically important only since LT B2 (Frána, Moucha, Sankot 1997; Kmošek 2020).

The fourth metallurgical phase begins in the Roman era and covers the Early and Late medieval periods (Kmošek 2020). Moravian material sees the introduction of zinc (Fikrlé, Frána, Droberjar 2006), but tin and lead are still frequently used as alloying agents. This applies for medieval artefacts too, with further specifics (Bourgarit, Thomas 2012; Brownsword 2021).

2.4. XRF – Process and Samples

Radioactive spectrometry using a pXRF device was chosen mainly due to the financial restrictions. While some authors outright do not recommend using this method (Zachar, Salaš 2018), others have proven that it is a viable option (Fernandes, Van Os, Huisman 2013; Arnoldussen et al. 2022) – we have to bear in mind the effect of surface corrosion. In copper artefacts, corrosion mainly affects copper, its values tend to be misrepresented. On the other hand, alloying metals and impurities tend to be overvalued (Frána, Moucha, Sankot 1997; Nicholas, Manti 2014). The exceptions are arsenic and nickel, which form a strong bond with copper, and their values tend to remain stable and change only during metallurgical processes (Sabatini 2015; Haubner, Strobl 2023). The best results were obtained from analysing drilled samples from the item's metal core.

The analyses of the elemental composition were carried out by the author at the Department of Archaeology and Museology of Masaryk University, Brno. I used the institute's handheld Innovex-X System Delta Professional device, model DPO, serial number 542296, docked in a lead-lined Olympus Test Stand. Elements were analysed using the Si Drift Detector and excitation source 4-watt X-ray



Fig. 4. Photo of item ID 99 and the sample of its metal core (M. Valent).

tube, 8–40 keV and 5–200 μ A. The device was calibrated for archaeological analysis and is capable of measuring arsenic. The device was operated through the connected laptop. At the start of each day, the device was recalibrated using the attached calibration token. I used the mode ‘Analysis Plus’ for the measurements. First measurements were taken from the unchanged surface of the objects. Objects were inserted into the test stand and their positioning was considered, so that the measured place was clean and not overly corroded. Each object was measured for 30 seconds at least three consecutive times, and mean values were later calculated. Documentation was meticulously kept during the measurements to avoid any confusion. The collected data was exported in a .csv file at the end of each day, then verified and edited in Microsoft Access. Further preparations were made in Microsoft Excel.

For the surface measurements I employed the methodology of Bray et al. 2015, modified according to Arnoldussen et al. 2022, for which all items were categorized into 16 copper alloy groups. The presence/absence of significant trace elements (arsenic, antimony, silver and nickel) was determined by a threshold value of 0.1 % (Bray et al. 2015). Additionally, the values of lead were examined, which are also important for the study's research questions. The artefacts were classified into five lead categories based on the scale amount present in the items (Arnoldussen et al. 2022). The established categories were then compared against typological determinations. The categorisation was performed

0	0	0	1	1	0	none
1	0	1	0	1	0	As
0	2	2	1	4	0	Sb
0	0	1	0	0	0	Ag
1	3	1	3	2	0	As+Sb
0	1	1	0	0	0	Sb+Ni
0	0	0	0	0	1	As+Ni
1	7	2	0	1	0	As+Sb+Ag
2	4	9	5	3	3	As+Sb+Ni
2	0	9	6	8	1	As+Sb+Ag+Ni
Blades	Bronzeworking waste	Jewellery	Tools	Undefined	Weapons	

Fig. 5. Heatmap showing copper categories and their relation to typological categories, based on surface measurements (M. Valent).

in R Studio – the code used is part of the supplementary material (Appendix 2).

To obtain more precise data, a decision to drill into some of the objects was made (Fig. 4). Due to the extensive fragmentation of the assemblage, not every object could be drilled. I have carefully selected 36 objects which would not be damaged or destroyed by the procedure. Samples were drilled using the institute's drill, a Proxxon Micromot 60/E. The drill was set to 5000 rpm. Two types of HSS DIN 338 aluminium drills with titanium tip were used: 1 mm and 1.5 mm. The titanium tip prevents contamination of the sample. Objects with a thicker mass were drilled using the 1.5 mm drill, which yielded more material. The borehole location was chosen so that the object would not disintegrate after drilling, so that its defining parts would not be affected and so that it would not be directly visible. Objects were firmly fixed in a small paper-lined clamp. Samples were large enough to ensure reliable measurement. The measuring process and data management were the same as with the surface measurements, but the drilled shavings were measured in a cuvette, which was carefully cleaned after each measurement. Drilled material (powder or shavings) was collected in a plastic tube, labelled using the item's ID and attached to the original object, so that future analyses are possible. Boreholes were sealed.

3. Results

3.1. Chronology Based on the Typology and Elemental Composition

The elemental analysis was split into two parts. A limited interpretation of the surface measurements was undertaken, mainly because such analysis involved 100 % of the site's bronze inventory, as compared to only 36 % that was drilled and sampled. Overall, the surface measurements show significant homogeneity when we consider just the presence/absence of the trace elements arsenic, antimony, silver and nickel. This applies especially to As and Sb, which are extremely common in the surface measurements, and they always bring Ag with them. The only exception observed in the database is the silvered copper spiral ID 32, which has no As or Sb measured. However, comparing the individual values of these elements reveals great variability, influenced by the corrosion of copper. When we look at the alloying agents – tin (Sn), lead (Pb) and zinc (Zn) – there is an absolute homogeneity in terms of both the presence/absence and the values. The most common alloying agent in the assemblage is Sn. Measured values of Sn on a surface are high, which is directly related to tin sweating, but it can be assumed that its true value is lower, albeit still enough to be considered the main alloying agent. With regard to Pb, the amounts are very small, but it is still consistent and very common in the assemblage. Only one brass item was

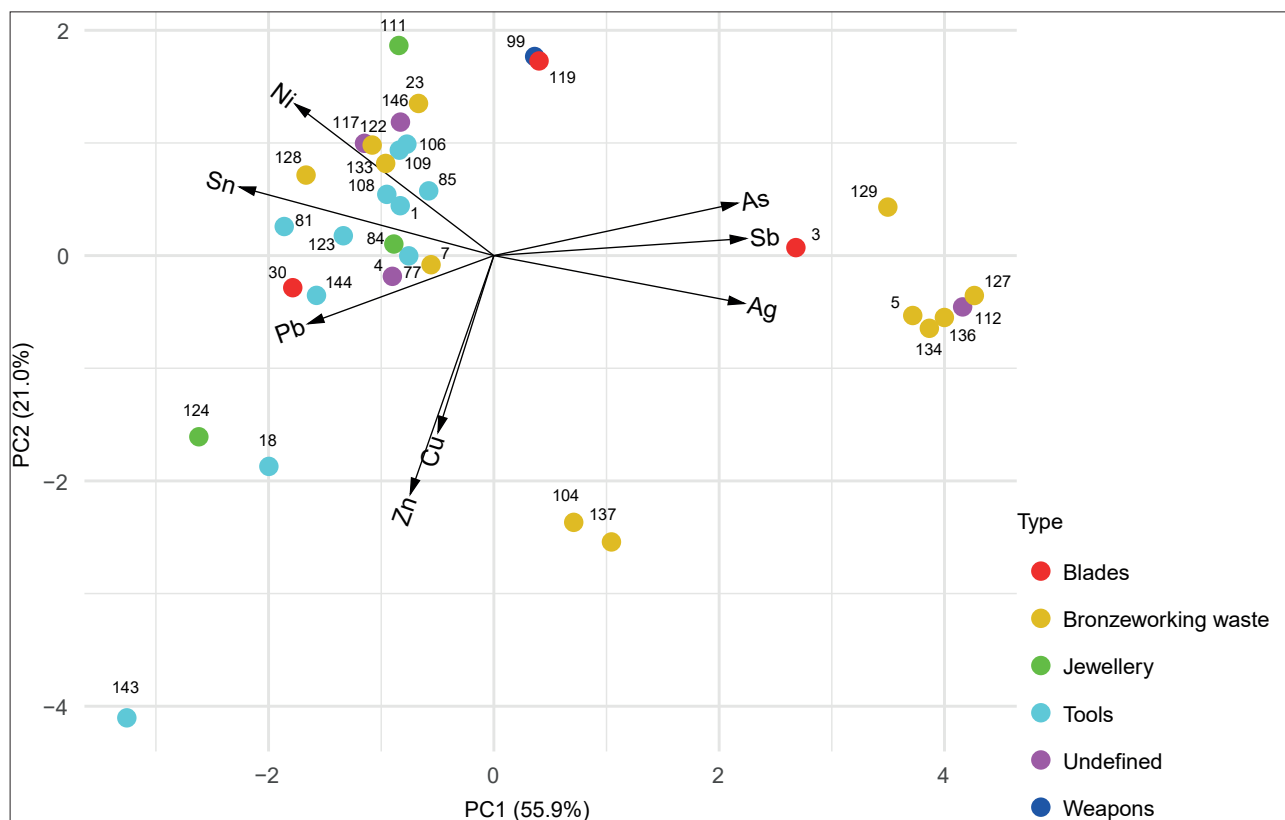


Fig. 6. Biplot showing the results of the PCA analysis. Individual items are identified and sorted based on their type (M. Valent).

identified. Categorising the surface measurements (based on Bray et al. 2015) identified 10 categories out of 16. The most frequent are categories 12 (As+Sb+Ag), 14 (As+Sb+Ni) and 16 (As+Sb+Ag+Ni), supplemented by a smaller but still interesting number of items from categories 3 (Sb) and 6 (As+Sb). Looking at the relation with typological groups, bronzeworking waste is predominantly fahlore based, with only a small fraction showing trace amounts of Ni. Artefact categories (jewellery, tools, weapons and blades) lean more towards an admixture with Ni, but there are a few artefacts with no Ni signature (Fig. 5).

Concerning the dating based on elemental composition, the primary focus was on 34 items which were sampled by drilling. Originally a 36-piece subcollection, two objects were excluded from the analysis (ID 28 and 132), as they proved to be non-bronze despite the presence of green patina. Combining typological and XRF data yields interesting results. The analysed assemblage is mostly homogenous in terms of its elemental composition. Reoccurring combinations are the fahlore triad (As/Ag/Sb) and a strong presence of tin and nickel. Only 3 out of 34 items are entirely devoid of As or Sb. A principal component analysis (PCA) was conducted to verify these observations. The first two principal components (PC1 and PC2) were selected as representative of the dataset, together accounting for 76.9 % of the

total variance (Fig. 6). PC1 explains the highest proportion of variance and reflects the dominant covariance structure in the dataset, which is defined by two element triads: the fahlore triad (As/Sb/Ag) and Sn/Ni/Pb. PC2, which accounts for 21 % of the variance, distinguishes between samples with significant Ni/Sn values (tin bronze) and samples dominated by higher Zn and Cu contents (brass-like alloys). The PCA biplot reveals two significant groups defined by PC1: one composed of raw materials closely associated with fahlore ores and another primarily consisting of finished products alloyed with tin. Three smaller subgroups are further defined by PC2. They will be discussed in relation to their typological determination.

Typological analysis reveals an interesting diversity in the assemblage (Fig. 3). My assessment is mostly approximate, but there are a few items which can be clearly identified and, most importantly, dated. Artefacts (i.e. finished products) are predominantly grouped in a Sn/Ni/Pb cluster with PC2 defining the difference between them. Jewellery is the most common group in the whole assemblage; however, most of it could not be sampled. Only three pieces of jewellery were sampled, and two of these could be identified. Concerning dating, four items can be identified and dated, including two of those sampled. Two unsampled items are both needles, a needle with a simple undecorated

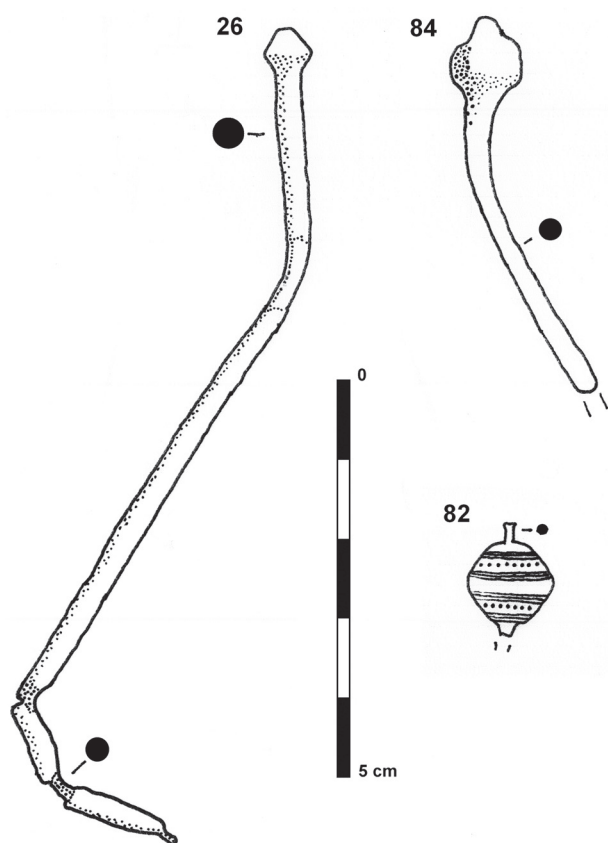


Fig. 7. Drawings of three identified pins (M. Valent).

double-conical head and a needle with a large, richly decorated vase-head (Fig. 7). Both appear frequently in Moravian material and have a long chronological interval, covering the Late and Final Bronze Age (Říhorský 1979, 121, 192). The sampled needle (ID 84) was identified as a 'needle with spindle-shaped head, type Klentnice'. The Klentnice variant has a long chronological interval of usage. These needles can be found in the large area of Central Europe and neighbouring areas. In Moravia, these needles appear most frequently at the beginning of the later phase of the Middle-Danube Urnfield Culture, phase Ha B1. Direct analogies can be found in cremation burial 195 from Domamyslice (Prostějov, Czech Republic; Gottwald 1932) or Urnfield burial grounds near Slatinky (Olomouc, Czech Republic; Přecechtěl 1891), while almost identical but decorated exemplars are found in the nearby site of Klentnice (Břeclav, Czech Republic; Říhorský 1979). Further analogies could be drawn from northwestern Hungary (Veleszentvid hill-top settlement, Románd hoard), based mostly on the shape of the head (Říhorský 1983). The elemental analysis shows a lower amount of Sn (3.17 %) and diminished values of As, Sb and Pb. In this case there is a chronological overlap between the typology and the elemental composition (Kmošek 2020, 45) pointing to a Late Bronze Age date. The

second identified piece of jewellery is a fragment of a torque (ID 111). Possible analogies can be found in Moravia (Salaš 2005b, Tab. 131/411), but also in Hungary, dated to the Kurd horizon (Ha A1) (Mozsolics, Schuhmacher-Matthäus 1985, Tab. 107/29–30) or in Croatia, dated to Ha A1 (Vinski-Gasparini 1973, Tab. 78/22). Dating of these torques in Moravia is extremely wide (Salaš 2005a, 76), but their presence in the LBA (exact dating from the other two) is frequent. The elemental analysis shows fahlore copper alloyed with Sn, with a significant amount of Ni and a low value for Pb. Both the elemental composition and the typology overlap and date it to the Late Bronze Age.

Eleven items identified as tools were sampled, constituting the typological majority within the sampled subcollection. Of these, two can be identified as an awl and six as a chisel. Together with jewellery and weapons, tools are defined by PC1 as a major cluster tied to Sn/Ni/Pb covariance. As was mentioned previously, PC2 demonstrates a higher scale of variability exclusively in this cluster. This relation is tied to the opposing relationship between Sn/Ni and Zn/Pb. Awls and chisels are unfortunately not typologically sensitive artefacts (Salaš 2005a). Their elemental composition shows Sn as an alloying agent; however the awls (ID 18; ID 85) are very low in Sn (1.58 and 2.18 %, respectively). There is a tendency towards Pb/Zn covariance in the awl ID 18 due to its Pb value (0.27 %), while other trace elements are not present in significant amounts. Chisels are usually richer in Sn, with the exception being two low-Sn items (ID 106: 3.39 % and ID 123: 2.55 %). Traces of As and Sb are stable and do not exceed 0.6 %, indicating their presence but in low volumes. A fahlore copper can be considered as a source for these items. Two remnants of an axe were also identified. One is a broken-off blade, made from a Cu/Sn alloy with a significant amount of Sn (ID 77: 5.05 % Sn). The other, ID 144, was identified as a remnant of a socketed axe (closest analogies in Salaš 2005b, Tab. 144/21), which could be dated to the Late and Final Bronze Age (Říhorský 1992, 190), but a precise group could not be identified. Its elemental composition shows tin alloying (Sn: 5.69 %) with trace remnants of arsenic (As: 0.19 %). Additionally, the assemblage contains five items which can be identified as a weapon: three shafted arrowheads, one flat arrowhead and one broken-off tip of a spear. All items have analogies in Moravian hoards (Říhorský 1996; Salaš 2005b). Only the broken-off spear (ID 99) could be sampled. It is a Cu/Sn alloy (8 % Sn) with a significant presence of As, Sb, Ag, Ni and Pb. Such a combination indicates the younger second metallurgical phase. Its elemental composition closely relates to one remnant of a blade (ID 119), with which it forms a small, distinct cluster in the analysis. They are Cu/

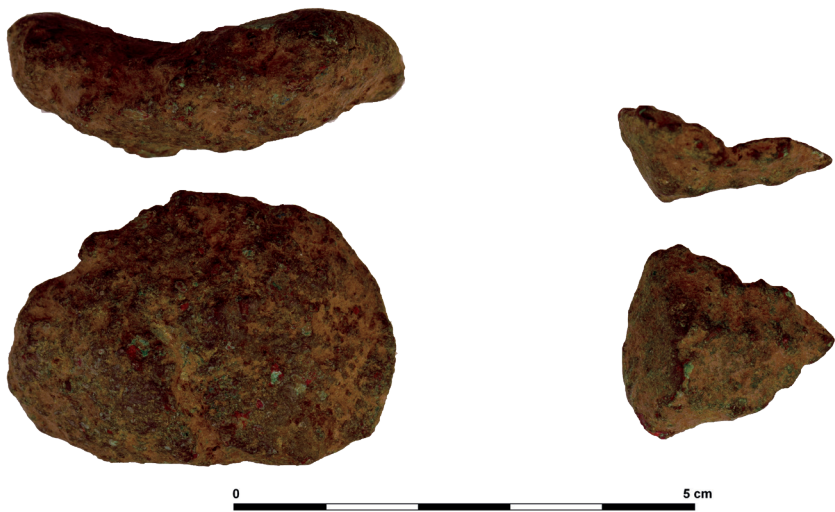


Fig. 8. Photo of bronzeworking waste with morphological imprint of crucibles. – Left: ID 23; right: ID 128 (M. Valent).

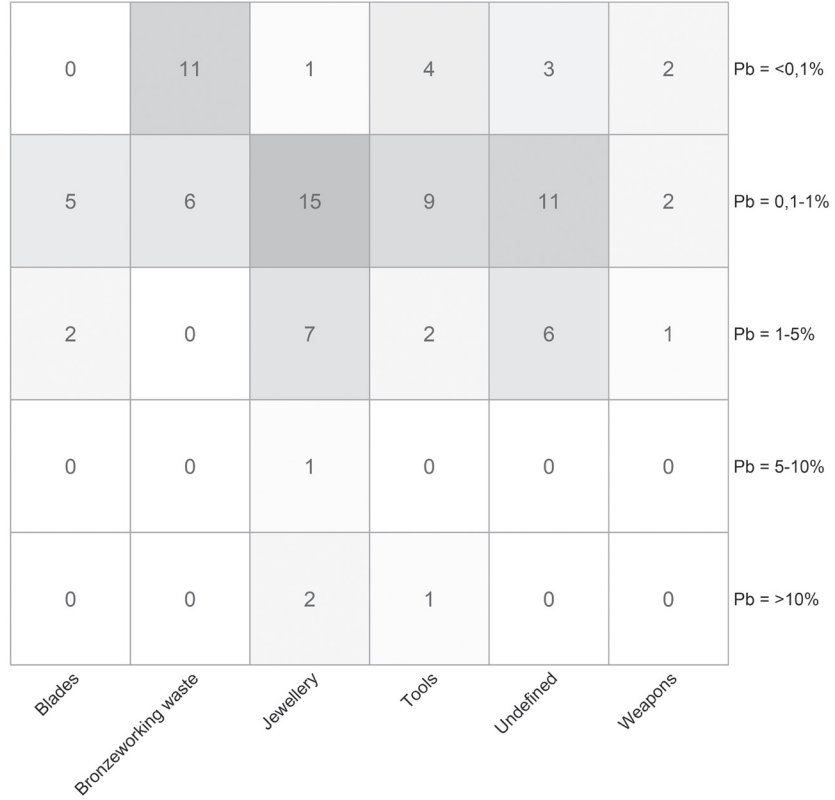


Fig. 9. Heatmap showing the representation of lead based on surface measurements (M. Valent).

Sn alloys with a strong presence of Ni, but they exhibit higher values for the fahlore triad than the remaining artefacts. The assemblage contains large amounts of bronzeworking waste. For now, this is the only evidence of bronzeworking at the site. Most of this waste has an amorphous shape, which does not relay any tangible information. However, items ID 23 and 128 have a distinctive morphology, which shows the imprint of a crucible (Fig. 8). Their elemental composition shows Cu/Sn alloying, with a trace presence

of the fahlore triad and nickel. PCA analysis places both items in a major Sn/Ni cluster and shows a strong relation to artefacts (i.e. finished products) in the assemblage. Overall, there are five pieces of bronzeworking waste which show a strong relationship to a Sn/Ni cluster. This relationship is tied to the high volume of these elements, but they also show trace values of As and Sb, which hints at fahlore being the main source of copper for alloying.

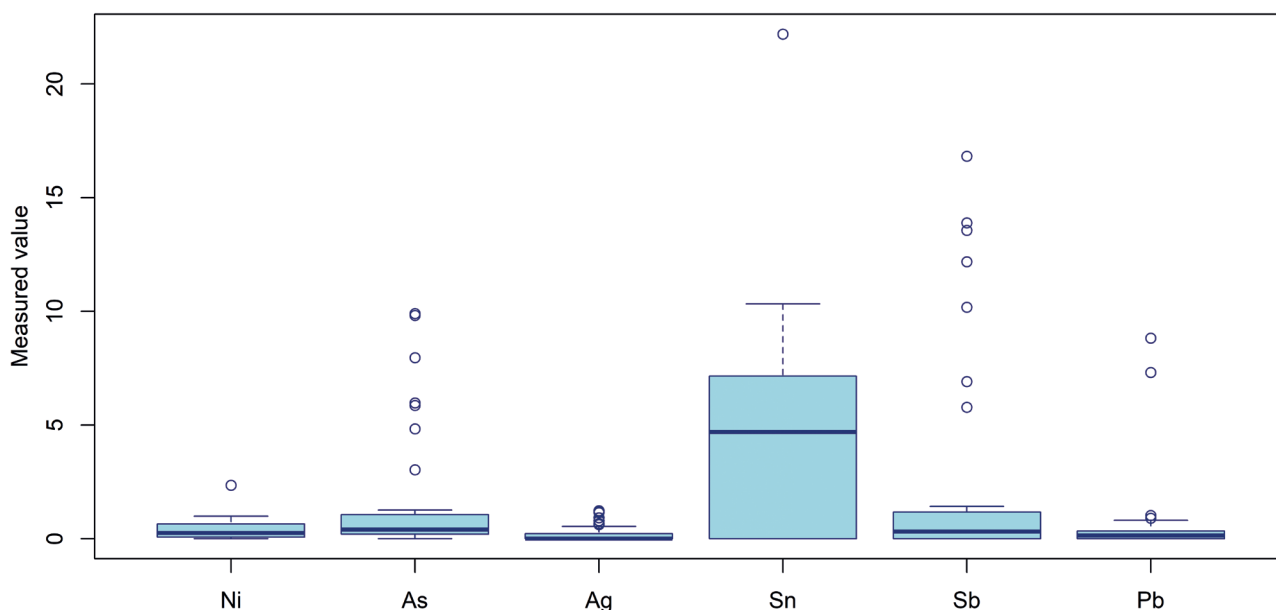


Fig. 10. Boxplot showing the elemental composition in drilled samples (M. Valent).

In this regard, the PCA analysis identified a group of seven items with an exceptional relationship to the fahlore triad. This grouping is dominated by remnants of metallurgy – there are five pieces with high amounts of As, Sb and Ag. One of these items is a possible remnant of a one-sided blade, made entirely from fahlore copper. Such a composition is typical for the first metallurgical phase, when tin was yet to be used. Dating of this item could fall anywhere between the late Eneolithic and the Middle Bronze Age; however the artefact cannot be precisely identified and therefore also not typologically dated and verified. One small subgroup of metallurgical waste is separated from the two major groups. It consists of two items (ID 137 and 104) made from almost pure copper – containing 98.98 % and 98.8 % Cu, respectively. The only detectable trace elements here are As and Sb, both with low values. This could suggest an efficient smelting process or recycling of fahlore-based copper materials.

Lead also serves as an indicator of a younger horizon in the assemblage (Frána, Moucha, Sankot 1997; Kmošek 2020). It is very common in the assemblage, albeit the overall amount is small. Looking at the surface measurements (Fig. 9), only four samples register more than 5 % lead, with the majority of the assemblage falling into categories with amounts below 1 %. Looking at the lead values in drilled samples (Fig. 10), we can see that they are very low and would fall nicely into the first categories. However, the drilled samples are distorted by two strong outliers: artefacts ID 143 and 124. Artefact ID 143 differs significantly in composition from the rest of the assemblage due to its

high lead (8.82 %) and tin (7.93 %) content, but also due to the only measured presence of zinc (1.48 %). Such a composition aligns with the composition of ‘leaded gunmetal alloy’ as classified by Bray et al. 2015. Unfortunately, the objects in question cannot be identified precisely – the most likely identification is a knife handle with a ring at the end or a fragment of a horse harness. In Moravian material, this composition is consistent with later technological developments, supporting a younger chronological placement – the fourth metallurgical phase (Kmošek 2020). Item ID 124 is most probably a remnant of jewellery. With its high Pb (7.31 %) and relatively low Sn (4.69 %) content, it can be considered to be from the third metallurgical phase – more precise dating eludes us due to the impossibility of typological identification.

3.2. Use-Wear Analysis

For use-wear analysis, exclusively objects identified as chisels or awls based on their morphology were included. This determination was not random; it was based on the analogical finds published by other authors (Kytlicová 1961; Furmánek 1973; Salaš 2005a). Twelve objects were examined, as presented in Figure 11. Unfortunately, the results of the analysis did not reveal any traces related to assumed work activities (compared with supplemental material from Dolfini et al. 2023). Thus, the question of whether these are indeed tools remains to be answered solely through morphological analogies. However, the absence of traces was not absolute. For some objects, potential pre-depositional surface interventions were identified.

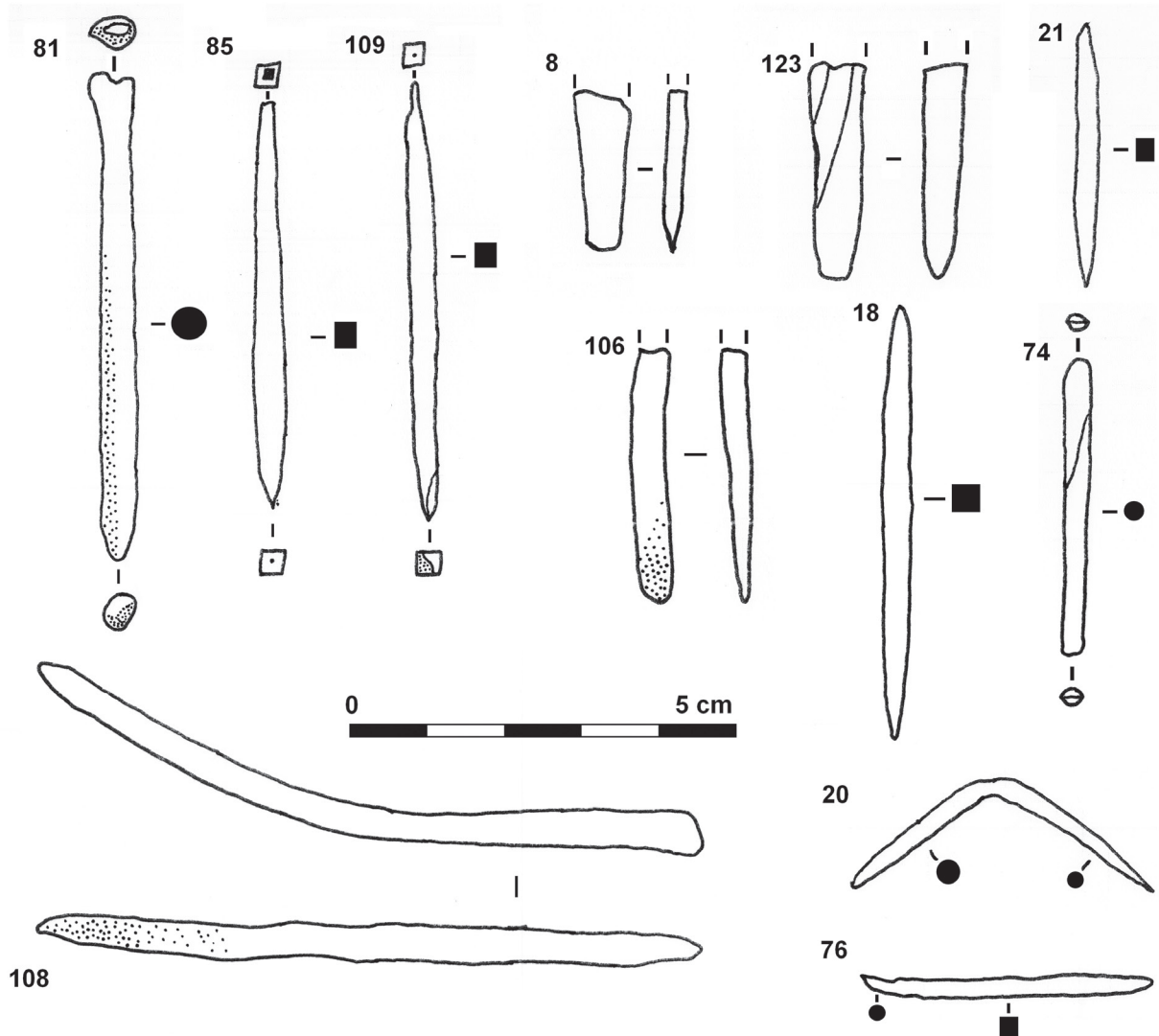


Fig. 11. Drawings of items identified as awls and chisels (M. Valent).

a) ID 76: This rod-shaped object is pointed at both ends without traces of breakage. It is identified as an awl. The central part of the object has a heavily striated surface overgrown with patina. Based on this stratigraphy, it can be concluded that the striations are on the original surface. The striation is perpendicular to both ends and therefore cannot be linked to working use. The observed striations might relate to contact with an organic handle.

b) ID 81: This rod-shaped object is flattened at both ends, a striking phenomenon being the mutual asymmetry of the two ends. This morphological phenomenon likely indicates reutilisation of the object. The artefact is identified as a chisel. Its surface is covered with numerous concentrations of striations, overgrown with patina. However, their precise identification is extremely complicated – only recent interventions can be clearly determined, which can be identified through the presence of recent scratches, showing as a

‘golden’ surface. Traces on the body may be related to manufacturing and maintenance; however a clearer distinction is not possible.

c) ID 109: This object has one end terminating in a blunt point and the other in a chisel-shaped surface, and is identified as a chisel. The entire surface of the object is riddled with corrosion, except for one of the sides, where a striated surface is visible in the centre. In the photograph taken, three different traces can be seen: 1) the silvery original surface of the object, heavily striated in a diagonal direction; 2) thin striations disturbing both the patina and the original surface but still overgrown by later corrosion; 3) recent interventions, which are evident from the exposure of the ‘golden’ surface. Traces of type 1) are the only potentially original ones, although their exact interpretation remains uncertain.

Additionally, the awl ID 18 exhibits visible surface interventions, however, the object has been lacquered, making

it impossible to determine whether the traces in question are original or the result of preservation treatment.

4. Interpretation and Discussion

Categorisation into copper categories based on Bray et al. 2015 and subsequently expanded by Arnoldussen et al. 2022 helped with interpretation of the surface measurements, at least to a limited degree. Great variability was observed in the categories present, but the most common are ‘mixed’ categories – 12, 14 and 16 – with the fahlore triad and nickel. The same composition was observed on material from Pálava hillforts (Navrátil et al. 2024), which offers an excellent comparison – they are relatively close, their horizons are contemporaneous and the material was also obtained during surface prospections (although using metal detectors). With regard to these hillforts, the authors are suggesting a great variability in copper sources, but also recycling (Navrátil et al. 2024, 834). I assume the same for Šobes and that both areas were part of the same distribution network. We know that Šobes was not an isolated site thanks to finds of non-local exchange goods (amber). As was mentioned before, the surface measurements can be regarded as homogenous. This homogeneity translates as a predominantly Cu/Sn alloy, with a trace presence of lead. Arsenic and antimony are very common, if only as trace elements. This potentially indicates that fahlore ore was the main source of copper for the site. A few items of interest are also present – ID 32 as a silver-coated remnant of jewellery, ID 33 as a distinct Hallstatt-type jewellery and ID 100 as a piece of brass jewellery.

Results obtained from drilled samples point to the material being from the second metallurgical phase (Kmošek 2020). The defining composition in the sampled subcollection is the fahlore triad (As-Sb-Ag) with nickel and alloyed with tin, which is similar to the surface measurements but unaffected by corrosion. An interesting cluster of unalloyed bronzeworking waste with a strong relation to fahlore ore was identified, which points to access to fresh fahlore-based copper. Most of the sampled subcollection created a strong cluster, which can be defined as mixed copper (As-Sb-Ni) alloyed with Sn in an amount that can be considered intentional. All sampled artefacts (i.e. finished products) are part of this cluster. Among them are also a few pieces of amorphous bronzeworking waste, some with the clearly defined imprint of a crucible and a high Sn content. These finds are the first direct evidence of alloying and production of bronze items on-site. I believe that ore smelting was not carried out on-site and fresh copper and tin were brought via trade and exchange networks. The sampled subcollection contained an unusual fragment of a bladed artefact made from fahlore copper, without alloying. Such a composition might hint at the beginnings of copper metallurgy, the EBA or even the

late Eneolithic. Eneolithic activities at this site were proven through the stratigraphy and pottery finds (Rožnovský 2015). There were only a few instances in which artefacts that were also sampled could be typologically identified. In those cases, however, the typological and elemental dating coincided. Among the sampled items was one distinct outlier – item ID 143 – which shows a higher amount of Pb, Sn and Zn. Such alloying corresponds with the fourth metallurgical phase, the Roman and medieval periods (Kmošek 2020). Both were previously proven for the site through finds of pottery (Říhový 1974; Čižmář 2000). Overall, the results from drilling suggest a material dated to the second metallurgical phase – the Late and Final Bronze Age to be more precise. The elemental composition coincides nicely with current knowledge on human activities at the site.

What does it say about the settlement itself? The results point to a possible central site, with links to bronze metallurgy. In Late Bronze Age Moravia, especially during the younger Podol phase, these activities seem to be concentrated at hillforts (Salaš 1995). Bronze metallurgical activities are assumed at the hillfort Hradisko in Brno-Obřany (Adámek 1961; Salaš 1995) and the unique settlement of Blučina-Cezavy (Salaš 1995). Based on the results presented here, the site seems to correlate with up-to-date knowledge of bronze production in the region, but we do not expect Šobes to be a metallurgical hub. The excavations have yet to prove any direct workshop features (kilns, moulds, anvils), which makes identification of this site as an artisanal centre less likely, but at least some degree of production must be expected here. The provided data can be regarded as sufficient evidence that Šobes was linked to a much wider contact network, directly tied to the southeastern Alps and Slovak Ore Mountains as possible sources for the copper required, mainly due to the absence of local ores to exploit. In the context of bronze metallurgy and extraregional contacts, the site acted as a consumer, but it is not clear whether we can understand this site as a direct node on a long exchange network. The economy of Šobes was probably tied to the more strategic sites with better potential for being a visible landmark in the network, like Tabulová hora near Klentnice (Navrátil et al. 2024).

Analysis of the awl/chisel subcollection did not yield any breakthrough. Based on the morphology, it can be assumed that these items are indeed awls and chisels. This is supported by typological identification of analogous finds from Czechia (Kytlicová 1961; Furmánek 1973; Salaš 2005a) and even from the wider Central European region (Karavanić, Kudelić 2019; Ondrkál 2025). Their morphological similarities with medieval and modern awls and chisels point to their use in textile and wood artisanry. However, it is possible to tie the Bronze Age exemplars to the metallurgical

production, based on contextual relations with specific artefacts, like moulds (Kytlicová 1961; Salaš 1995), or in context with a studied metalworking workshop (Karavanić, Kudelić 2019, Fig. 11.3/6). For this subcollection it can be stated that these items were indeed finished items and were not reutilised from other objects, as was observed in different instances (Kytlicová 1961). Use-wear analysis of the awl/chisel subcollection was intended to observe possible traces of usage, linked to ‘plastic shaping’ activities which change the form of the final product (Armbruster 2023, 8–9). More precise activities are expected to be cutting and gouging (Nessel 2023, 76), and potentially decorating finished items (Kytlicová 1961). Focusing on assumed work areas (ends of the items) did not yield any data – mainly due to the heavy corrosion present. Analysis of the central part – the body – of the artefacts however showed use-wear traces. Unfortunately, decisive interpretation of these traces is impossible, but they appear to be of pre-depositional origin due to interlaying with the patina and fresh bruises. The precise use of these items remains tied to their morphological analogies.

5. Conclusion

The bronze assemblage presented in this article currently represents all metal finds from the hillfort Šobes. Due to its high degree of fragmentation and surface recovery context, all relevant items had to be included to obtain statistically meaningful data. Several analytical methods were successfully employed, including pXRF, typological identification, and use-wear analysis. Although more advanced and precise analyses were not applied, the chosen approach proved sufficient for obtaining useful data from the fragmented assemblage. The data gathering was performed with reproducibility in mind, which will facilitate future methodological improvements. The experience gained during this study is invaluable.

Analyses have shown that dating based on the elemental composition coincides with current dating based on the stratigraphy and pottery chronology. The vast majority of bronze finds correlate with the Late and Final Bronze Age, which have proven to be the strongest horizons at the site. A few bronze outliers can be identified as leaded bronzes and brass, which coincides with the low-scale presence of Roman and Early medieval human activities at the site. The assemblage also contained a lot of clearly modern bronzes, with signs of machine production, which coincides with undisturbed agricultural activities at the site until the present day. Only one questionable outlier might coincide with activities at the site during the Eneolithic, but this cannot be stated absolutely due to the inability to distinguish the precise typology of this item.

The typological analysis has revealed great variability in the assemblage. A few items were identified as an exact type, datable based on established typology to the Late and Final Bronze Age. These include pins, a remnant of a torque, a socketed axe, the tip of a spear and four arrowheads. The assemblage contains a large subcollection of bronzeworking waste, which yielded an elemental composition showing access to fresh, unrecycled fahlore-based copper and active alloying with tin. This is currently the first direct evidence of bronzeworking at the site.

Another subcollection, of awls/chisels, was studied using use-wear analysis. We can conclude that these items are indeed tools, but no specific activities for which they were used could be distinguished. The main hinderance proved to be corrosion and the lack of comparable experimental data. However, the methodology used by previous authors (Dolfini et al. 2023) proved to be effective.

The site itself has great potential for future research and analysis of the bronze assemblage proved to be a step in the right direction. This study may provide a stable foundation for analyses of future finds from this site and contributes to the knowledge about the Podyjí region and its Late Bronze Age horizon. All of the data are available as supplements to this paper (Appendix 1 and 2, see below) in case future researchers are interested in this exceptional Urnfield Culture hillfort.

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Appendix 1

Supplementary figures can be found at:
https://austriaca.at/onlineArchA110_Valent_Appendix1.

Appendix 2

Appendix 2 contains a .qmd file that can be opened in the R Studio program, containing the code and the analyses carried out for the study. Excel files containing the data required for the above file to function properly can also be found in Appendix 2:
https://austriaca.at/onlineArchA110_Valent_Appendix2.

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