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Large-scale ironworking in Early Medieval proto-urban settlements: A case study from Mikulčice-Valy, Czech Republic

Intenzivní zpracování železa v raně středověkých proto-urbánních sídlištích: případová studie z lokality Mikulčice-Valy, Česká republika

– *Michael Lebsak*, Jaroslav Kapusta* –

KEYWORDS

Ironworking – urbanity – Early Middle Ages – Mikulčice-Valy – metallography – slags – sem-eds – wd-xrf – economy – specialisation

ABSTRACT

Pyrometallurgical remnants, including slags and technical ceramics, offer crucial insights into Early Medieval ironworking. Iron held substantial economic significance during this era and its processing is particularly evident in settlement agglomerations and proto-urban sites across Northern and East Central Europe. Despite its importance, large-scale ironworking remains inadequately explored within broader socio-economic contexts. Our study examines around 300 kg of pyrotechnical waste from the northern suburbium of the Mikulčice-Valy settlement agglomeration (Czech Republic) using macroscopic and metallographic (SEM-EDS, WD-XRF) methods. The findings reveal specialised blacksmithing characterised by intensity and diversity contributing to a better understanding of the operational dynamics and installations in craft-production workshops. We propose that blacksmiths capitalised on the proto-urban environment, satisfying a high demand for diverse iron commodities of a dense population actively engaged in household, agricultural and artisanal work. While elites facilitated access to raw materials and maintained relative peace, direct control over iron production and distribution among the elites appears limited, apart from valuables like weapons. This study sheds light on the complex interplay between ironworkers and political-economic structures, offering new perspectives on the mechanisms driving Early Medieval iron economies.

* Corresponding author – E-mail address: lebsak@arub.cz

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1. Introduction: Ironworking in Early Medieval Central Europe

The younger Early Middle Ages (ca 700–1000 AD) are commonly viewed as a time of significant economic change, marked by intensified resource use and the expansion and diversification of specialised craft production (e.g. Verhulst 2002, 76–84; McCormick 2003, esp. 791–798; Loveluck 2013, 71–73; Měřínský 2014a, 110). Iron, in particular, had considerable socio-economic importance during this era. Archaeological evidence from sites such as settlements, burials, and hoards indicate a high demand for iron in the production of a wide range of agricultural and craft tools, weapons, and infrastructure, including bridges and ships (e.g. Coupland 1990, esp. 50; Westphalen 2002; Poláček 2003; Disser et al. 2016; Zachrisson 2020, 110–111; Borzová et al. 2020; Müllerová 2021).

The wealth of these sources contrasts with the archaeological remnants found at the actual ironworking loci. Apart from hearths, scrap and very rarely discarded tools, the primary archaeological evidence for iron metallurgical activities consists of debris such as slags, furnace fragments, and hammer-scale (Senn-Luder 1997, 33–37; Gassmann 2004; Pleiner 2006, 109–122; Herdick 2015, 98; Hauptmann 2020, 200, Tab. 5.1). This type of source is frequently overlooked and published with scientific indifference, resulting in a shortage of both quantitative and qualitative data. This oversight leads to a biased assessment of its economic-historical significance (e.g. Mittelstädt et al. 2022, 155).

What likely contributes to this perception is the notion that ironworking in Medieval settlements was a commonplace economic activity (Janssen 1983, 341–347; Baumhauer 2003, 297–298; Milo 2014, 67), especially considering that iron could theoretically be smelted anywhere using locally available bog ores (Hauptmann 2020, 117). However, the notion of universal, self-evident iron production and processing oversimplifies or even ignores its internal organisation, which is crucial for understanding the connection between craft production, distribution, and social complexity (Brumfiel, Earle 1987; Costin 1991; 2001; 2005).

The European iron crafting landscape of the Early Middle Ages is extremely diverse. Its scale and intensity ranges from independent household production to large-scale industries in urbanised milieus. Intensive blacksmithing, sometimes associated with high slag quantities exceeding several tons, is, for instance, known from rural settings in Western Europe (e.g. Serneels 1995; Eschenlohr et al. 2007; Loveluck 2013, 71–72). In Eastern Central and Northern Europe, it is predominantly associated with high-order settlements like fortified hillforts, early trading towns or proto-urban sites (Vendtová 1969; Schoknecht 1977; Westphalen 1989; Brinch Madsen 2004; Macháček et al. 2007; Brather 2008, 211–212; Milo 2014, 74, 76).

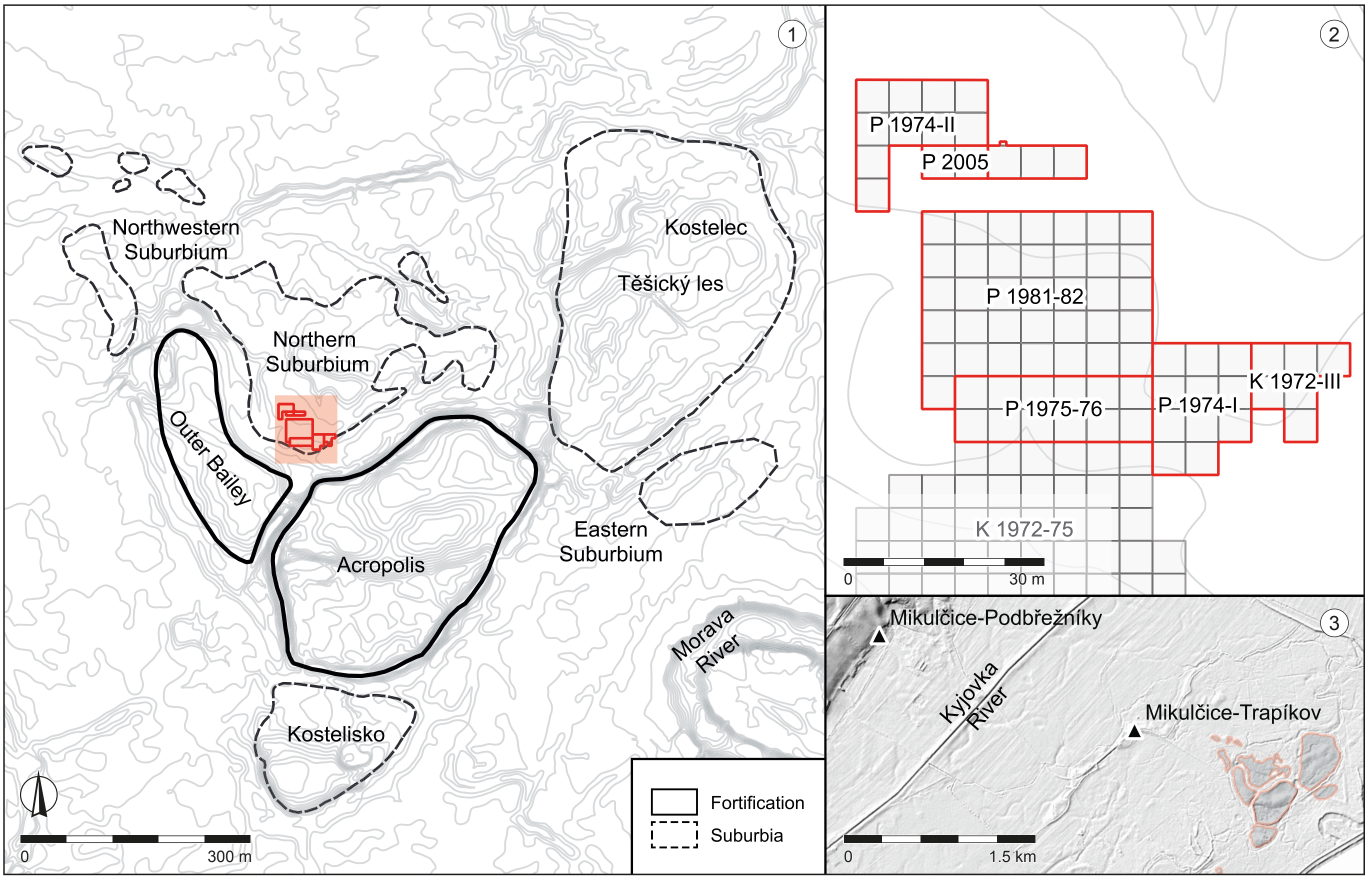


Fig. 1. The Mikulčice-Valy settlement agglomeration. 1 – Schematic overview of the fortified acropolis and the outer bailey with adjacent suburbia during the 2nd half of the 9th century AD; 2 – Plan of the northern suburbium with excavated areas between 1972 and 2005; 3 – Middle Hillfort (800–950 AD) rural settlements with attested ironworking in the hinterland of the agglomeration. Graphic by M. Lebsak.

Obr. 1. *Sídelní aglomerace Mikulčice-Valy. 1 – Schematický přehled opevněné akropole a vnějšího předhradí s přilehlým předměstím ve druhé polovině 9. století; 2 – plán severního předhradí s výzkumy v letech 1972–2005; 3 – středohradištní (800–950) venkovské osídlení s doloženým železářstvím v zázemí aglomerace. Grafika M. Lebsak.*

One of such proto-urban places is the Mikulčice-Valy stronghold or settlement agglomeration in the southern Czech Republic, where intensive ferrous and non-ferrous craft production is evidenced, especially in its attached extramural settlements (Klanica 1974; Klíma 1985; Poláček 2008, 280–284; Ungerman 2020, 179–180). In stark contrast to the unequivocal craft-related character of this site, the evaluation of its rich pyrometallurgical material has been hitherto assessed only unsystematically (Poláček 2008, 280–281; Poláček et al. 2019, 467). The present study aims to expand the current state of research on iron metallurgical activities in Mikulčice-Valy significantly through macro and microscopic analysis of its production debris as well as seeking to discuss the results in the context of specialisation, elite sponsorship, and proto-urbanity.

2. Archaeological background: The Mikulčice-Valy site and its northern suburbium

The Mikulčice-Valy site, located in the Hodonín district of the South Moravian region, lies within the floodplain of the River Morava, situated on the modern border between the Czech Republic and Slovakia (Fig. 1: 1). Emerging as a central settlement in the late 8th century AD, Mikulčice-Valy evolved during the 9th century AD into what is typically categorised as a 'fortified town' (ger. *Burgstadt*) or 'settlement agglomeration', characterised by a cluster of features and functions typical of urbanised milieus (Brather 2008, 148–154; Měřínský 2012, esp. 16, 31–35; Poláček 2020a; 2020b). By the second half of the 9th century AD, it consisted of a complex settlement topography, comprising a fortified acropolis with a densely built-up outer bailey and adjacent open suburbia (e.g. Poulík 1975; Procházka 2009, 159–176; Poláček 2020a; see also Poláček, Marek 2005). This urbanised layout included secular as well as ecclesiastical masonry architecture and a high population density (Měřínský 2012, 35; Poláček 2020c; Poláček 2020d). The proto-urban economy was driven by intensive craft production, access to long-distance trade networks, a local market economy, and a dynamic relationship with an agrarian hinterland (Poláček 2008; Hlavica, Procházka 2020a; 2020b; Hladík et al. 2022; Hlavica 2023). Furthermore, its designation as a princely seat established it as a residential power centre of the so-called 'Great Moravian' political entity until its decline in the early 10th century AD (Kalhous 2020; Poláček 2020b; for the term 'Great Moravia', see also Štefan 2011; Macháček 2009; 2015; 2021).

One significant topographic feature of the Mikulčice-Valy agglomeration is the presence of open, extensive extramural settlements or suburbia located on both sand dunes and alluvial floodplains, extending within a radius of 700 m from the fortified nucleus (Fig. 1: 1; Poláček 2019). Although eight suburbia covering an area of 150 ha have been identified so far, according to the archaeological state of research, only 15 ha or 10% are believed to have been inhabited (Poláček 2019, 12). The suburbia were not fortified and primarily intended for basic dwelling purposes, thus the economy of their inhabitants mainly revolved around household subsistence. However, agricultural activities and especially craft production are also archaeologically attested (Poláček, Marek 2005, 219, 237, 241–242; Poláček 2019).

The northern suburbium (Fig. 1: 1, 1: 2), covering a total area of 5 ha, extends on low-lying alluvial floodplains and is separated from the nucleus by a former river branch of the River Morava. Six archaeological campaigns conducted in 1972, 1974, 1975–1976, 1981–1982 and 2005, covering an area of approximately 0.2 ha, yielded evidence of a short-lived settlement horizon with a dense building structure consisting of floor backfills and pits dated to the second half of the 9th/early 10th centuries AD (see below Fig. 12; Poláček, Marek 2005, 219, 237, 241–242; Mazuch 2019; Poláček 2019; Poláček et al. 2019, 450–455). Particularly noteworthy is the high quantity of pyrometallurgical debris uncovered in this area (Klíma 1985; Poláček 2008, 280–284). Almost 300 kg of iron slags and technical ceramics form the material basis for the study presented here.

3. Materials and methods

In the preliminary stage, 287.5 kg of pyrometallurgical debris (Tab. 1) were macroscopically-morphologically assessed based on quantifiable parameters. These parameters included weight, maximum length, width, height, top and profile shape, as well as optical peculiarities, inclusions, and magnetisability, utilising a standard hand magnet (Westphalen 1989, 20–24; Cech, Walach 1998; Serneels, Perret 2003; Gassmann 2004, 73–74). Representable slag agglomerations were furthermore photographed and drawn (for exemplary forms of presentation, see Eschenlohr et al. 2007, 39–50; Schäfer 2013). Fragmentary and indeterminable objects as well as clay slags and possible hearth parts were only weighed.

Every object was assigned to an excavation grid of 5 × 5 m (for the established excavation technique of the Mikulčice-Valy site, see Poláček, Marek 2005, 17–20). The contextualization of debris with archaeological features, particularly for the identification of workshops, posed challenges. One major flaw is the loss of the archaeological documentation from excavation campaigns K 1972-III and P 1981-82 (Poláček, Marek 2005, 218, 241), altogether representing around 50% of the total excavated area in the northern suburbium. Unverifiable results of those excavations, like plana drawings, are only available in the form of preliminary reports (Klanica 1973; 1985). Despite the satisfactory standard of documentation for the remaining campaigns P 1974-I and P 1974-II as well as the very detailed revision excavation P 2005, their contribution to the assessment of ironworking-related questions, especially regarding the comparative qualification and classification of production waste, remains limited (Poláček, Marek 2005, 218, 237; Mazuch 2019, esp. 185–187).

Five representative slag agglomerations (Tab. 2) were selected for further scientific analysis to understand their role in the ironworking *chaîne opératoire*. They were impregnated by epoxy resin due to either high porosity or compromised cohesion resulting from extensive weathering. Individual samples were cut to the appropriate format using a diamond saw after the hardening time had elapsed. The cut-outs were further processed into thin sections, which were polished with progressively finer diamond pastes (up to 0.25 μm). The final polished thin sections were thoroughly studied using an optical microscope in PPL, XPL, and RL (reflected light) modes. Additionally, microphotos were acquired in selected modes. The thin sections were subsequently carbon-sputtered (with a 25 nm layer). The selected phases were studied using an electron microprobe (JXA 8600). Point analyses were acquired by energy dispersive spectrometry (EDS mode).

The bulk composition was determined by a WD-XRF S4 Pioneer. The measurements were carried out on 40 mm diameter discs pressed from samples mixed with microcrystalline cellulose in a ratio of 4: 1 under a pressure of 20 t. In-house reference material (iron-slags) from the Department of Geology at Palacký University Olomouc were used to calibrate the method.

4. Results

4.1 Metallurgical debris

The results drawn from the morphological and microscopical evaluation of the material allows the classification into four categories: blacksmithing slag, smelting slag, technical ceramics, and ceramic slag (Tab. 1).

Blacksmithing or processing slag represent a total mass of 268.6 kg. The first type consists of 81.5 kg of 409 undamaged calottes or so called plano-convex hearth bottoms, commonly abbreviated as PCBs (Sperl 1980, 15; Serneels 1993, 47–49, 51, Fig. 4, 118–119; Senn-Luder 1997, 35; Serneels, Perret 2003; Pleiner 2006, 112–120; Eschenlohr et al. 2007, 30–34; Leroy et al. 2019, 30–33, Fig. 11; Hauptmann 2020, 243–244). The second and third type comprise 24.3 kg of fragmented PCBs (25% to 75% of preservation) and 163 kg of slags representing mostly small PCB fragments and irregular blacksmithing slags.

The most important morphological characteristic of PCBs is the round or oval shape and convex bottom, originating from the solidification on the base of a shallow sunken hearth or fire

Category	Type	Mass (kg)	Mass (%)	Method
Blacksmithing slag	PCB (n = 409)	81.5	28%	Macroscopical, SEM-EDS, WD-XRF
	PCB fragments (25–75% preservation)	24.3	8%	
	PCB fragments, irregular slags	163	57%	
Smelting slag	Tap slag(?)	2.7	1%	Macroscopical, SEM-EDS, WD-XRF
Technical ceramics	Tuyères, clay plugs, hearth parts	4.4	2%	Macroscopical
Ceramic slag	Slagged clay, irregular hearth parts	11.6	4%	Macroscopical
Total		287.5	100%	

Tab. 1. Qualitative and quantitative overview of pyrometallurgical debris types from Mikulčice-Valy and their percentage of the total mass.

Tab. 1. *Kvalitativní a kvantitativní přehled typů pyrometalurgické suti a jejich procentuální podíl na celkové hmotnosti.*

Inv. No.	Square	Season	Type	Weight (g)	Profile	Comment	Figure
594-357/72; K877/72	−7/−22	K 1972-III	PCB	331	Flat-convex	With tuyère brick fragment	Fig. 2: 9
594-386/74; K153/74	−11/−23	P 1974-I	PCB	409	Concave-convex	Slightly dense	Fig. 2: 6
594-465/74; P1096/74	−16/−30	P 1974-II	PCB	298	Flat-convex	Hammer-scales on PCB top	Fig. 2: 1
P324/75	−16/−23	P 1975-76	PCB	545	Flat-convex	With tuyère brick fragment	Fig. 2: 8
594-571/82; P1836/82	−14/−26	P 1981-82	Tap slag(?)	979	Irregular	Very dense, slightly viscious	Fig. 2: 7

Tab. 2. Overview of the selected slag samples analysed by SEM-EDS and WD-XRF.

Tab. 2. *Přehled vybraných vzorků strusky analyzovaných pomocí SEM-EDS a WD-XRF.*

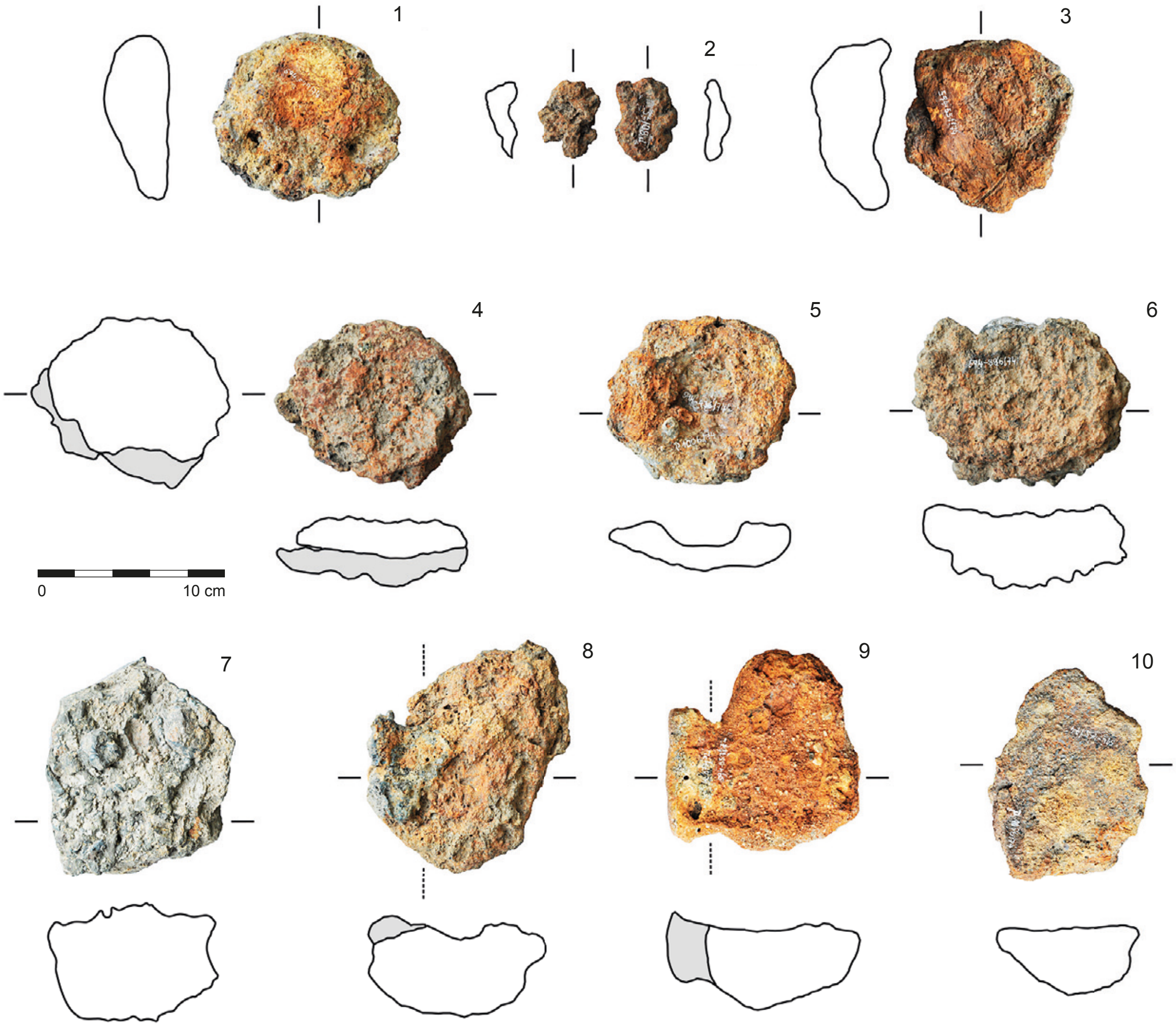


Fig. 2. Selection of iron slags from the northern suburbium of the Mikulčice-Valy settlement agglomeration. 1 – PCB (594-508/74; P877/74); 2 – Small oval PCBs (left P80/75, right P84/75); 3 – PCB (594-551/74; P1200/74); 4 – double PCB (594-372/74; K150); 5 – PCB (594-436/74; P1006/74); 6 – PCB (594-386/74; K153/74); 7 – smelting slag (594-571/82; P1836/82); 8 – PCB with tuyère brick fragment (P324/75); 9 – PCB with tuyère brick fragment (594-357/72; K877/72); 10 – PCB with hammer-scale inclusion (594-465/74; P1096/74). Photo and drawing by M. Lebsak.

Obr. 2. *Výběr železářských strusek ze severního suburbia sídelní aglomerace Mikulčice-Valy. 1 – PCB (594-508/74; P877/74); 2 – malé oválné PCB (vlevo P80/75, vpravo P84/75); 3 – PCB (594-551/74; P1200/74); 4 – dvojitá PCB (594-372/74; K150); 5 – PCB (594-436/74; P1006/74); 6 – PCB (594-386/74; K153/74); 7 – hutnická struska (594-571/82; P1836/82); 8 – PCB s úlomkem dyznové cihly (P324/75); 9 – PCB s úlomkem dyznové cihly (594-357/72; K877/72); 10 – PCB s inkluzí okuje (594-465/74; P1096/74). Foto a kresba M. Lebsak.*

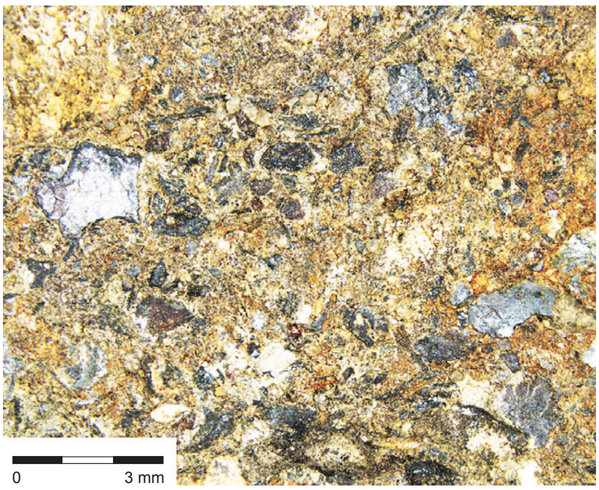


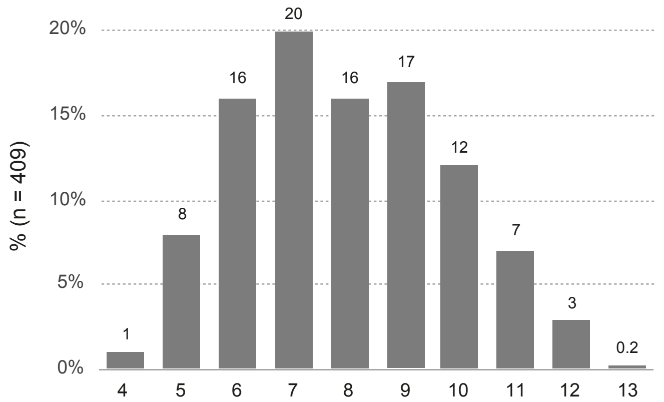
Fig. 3. Lamellar hammer-scales accumulated on top of PCB (594-465/74; P1096/74) under the stereomicroscope. Photo by M. Chovanec.

Obr. 3. *Lamelární kladívkové šupiny nahromaděné na vrcholu PCB (594-465/74; P1096/74) pod stereomikroskopem. Foto by M. Chovanec.*

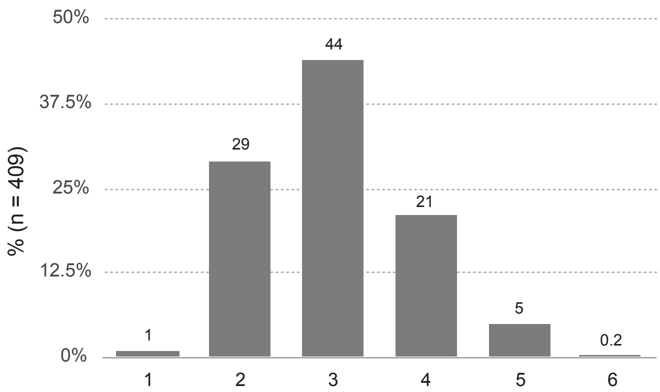
pit (Fig. 2: 1, 3–6, 8–10). Smaller specimens tend to be more oval in shape (Fig. 2: 2) but can be also irregular. Charcoal imprints extending to several centimetres and sandy-clayish adhesions are indicative of direct contact with fuel material and the hearth lining during work. Fresh breakage displays a heterogenous micro-stratigraphical composition with alternating dense and porous layers, indicating a successive formation process of repeated cooling and reheating of the hearth during one unit of work (Serneels, Perret 2003, 473), the changing of process steps without cooling or the simultaneous work on multiple objects (Kerbler 2019, 217). This is underpinned by the occurrence of double PCBs consisting of two specimens solidified on top of each other (Fig. 2: 4). Slag agglomerations of this type were formed after the first solidification process was already finished and shows that the hearth was not cleaned out before a new unit of work was begun (Eschenlohr et al. 2007, 34–35, Fig. 38). One PCB shows an accumulation of lamellar hammer scales on the top side (Fig. 2: 10; Fig. 3). Hammer-scale of lamellar shape forms as a result of oxidation on the iron surface during heating and is a direct proof for the blacksmithing or forging of iron

Site	Total mass blacksmithing slags (kg)	Total mass PCBs (kg)	PCBs (n)	Ø (mean) mass or range (g)	Ø (mean) length or range (cm)	Dating	Settlement type	Production steps	Source
Mikulčice-Valy Northern surburbium (CZ)	268.6	81.5	409	199.2	7.9	Late 9th/early 10th century AD	Proto-town/ agglomeration	Blacksmithing	
Břeclav-Pohansko Lesní školka (CZ)	137.5	n/a	199	n/a	n/a	9th century AD	Proto-town/ agglomeration	Blacksmithing	Macháček et al. 2007.
Brno-Modřice (CZ)	8.2	n/a	n/a	n/a	n/a	11th century AD	Rural	Blacksmithing	Beran et al. 2013.
Bořitov Zádvoří, Niva (CZ)	0.6	n/a	n/a	n/a	n/a	9th century AD	Rural	Smelting, refining?, blacksmithing	Mikulec et al. 2022.
Hedeby/Haithabu (DE)	3400	n/a	1694	300–400	<10	8th–11th century AD	Proto-town/ agglomeration	Blacksmithing	Westphalen 1989.
Ribe 1970–1976 (DK)	min. 191	93	277	ca 100–300	ca 7–10	8th/9th century AD	Proto-town/ agglomeration	Refining, blacksmithing	Brinch Madsen 2004.
Flixborough (GB)	180	18.1	148	166	7.4	8th–10th century AD	Rural	Smelting, blacksmithing	Starley, Loveluck 2009.
Develier-Courtételle (CH)	3925	1029	1432 (>50% preserva-tion)	500–650 (n = 608); 1200–1400 (n = 479); 1850 (n = 58)	ca 9–15	6th/7th century AD	Rural	Refining, blacksmithing	Eschenlohr et al. 2007.
Liestal-Röserntal (CH)	670	250	400	ca 300–1000	ca 5–20	8th–12th century AD	Rural	Smelting, refining, blacksmithing	Serneels 1995.

Tab. 3. Comparative qualitative data on PCBs from Mikulčice-Valy and other Early Medieval sites in Europe with attested ironworking.
Tab. 3. *Srovnávací kvalitativní údaje o PCB z Mikulčic-Valů a dalších raně středověkých lokalit v Evropě s doloženým zpracováním železa.*



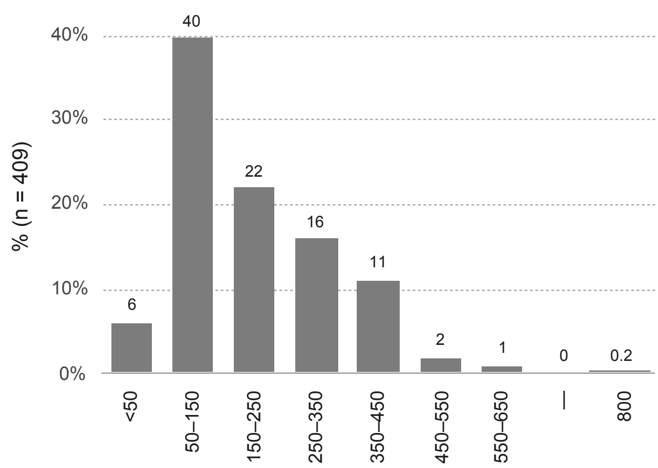
Graph 1. Percentage bar graph for PCB lengths per cm rounded to integer.
Graf 1. *Procentuální sloupcový graf pro délky PCB na cm zaokrouhlené na celá čísla.*



Graph 2. Percentage bar graph for PCB heights per cm rounded to integer.
Graf 2. *Procentuální sloupcový graf pro výšky PCB na cm zaokrouhlené na celá čísla.*

objects (Eschenlohr et al. 2007, 73; Dungworth, Wilkes 2009). In summary, PCBs emerge during heating of iron objects, when the oxidation crust on the object drops into the hearth and connects with charcoal ash and silica-rich liquid from fluxes or the hearth lining (e.g. Serneels, Perret 2003). The potential working steps leading to the formation of PCBs can range from the reheating of iron blooms to, for instance, the complex manufacturing or repairing of iron objects (Gassmann 2004, 73). This also directly affects their mineralogical and chemical composition. Morphological parameters allow the comparison to similar slag assemblages from other Early Medieval sites in Europe (Tab. 3). PCB lengths range between 3.8–12.5 cm, with a height or thickness between 1.3–6 cm and weight between 21–832 g (Graph 1–3).

PCBs constitute typical iron-rich silicate slags consisting of ferrous olivine crystals, wüstite, leucite, and glass (Tab. 4–8; Fig. 4–7). The chemical composition of olivine is predominantly influenced by the fayalite (Fe_2SiO_4) end member, which is typical for slags derived from iron smelting and processing. Wüstite ($Fe^{2+}O$) represents another important slag constituent formed as a result of iron oxidation and formation of hammer scales



Graph 3. Percentage bar graph for PCB weight per weight groups in grams.
Graf 3. *Procentuální sloupcový graf pro hmotnosti PCB v hmotnostních skupinách v gramech.*

during blacksmithing (Eschenlohr et al. 2007, 22). Original hammer scales of different shapes are occasionally identifiable in PCBs and allow conclusions about the individual steps in the metallurgical chain (Gassmann 2004, 76, 79; Kerbler 2019, 217; Hauptmann 2020, 244). However, such observations were not made within the analysed samples. The presence of wüstite varies across samples and within each sample, ranging from wüstite-dominated to nearly wüstite-free zones. Wüstite forms either oval isolated grains or more complicated intergrowths (Fig. 6, 7). Leucite ($K[AlSi_2O_6]$) is one of the final phases in the crystallisation sequence of slags, and in certain instances, it exhibits signs of simultaneous formation with olivine. Leucite often forms eutectic intergrowths with wüstite and occasionally with olivine. The shapes are typically irregular or oval (Fig. 7, 8). Glass is an irregular infill between individual crystalline phases. While no sample is holocrystalline, they are mostly well crystalised. The colour in PPL ranges from light yellowish green to opaque. Interstitial glass is also host to minute olivine crystals. The chemical composition of glass is in some samples surprisingly homogenous (Tab. 9) with a prevalence of silicon

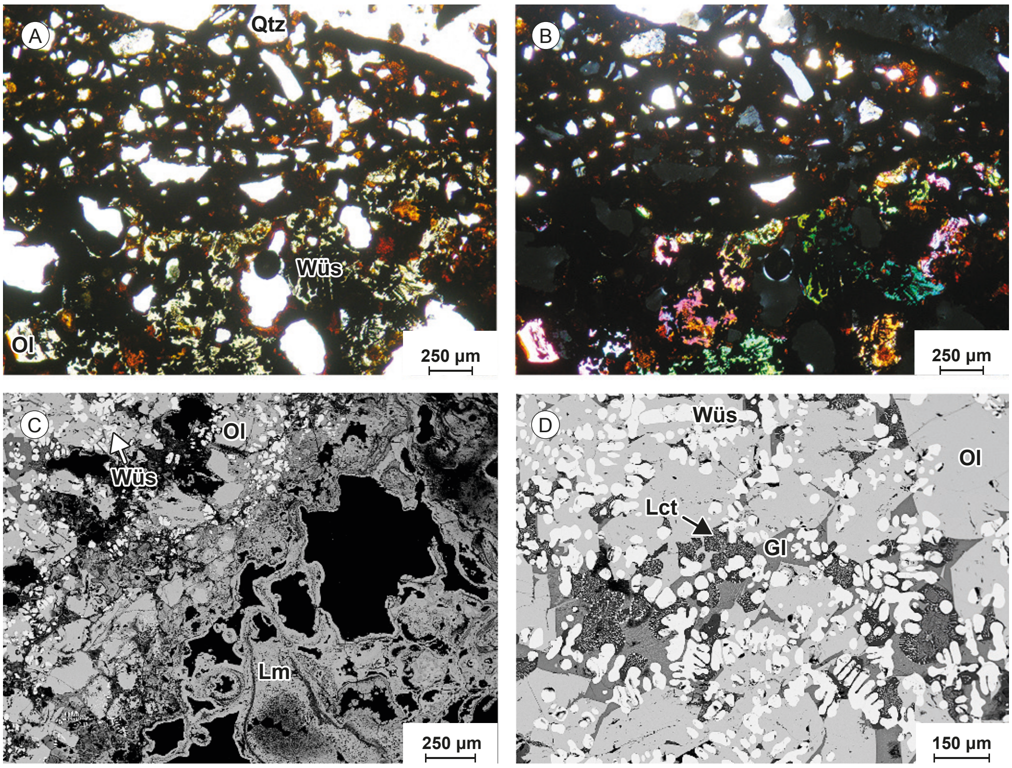


Fig. 4. Examples of phases present in sample 594-357/72; K877/72. A – PPL; B – XPL; C – BSE; D – BSE. Ol – olivine, Wüs – wüstite, Gl – glass, Lct – leucite, Qtz – quartz, Lm – limonite. Photo by J. Kapusta.

***Obr. 4.** Příklady fází přítomných ve vzorku 594-357/72; K877/72. A – PPL; B – XPL; C – BSE; D – BSE. Ol – olivín, Wüs – wüstit, Gl – sklo, Lct – leucit, Qtz – křemen, Lm – limonit. Foto J. Kapusta.*

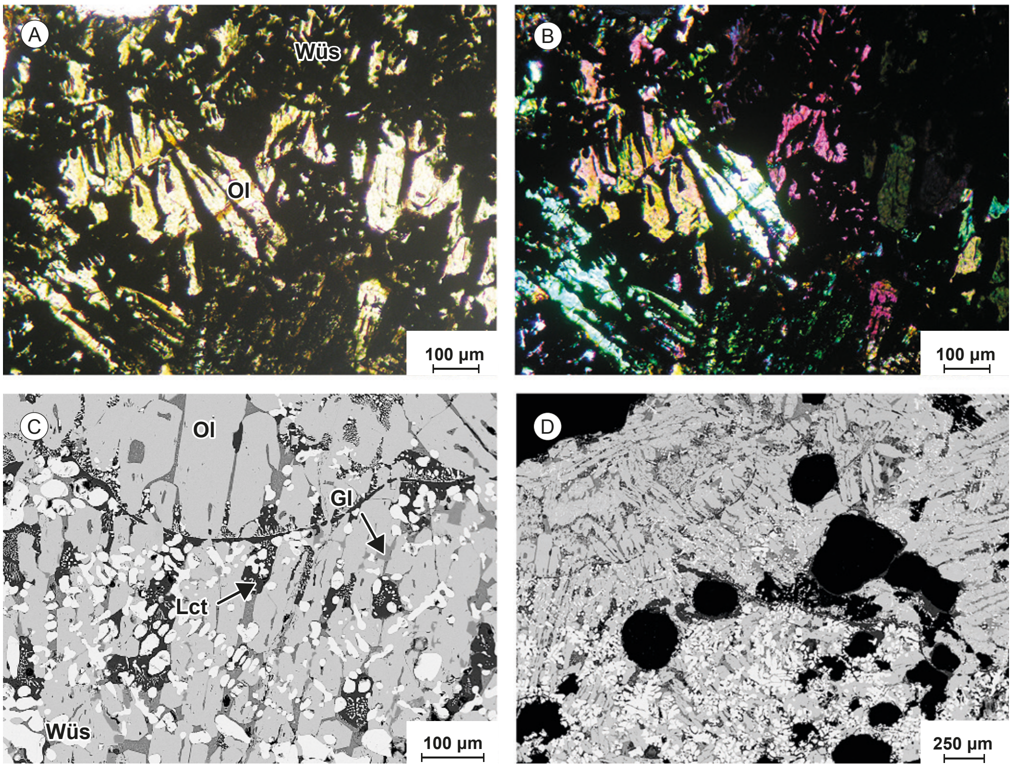


Fig. 5. Examples of phases present in sample 594-386/74; K153/74. A – PPL; B – XPL; C – BSE; D – BSE. Ol – olivine, Wüs – wüstite, Gl – glass, Lct – leucite. Photo by J. Kapusta.

***Obr. 5.** Příklady fází přítomných ve vzorku 594-386/74; K153/74. A – PPL; B – XPL; C – BSE; D – BSE. Ol – olivín, Wüs – wüstit, Gl – sklo, Lct – leucit. Foto J. Kapusta.*

dioxide (SiO_2), calcium oxide (CaO), iron-(II)-oxide (FeO) and aluminium oxide (Al_2O_3).

The chemical composition of the studied smithing slags consists mainly of iron oxides (56.19–72.59 wt. % of FeO), silica (17.61–28.58 wt. % of SiO2) and alumina (2.19–4.53 wt. % of Al_2O_3) (Tab. 10). Sample K877/2 is enriched in calcium oxide (4.64 wt. % of CaO), which can be explained by a strong contribution of charcoal during slag formation (Eschenlohr et al. 2007, e.g. 41, 45). Sample P1096/74 is characterised by a relatively high phosphorus pentoxide content (1.25 wt. % of P_2O_5). It can hardly be interpreted as a smelting slag considering its typical PCB morphology and visible large inclusions of hammer scales (Fig. 2: 10; Fig. 3). Increased P_2O_5 contents are known from comparable ironworking slags (Selskienė 2007, 24; Dunster, Dungworth 2012, 15, Tab. 6) and hammer scales (Dungworth, Wilkes 2009).

Iron smelting slags are large, chunky in shape, very dense and bear a heavy metallic-grey, slightly viscous surface (Fig. 2: 7). The magnetizability is low. Slags of this type constitute a mass of 2.69 kg in total. Chemically, they represent iron-rich silicate slags with similar phases as mentioned for PCBs yet showing

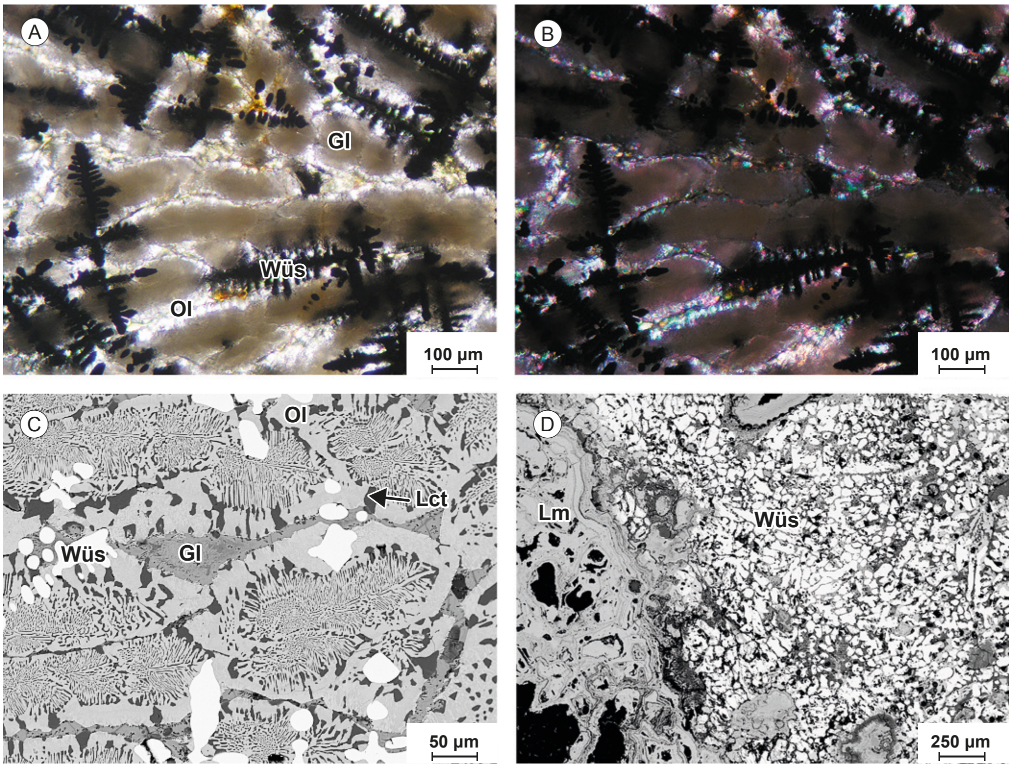


Fig. 6. Examples of phases present in the sample 594-465/74; P1096/74. A – PPL; B – XPL; C – BSE; D – BSE. Ol – olivine, Wüs – wüstite, Gl – glass, Lct – leucite. Photo by J. Kapusta.

Obr. 6. *Příklady fází přítomných ve vzorku 594-465/74; P1096/74. A – PPL; B – XPL; C – BSE; D – BSE. Ol – olivín, Wüs – wüstit, Gl – sklo, Lct – leucit. Foto J. Kapusta.*

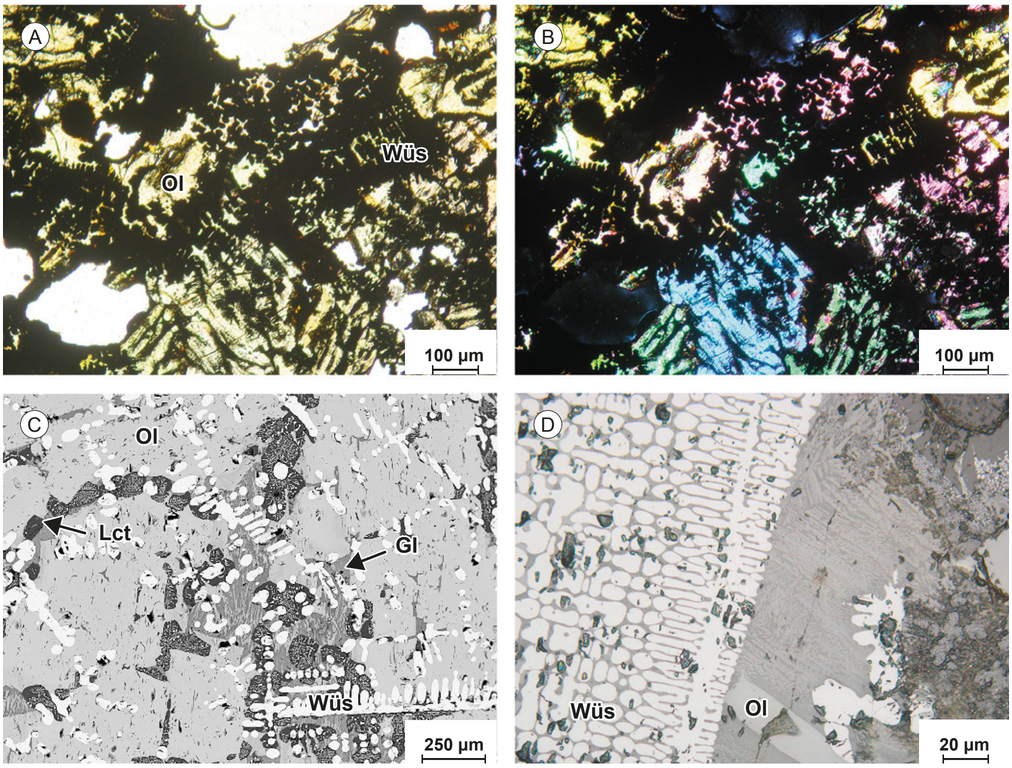


Fig. 7. Examples of phases present in sample P324/75. A – PPL; B – XPL; C – BSE; D – RL. Ol – olivine, Wüs – wüstite, Gl – glass, Lct – leucite. Photo by J. Kapusta.

Obr. 7. *Příklady fází přítomných ve vzorku P324/75. A – PPL; B – XPL; C – BSE; D – RL. Ol – olivín, Wüs – wüstit, Gl – sklo, Lct – leucit. Foto J. Kapusta.*

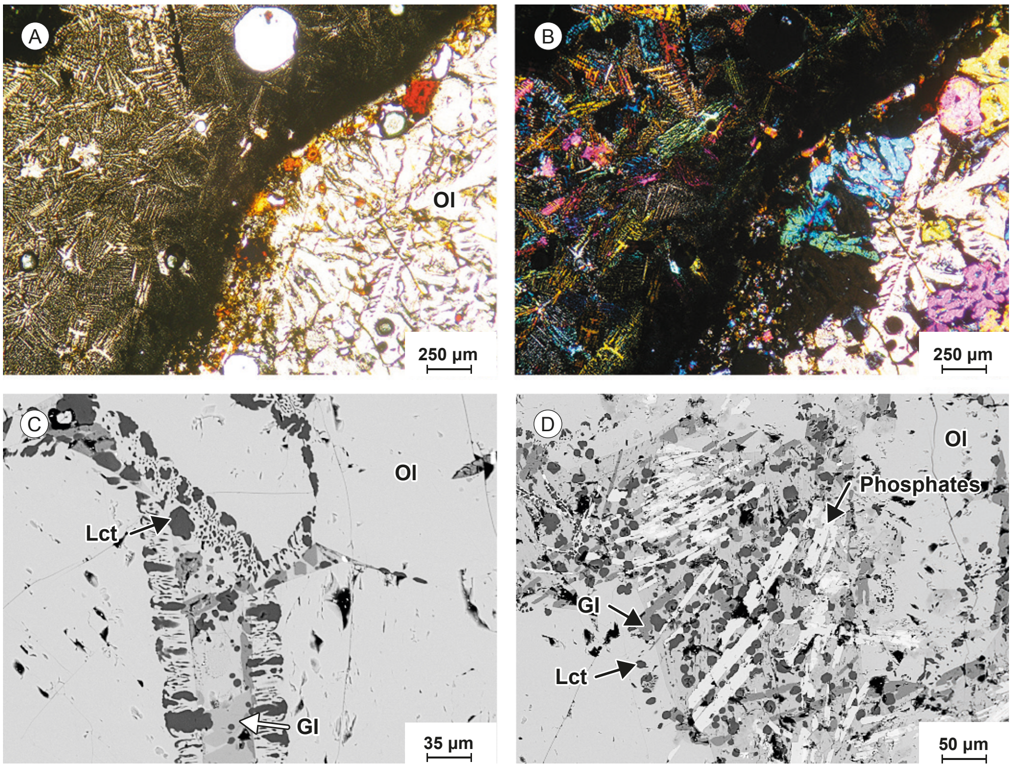


Fig. 8. Examples of phases present in sample 594-571/82; P1836/82. A – PPL; B – XPL; C – BSE; D – BSE. Ol – olivine, Gl – glass, Lct – leucite. Photo by J. Kapusta.

Obr. 8. *Příklady fází přítomných ve vzorku 594-571/82; P1836/82. A – PPL; B – XPL; C – BSE; D – BSE. Ol – olivín, Gl – sklo, Lct – leucit. Foto J. Kapusta.*

Sample	Ol	Wüs	Spn	Lct	Phos	Fe	Gl	Lm
594-386/74; K153/74	+++	++	+	+			++	
594-357/72; K877/72	+++	++		+			+	+
594-571/82; P1836/82	+++	+	+	+	+		+	
P324/75	+++	++		+			++	
594-465/74; P1096/74	+++	+		+			+	++

Tab. 4. Identified phase associations, based on EPMA and optical microscopy data. Ol – olivine, Wüs – wüstite, Spn – spinelide, Lct – leucite, Phos – phospates, Fe – iron, Gl – glass, Lm – limonite.

Tab. 4. *Identifikované fázové asociace na základě dat EPMA a optické mikroskopie. Ol - olivín, Wüs - wüstit, Spn - spinelid, Lct - leucit, Phos - fosfáty, Fe - železo, Gl - sklo, Lm - limonit.*

An. N.	1	2	3	4	5	6	7	8	9	10	11	12	13
Phase	**Ol**	**Ol**	**Ol**	**Ol**	**Wüs**	**Wüs**	**Wüs**	**Lct**	**Lct**	**Lct**	**Gl**	**Gl**	**Gl**
SO_3	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.	0.5	0.3	0.2	0.6	0.6	0.5
P_2O_5	0.2	0.3	b.d.	b.d.	b.d.	b.d.	b.d.	0.5	0.4	0.4	4.9	5.3	4.2
SiO_2	28.9	28.5	28.7	28.9	b.d.	b.d.	b.d.	56.4	56.6	57.4	33.1	32.7	33.6
TiO_2	b.d.	b.d.	b.d.	b.d.	0.2	0.3	0.3	0.3	0.2	0.2	0.3	0.2	0.2
Al_2O_3	b.d.	b.d.	b.d.	b.d.	0.2	0.3	0.3	24.3	24.3	24.7	14.1	18.7	12.8
Cr_2O_3	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.
CaO	0.8	1.1	0.8	1.2	b.d.	b.d.	b.d.	0.2	0.2	0.2	17.8	17.3	16.1
FeO	68.3	67.9	68.3	68.5	98.8	97.2	97.1	2.4	2.1	1.5	25.7	20.8	30.4
MgO	1.5	0.5	0.9	0.4	b.d.	b.d.	b.d.	0.3	0.3	0.3	b.d.	b.d.	b.d.
MnO	0.2	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.
ZnO	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.
K_2O	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.	14.6	15.1	15.9	1.5	1.9	1.5
Na_2O	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.	1.6	1.1	0.7	2.5	3.4	2.5
Sum	**99.9**	**98.3**	**98.7**	**99.1**	**99.2**	**97.7**	**97.7**	**101.0**	**100.6**	**101.4**	**100.6**	**100.8**	**101.7**
S^{6+}	–	–	–	–	–	–	–	0.012	0.008	0.005	–	–	–
P^{5+}	0.007	0.008	–	–	–	–	–	0.014	0.011	0.011	–	–	–
Si^{4+}	0.974	0.980	0.983	0.987	–	–	–	1.971	1.986	1.994	–	–	–
Ti^{4+}	–	–	–	–	0.002	0.002	0.003	0.007	0.006	0.005	–	–	–
Al^{3+}	–	–	–	–	0.002	0.004	0.005	0.999	1.003	1.011	–	–	–
Ca^{2+}	0.030	0.040	0.028	0.045	–	–	–	0.009	0.008	0.007	–	–	–
Fe^{2+}	1.924	1.955	1.958	1.957	0.992	0.988	0.988	0.069	0.061	0.043	–	–	–
Mg^{2+}	0.075	0.024	0.048	0.023	–	–	–	0.018	0.017	0.017	–	–	–
Mn^{2+}	0.006	–	–	–	–	–	–	–	–	–	–	–	–
K^{+}	–	–	–	–	–	–	–	0.649	0.676	0.704	–	–	–
Na^{+}	–	–	–	–	–	–	–	0.109	0.074	0.050	–	–	–
Catsum	**3.016**	**3.008**	**3.017**	**3.013**	**0.997**	**0.995**	**0.995**	**3.856**	**3.849**	**3.846**	**–**	**–**	**–**

Tab. 5. Selected EDS analysis of phases from sample 594-357/72; K877/72. The apfu values are calculated based on 4 oxygen for olivine, 6 oxygen for leucite and 1 oxygen for wüstite. B.d. – below the limit of detection.

Tab. 5. *Vybrané EDS analýzy fází ze vzorku 594-357/72; K877/72. Hodnoty apfu jsou vypočteny na základě 4 kyslíků pro olivín, 6 kyslíků pro leucit a 1 kyslík pro wüstit. B.d. – pod mezí detekce.*

An. N.	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
Phase	**Ol**	**Ol**	**Ol**	**Wüs**	**Wüs**	**Wüs**	**Lct**	**Lct**	**Hc**	**Hc**	**Gl**	**Gl**	**Gl**
SO_3	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.	0.2	0.2	b.d.	b.d.	0.9	0.7	0.6
P_2O_5	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.	0.3	0.4	b.d.	b.d.	4.2	3.3	2.7
SiO_2	28.8	28.4	28.6	b.d.	0.2	b.d.	57.6	57.0	0.6	0.3	30.9	34.3	40.7
TiO_2	b.d.	b.d.	b.d.	0.2	0.2	b.d.	b.d.	0.2	0.2	0.2	b.d.	0.2	b.d.
Al_2O_3	b.d.	b.d.	b.d.	0.4	0.4	b.d.	24.7	24.6	49.1	49.7	15.9	20.5	12.9
Cr_2O_3	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.
Fe_2O_3	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	8.7	9.2	n.a.	n.a.	n.a.
CaO	1.3	0.6	0.3	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.	13.3	9.5	4.5
FeO	69.7	68.5	70.7	98.5	97.6	99.2	1.5	1.5	40.3	39.7	29.7	22.8	29.2
MgO	b.d.	0.2	b.d.	b.d.	b.d.	b.d.	0.3	0.3	b.d.	0.2	b.d.	b.d.	b.d.
MnO	0.4	0.8	b.d.	0.2	0.3	b.d.	b.d.	b.d.	b.d.	0.2	b.d.	b.d.	b.d.
ZnO	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.
K_2O	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.	15.7	15.8	b.d.	b.d.	2.0	6.6	7.1
Na_2O	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.	0.7	0.7	b.d.	b.d.	2.5	0.9	1.4
Sum	**100.2**	**98.5**	**99.6**	**99.2**	**98.8**	**99.2**	**101.2**	**100.7**	**99.0**	**99.5**	**99.5**	**98.8**	**99.1**
S^{6+}	–	–	–	–	–	–	0.006	0.006	–	–	–	–	–
P^{5+}	–	–	–	–	–	–	0.010	0.012	–	–	–	–	–
Si^{4+}	0.979	0.982	0.981	–	0.003	–	2.002	1.993	0.018	0.009	–	–	–
Ti^{4+}	–	–	–	0.002	0.001	–	–	0.005	0.005	0.005	–	–	–
Al^{3+}	–	–	–	0.006	0.006	–	1.013	1.015	1.755	1.764	–	–	–
Fe^{3+}	–	–	–	–	–	–	–	–	0.200	0.209	–	–	–
Ca^{2+}	0.046	0.023	0.011	–	–	–	–	–	–	–	–	–	–
Fe^{2+}	1.983	1.980	2.027	0.986	0.979	1.000	0.043	0.043	0.823	0.790	–	–	–
Mg^{2+}	–	0.011	–	–	–	–	0.017	0.016	–	0.009	–	–	–
Mn^{2+}	0.013	0.023	–	0.002	0.003	–	–	–	–	0.005	–	–	–
K^{+}	–	–	–	–	–	–	0.697	0.705	–	–	–	–	–
Na^{+}	–	–	–	–	–	–	0.050	0.047	–	–	–	–	–
Carsum	**3.021**	**3.018**	**3.019**	**0.995**	**0.993**	**1.000**	**3.838**	**3.841**	**2.801**	**2.791**	**–**	**–**	**–**

Tab. 6. Selected EDS analysis of phases from the sample 594-386-77. The apfu values are calculated based on 4 oxygen for olivine, 6 oxygen for leucite, 4 oxygen for hercynite and 1 oxygen for wüstite. B.d. – below the limit of detection, n.a. – not analyzed.

Tab. 6. *Vybrané EDS analýzy fází ze vzorku 594-386-77. Hodnoty apfu jsou vypočteny na základě 4 kyslíků pro olivín, 6 kyslíků pro leucit, 4 kyslíků pro hercynit a 1 kyslík pro wüstit. B.d. – pod mezí detekce, n.a. – neanalyzováno.*

An. N.	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
Phase	**Ol**	**Ol**	**Ol**	**Ol**	**Lct**	**Lct**	**Lct**	**Wüs**	**Wüs**	**Wüs**	**Gl**	**Gl**	**Gl**
SO_3	0.2	0.3	b.d.	b.d.	b.d.	0.2	0.2	b.d.	b.d.	b.d.	0.8	1.1	1.0
P_2O_5	0.2	0.2	0.5	b.d.	0.2	b.d.	0.2	b.d.	b.d.	b.d.	3.5	1.8	4.4
SiO_2	30.4	30.2	29.6	29.8	56.0	55.6	55.7	b.d.	b.d.	b.d.	42.0	45.5	41.3
TiO_2	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.	0.2	0.2	0.7	1.0	0.5
Al_2O_3	b.d.	b.d.	b.d.	b.d.	23.8	23.7	23.4	b.d.	b.d.	b.d.	2.9	2.9	2.4
Cr_2O_3	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.
CaO	17.5	12.4	10.3	9.8	b.d.	0.2	0.2	b.d.	b.d.	b.d.	3.9	3.0	5.4
FeO	51.0	56.5	59.0	59.5	1.2	1.4	2.0	99.5	99.3	99.2	30.8	29.5	29.5
MgO	0.5	0.4	1.1	0.2	0.3	0.3	0.3	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.
MnO	b.d.	0.2	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.
ZnO	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.
K_2O	b.d.	b.d.	b.d.	b.d.	18.3	18.4	17.7	b.d.	b.d.	b.d.	12.6	13.2	12.6
Na_2O	b.d.	b.d.	b.d.	b.d.	0.2	b.d.	0.2	b.d.	b.d.	b.d.	2.4	2.2	3.1
Sum	**99.8**	**100.2**	**100.4**	**99.3**	**99.9**	**99.8**	**100.0**	**99.5**	**99.4**	**99.4**	**99.6**	**100.3**	**100.2**
S^{6+}	0.005	0.007	–	–	–	0.006	0.005	–	–	–	–	–	–
P^{5+}	0.006	0.005	0.013	–	0.006	–	0.007	–	–	–	–	–	–
Si^{4+}	0.982	0.984	0.969	0.991	2.003	1.996	1.996	–	–	–	–	–	–
Ti^{4+}	–	–	–	–	–	–	–	–	0.001	0.002	–	–	–
Al^{3+}	–	–	–	–	1.003	1.003	0.988	–	–	–	–	–	–
Ca^{2+}	0.605	0.433	0.360	0.350	–	0.006	0.006	–	–	–	–	–	–
Fe^{2+}	1.378	1.539	1.616	1.657	0.035	0.043	0.061	1.000	0.997	0.996	–	–	–
Mg^{2+}	0.023	0.022	0.054	0.012	0.016	0.015	0.016	–	–	–	–	–	–
Mn^{2+}	–	0.005	–	–	–	–	–	–	–	–	–	–	–
K^{+}	–	–	–	–	0.834	0.843	0.811	–	–	–	–	–	–
Na^{+}	–	–	–	–	0.011	–	0.013	–	–	–	–	–	–
Catsum	**2.999**	**2.995**	**3.012**	**3.009**	**3.909**	**3.912**	**3.902**	**–**	**–**	**–**	**–**	**–**	**–**

Tab. 7. Selected EDS analysis of phases from the sample 594-465/74; P1096/74. The apfu values are calculated based on 4 oxygen for olivine, 6 oxygen for leucite and 1 oxygen for wüstite. B.d. – below the limit of detection.

Tab. 7. *Vybrané EDS analýzy fází ze vzorku 594-465/74; P1096/74. Hodnoty apfu jsou vypočteny na základě 4 kyslíků pro olivín, 6 kyslíků pro leucit a 1 kyslík pro wüstit. B.d. – pod mezí detekce.*

An. N.	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
Phase	**Ol**	**Ol**	**Ol**	**Ol**	**Wüs**	**Wüs**	**Wüs**	**Lct**	**Lct**	**Lct**	**Gl**	**Gl**	**Gl**
SO_3	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.	0.2	0.3	0.2	0.8	0.7	1.1
P_2O_5	b.d.	b.d.	0.7	0.6	b.d.	b.d.	b.d.	0.4	0.3	0.4	4.3	4.0	4.3
SiO_2	29.5	29.4	29.8	29.8	b.d.	b.d.	b.d.	57.4	56.9	56.8	33.6	34.0	33.2
TiO_2	b.d.	b.d.	b.d.	b.d.	0.3	0.3	0.3	b.d.	b.d.	0.2	0.3	0.3	0.7
Al_2O_3	b.d.	b.d.	b.d.	b.d.	0.2	0.3	b.d.	24.9	24.5	24.6	17.7	14.8	13.2
Cr_2O_3	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.
CaO	1.4	1.6	16.8	13.7	b.d.	b.d.	b.d.	b.d.	0.2	0.2	17.1	17.7	18.1
FeO	65.7	66.4	52.6	55.7	98.7	98.5	98.4	2.1	1.7	1.2	22.0	24.7	25.6
MgO	2.5	2.2	b.d.	0.2	b.d.	b.d.	b.d.	0.4	0.3	0.3	b.d.	b.d.	b.d.
MnO	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.
ZnO	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.
K_2O	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.	15.1	16.5	16.5	2.5	2.2	1.7
Na_2O	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.	0.8	0.8	0.7	2.5	2.0	2.3
Sum	**99.2**	**99.7**	**99.8**	**100.0**	**99.2**	**99.1**	**98.6**	**101.3**	**101.5**	**101.3**	**100.6**	**100.4**	**100.1**
S^{6+}	–	–	–	–	–	–	–	0.006	0.007	0.006	–	–	–
P^{5+}	–	–	0.019	0.016	–	–	–	0.011	0.008	0.012	–	–	–
Si^{4+}	0.989	0.985	0.968	0.973	–	–	–	1.993	1.988	1.983	–	–	–
Ti^{4+}	–	–	–	–	0.003	0.002	0.002	–	–	0.005	–	–	–
Al^{3+}	–	–	–	–	0.002	0.004	–	1.020	1.010	1.014	–	–	–
Ca^{2+}	0.052	0.058	0.584	0.481	–	–	–	–	0.007	0.009	–	–	–
Fe^{2+}	1.843	1.860	1.432	1.524	0.991	0.989	0.995	0.061	0.049	0.035	–	–	–
Mg^{2+}	0.127	0.112	–	0.011	–	–	–	0.019	0.017	0.017	–	–	–
K^{+}	–	–	–	–	–	–	–	0.667	0.734	0.736	–	–	–
Na^{+}	–	–	–	–	–	–	–	0.056	0.056	0.050	–	–	–
Catsum	**3.011**	**3.015**	**3.003**	**3.004**	**0.996**	**0.996**	**0.998**	**3.831**	**3.875**	**3.867**	**–**	**–**	**–**

Tab. 8. Selected EDS analysis of phases from sample P324/75. The apfu values are calculated based on 4 oxygen for olivine, 6 oxygen for leucite and 1 oxygen for wüstite. B.d. – below the limit of detection.

Tab. 8. *Vybrané EDS analýzy fází ze vzorku P324/75. Hodnoty apfu jsou vypočteny na základě 4 kyslíků pro olivín, 6 kyslíků pro leucit a 1 kyslík pro wüstit. B.d. – pod mezí detekce.*

An. N.	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
Phase	**Ol**	**Ol**	**Ol**	**Ol**	**Ol**	**Ol**	**Wüs**	**Wüs**	**Phos**	**Phos**	**Phos**	**Phos**	**Phos**
SO_3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	b.d.	b.d.	b.d.	b.d.	b.d.
$P2O_5$	1.3	2.2	1.3	1.1	0.7	3.2	b.d.	b.d.	45.0	38.4	37.7	42.1	41.8
SiO_2	27.2	26.8	27.5	27.6	28.0	26.1	b.d.	0.2	0.5	1.8	2.3	0.7	0.6
TiO_2	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.	1.2	1.2	0.8	0.6
Al_2O_3	b.d.	0.2	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.	0.2	b.d.	0.3	b.d.	b.d.
Cr_2O_3	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.
CaO	0.2	0.3	0.3	0.2	0.2	0.3	b.d.	b.d.	43.9	7.8	7.4	20.9	20.7
FeO	68.9	68.9	69.6	69.1	69.7	69.0	98.5	97.3	8.9	42.5	42.0	34.1	33.4
MgO	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.	0.2	b.d.
MnO	1.6	1.5	1.5	1.7	1.7	1.4	0.3	0.3	0.3	1.6	1.3	2.3	2.3
ZnO	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.
K_2O	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.	0.6	4.6	5.9	0.2	b.d.
Na_2O	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.	1.5	1.4	1.4	b.d.	b.d.
Sum	**99.2**	**99.8**	**100.1**	**99.7**	**100.4**	**99.9**	**98.8**	**97.8**	**101.0**	**99.3**	**99.5**	**101.1**	**99.4**
P	0.038	0.063	0.036	0.033	0.021	0.092	–	–	–	–	–	–	–
Si	0.936	0.910	0.936	0.943	0.954	0.882	–	0.002	–	–	–	–	–
Al	–	0.008	–	–	–	–	–	–	–	–	–	–	–
Ca	0.007	0.010	0.011	0.007	0.007	0.010	–	–	–	–	–	–	–
Fe	1.980	1.960	1.983	1.976	1.983	1.955	0.997	0.992	–	–	–	–	–
Mn	0.047	0.042	0.044	0.048	0.050	0.040	0.003	0.003	–	–	–	–	–
Catsum	**3.008**	**2.992**	**3.010**	**3.007**	**3.015**	**2.980**	**1.000**	**0.998**	**–**	**–**	**–**	**–**	**–**

Tab. 9. Selected EDS analysis of phases from the sample 594-571/82; P1836/82. The apfu values are calculated based on 4 oxygen for olivine and 1 oxygen for wüstite. B.d. – below the limit of detection.

Tab. 9. *Vybrané EDS analýzy fází ze vzorku 594-571/82; P1836/82. Hodnoty apfu jsou vypočteny na základě 4 kyslíků pro olivín a 1 kyslíku pro wüstit. B.d. – pod mezí detekce.*

a more homogeneous microstructure (Tab. 9; Fig. 8). Moreover, olivines are more isometric in shape than tabular or skeletal. One remarkable feature is the significantly high phosphorus pentoxide (5.44 wt. % P_2O_5) and manganese (II)-oxide (1.6 wt. % of MnO) content in sample 594-571/82; P1836/82 (Tab. 10). The enrichment in P_2O_5 can is a strong sign for the smelting of phosphorus-rich bog ores.

The morphology of iron smelting slags however stands in contrast to the ones of other contemporaneous reduction slags, which are typically constituted of much more delicate and dendritic tap slags and porous, rusty hearth slags with many charcoal inclusions (Serneels 1993, 108–112; Hauptmann 2020, 236–237).

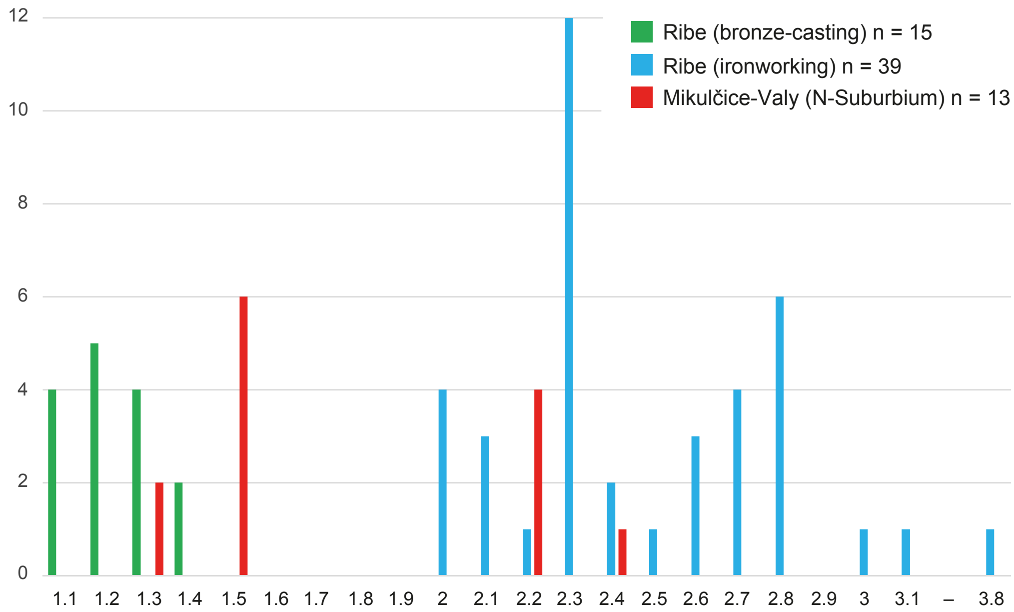
Technical ceramics constitute 4.4 kg (Tab. 1). The first type is of sherd-like appearance, on 13 occasions with partially

Sample	594-357/72; K877/72	594-386/74; K153/74	594-465/74; P1096/74	P324/75	594-571/82; P1836/82
SO_3	0.033	0.026	0.055	0.023	0.026
P_2O_5	0.797	0.605	1.249	0.450	5.439
SiO_2	28.58	17.61	24.05	28.42	23.65
TiO_2	0.137	0.108	0.190	0.253	0.123
Al_2O_3	4.528	3.313	4.04	4.088	2.19
FeO	57.374	72.592	62.378	56.186	59.894
CaO	4.643	1.016	2.123	3.831	1.54
MgO	0.392	0.145	0.330	1.828	0.049
MnO	0.111	0.317	0.111	0.041	1.598
K_2O	2.657	0.805	1.22	1.337	0.686
Na_2O	0.268	0.231	0.449	0.359	0.231
Sum	**99.519**	**96.768**	**96.195**	**96.815**	**95.426**

Ag (ppm)	b.d.	b.d.	b.d.	b.d.	b.d.
As	29	21	27	15	17
Ba	26	160	150	b.d.	3010
Cd	b.d.	b.d.	b.d.	b.d.	b.d.
Co	57.6	69.23	57.26	52.91	55.04
Cu	198.7	404.9	80.8	46.1	36.7
Ni	44.2	62.2	28.3	39.4	14.2
Sb	7.7	b.d.	b.d.	7.8	8.68
Sn	7.137	7.622	7.478	7.283	7.451
Sr	98.39	50.2	68.7	89.34	97.6
Zn	b.d.	b.d.	b.d.	b.d.	11

Tab. 10. Bulk chemical composition of the studied slags. Oxides are in wt. %, trace elements are in ppm; b.d. – below the limit of detection.

Tab. 10. *Objemové chemické složení studovaných strusek. Oxidy jsou uvedeny v hmotnostních procentech, stopové prvky v ppm; b.d. – pod mezí detekce.*



Graph 4. Comparison between tuyère brick fragments with measurable inner diameter of the nozzle from Viking Age Ribe (Denmark) and Mikulčice-Valy in cm.

Graf 4. *Srovnání fragmentů dyznové cihly s měřitelným vnitřním průměrem trysky z vikingského Ribe (Dánsko) a Mikulčice-Valy v cm.*

preserved nozzles (Fig. 9: 1–6). This type represents remains of tuyère bricks for protecting the bellows from sparks and heat from the hearth. Identical debris are known from several Early Medieval sites in Central Europe and Scandinavia (Schoknecht 1977, 155; Roesdahl 1977, 45, 61–62; Westphalen 1989, 74–80; Senn-Luder 1997, 36; Brinch Madsen 2004, 187–188; Pleiner 2006, 132–133).

Caused by varying atmospheric conditions and temperatures, the front surface facing the hearth interior appears ochreous to greenish-black and glazed. The outer surface is beige, smoothly transitioning to reddish-orange colours around the blowhole (Fig. 9: 1, 4–6). In some cases, straight-lined vitrified clay was identified on top of PCBs (Fig. 2: 8–9). This proves that the tuyère brick front protruded inside the fire-pit and formed in contact with the slag mass. The nozzle must have been situated only several centimetres above the lower edge of the tuyère brick (for a similar observation, see Schäfer 2013, 300).

The inner diameter of the nozzles can be divided into two groups of either ca 1.3–1.5 cm or 2.2–2.4 cm if measured at the outer surface facing away from the hearth (Tab. 11). Similar results from Viking Age Ribe show, that this is no arbitrariness, for instance from measuring two sides of one and the same conical nozzle. In Ribe, the narrower type of nozzle with a diameter between 1.1–1.4 cm is associated exclusively with bronze-casting, while the wider type around 2–3.8 cm is related to ironworking (see Graph 4; Brinch Madsen 1984, 30; 2004, 192; for a similar observation in Viking Age Hedeby, yet without data, see Drescher 1983, 184). The northern suburbium yielded the highest concentration of crucibles in the Mikulčice-Valy settlement agglomeration (Poláček, Krupičková 2020, 188–189, Fig. 107)

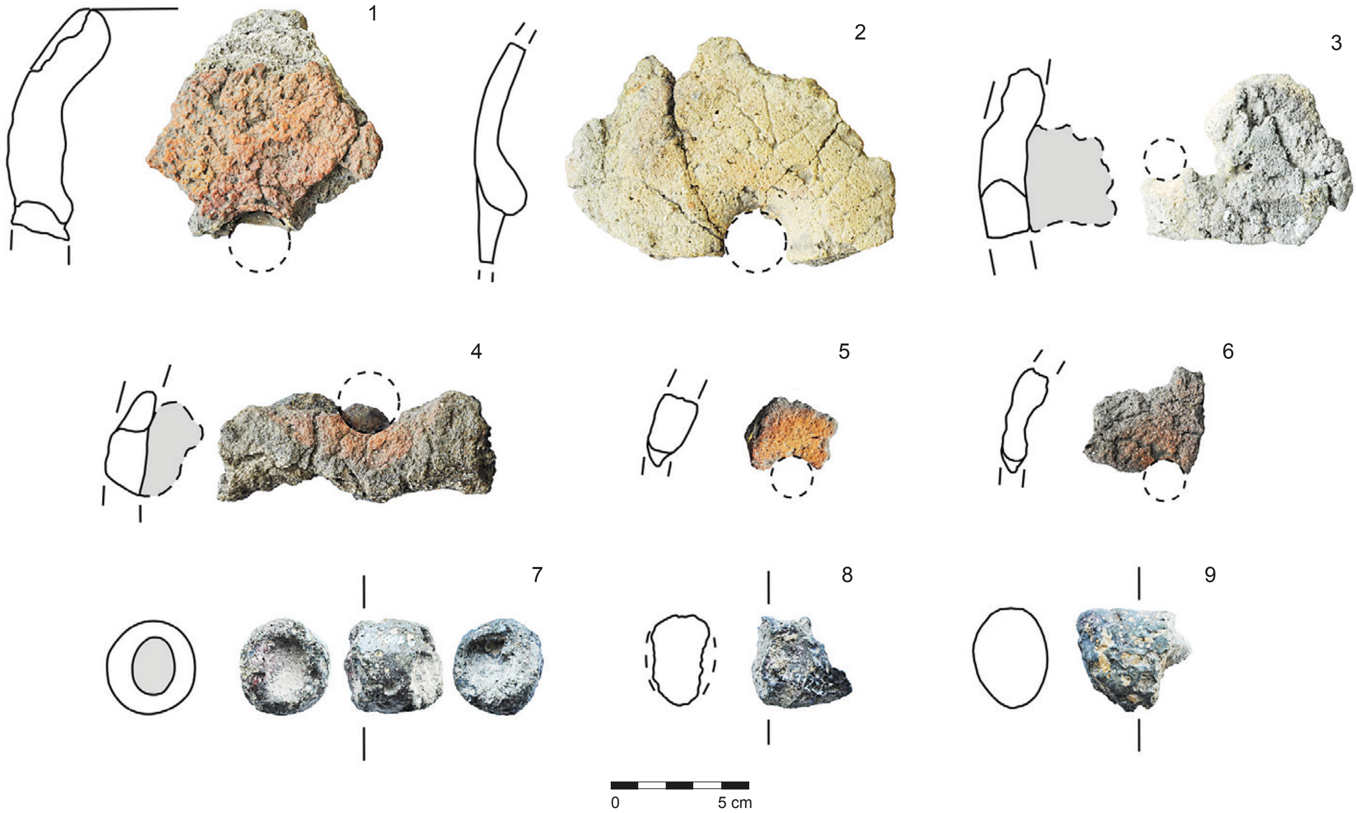


Fig. 9. Selection of technical ceramics from the northern suburbium of the Mikulčice-Valy settlement agglomeration. 1, 2, 4 – Tuyère brick fragments with large nozzles; 3, 5, 6 – tuyère brick fragments with small nozzles; 7 – tubular tuyere(?); 8, 9 – clay plugs. Photo and drawing by M. Lebsak.

***Obr. 9.** Výběr technické keramiky ze severního suburbia sídelní aglomerace Mikulčice-Valy. 1, 2, 4 – Zlomky dyznové cihly s velkými nálevkami; 3, 5, 6 – zlomky dyznové cihly s malými nálevkami; 7 – trubkovitá dyzna(?); 8, 9 – hliněné zátky. Foto a kresba M. Lebsak.*

Inv. No.	Square	Season	Tuyère diameter (cm)
P1435/82	−15/−27	P 1981-82	2.4
K935/72	−8/−23	K 1972-III	2.2
720/74	−18/−31	P 1974-II	2.2
P58/81	−12/−24	P 1981-82	2.2
P1751/81	−14/−25	P 1981-82	2.2
P1045/74	−20/−29	P 1974-II	1.5
P723/74	−18/−31	P 1974-II	1.5
P321/75	−15/−23	P 1975-76	1.5
P1146/81	−18/−23	P 1981-82	1.5
P3072/81	−18/−23	P 1981-82	1.5
P4/81	−13/−24	P 1981-82	1.5
P367/75	−14/−22	P 1975-76	1.3
P1993/81	−14/−25	P 1981-82	1.3

Tab. 11. Overview of tuyère brick fragments from Mikulčice-Valy with measurable inner diameter of the nozzle.

***Tab. 11.** Přehled fragmentů dyznových cihel z Mikulčic-Valů s měřitelným vnitřním průměrem trysky.*

and non-ferrous metal working therefore was undoubtedly conducted in this area. However, such a technical differentiation between tuyères types, or ultimately types of bellows, cannot yet be proven archaeologically in our case, but neither can it be refuted a priori.

Tuyère bricks have a wall thickness between 0.7–2.8 cm. It is unclear if this represents the original state or the final stage after intensive wear (Gustafsson 2009, 258; Jentgens 2009, 45). Due to the degree of fragmentation, it is not possible to reconstruct the exact shape, height, and length of the tuyère bricks. Analogical material from Scandinavia made of clay and steatite suggests a movable semi-circular disc with a height of 10–15 cm, width of 20–25 cm, and a wall thickness ranging between 1–10 cm with a focus between 3–5 cm (see below Fig. 13; Glob 1959; Resi 1979, 67–72; Westphalen 1989, 74–77, Fig. 25; Brinch Madsen 2004, 187–188). Such portable devices with inserted pairs of concertina bellows are depicted on the mid-11th century AD Ramsund rock carving in Södermanland, Sweden (Fig. 10: 1) and a wooden door panel from the Hyllestad stave church in Norway dated to the 12th century AD (Fig. 10: 3; for dating see Düwel 1988, 134; Roden, Weisgerber 1998). Another interpretative solution is a stationary tuyère as a hypothetical combination of a clay superstructure system with the hearth lining, as can be seen on a depiction of the Carolingian 9th century AD Stuttgart Psalter (Fig. 10: 2; see also Senn-Luder 1997, 31, Fig. 10, 36; Eschenlohr et al. 2007, 31, Fig. 32). In this case, the archaeological remains clearly constitute the vitrified outer surface of the tuyère installation.

The second type of bellows protection is represented by a small heavily sintered tubular clay tuyère with a diameter of 3.1 × 3.4 cm and a deformed inner width of approximately 1.5 × 2.1 cm (Fig. 9: 7). Although tubular tuyères have been in some cases attributed to blacksmithing hearths (Galuška 1992, 152, Fig. 17: 9; Senn-Luder 1997, 32; Pleiner 2000, 206), the majority, at least in Central European Medieval contexts, relates to iron smelting in embanked or free-standing shaft furnaces (e.g. Souchopová 1986; Kempa 2003, 28–29, Fig. 15). The relation between the tubular tuyère and the sparse proof of smelting slags remains unclear. Due to its deformed condition and relatively small size, even an attribution as a partially molten crucible or clay plug cannot be ruled out.

Fig. 10. Depiction of tuyère bricks, bellows, and ironworking hearths in Medieval iconography. 1 – Ramsund rock carving, Sweden (11th c. AD); 2 – Stuttgarter Psalter, Germany (9th c. AD); 3 – Hyllestad church, Norway (12th c. AD). After Nordisk familjebok (1), Württembergische Digitale Bibliothek (2), Riksantikvaren (3). Adapted by M. Lebsak.

***Obr. 10.** Vyobrazení dyznových cihel, měchů a železářských ohnišť ve středověké ikonografii. 1 – Skalní rytina v Ramsundu, Švédsko (11. století); 2 – Stuttgartský žaltář, Německo (9. století); 3 – kostel Hyllestad, Norsko (12. století). Podle Nordisk familjebok (1) a Württembergische Digitale Bibliothek (2), Riksantikvaren (3). Upravil M. Lebsak.*

The third type of technical ceramics is represented by two cylindric, vitrified clay plugs with a length of about 3.5 cm and an oval profile (Fig. 9: 8, 9). Both appear to be fragmented on one end. Identical objects are known from Viking Age Hedeby and Ribe, however without a clearly assigned function (Westphalen 1989, 20; 100, Tab. 6: 1–3; Brinch Madsen 2004, 201). More recent studies from Anglo-Scandinavian contexts suggest a connection with copper brazing, more specifically for joining or soldering the components of padlocks, or iron bells, in clay wrappings (Ottaway, Rogers 2002, 2863; Gustaffson 2005). In this case, plugs are to be interpreted as remnants of wrapping closures (Söderberg 2008, 166–167; 2014, esp. 23, Fig. 2a). As Mikulčice-Valy yielded indirect evidence for padlocks in form of at least two keys (Klíma 1980, 66, Fig. 29, 83–85) and iron bells (Poláček 2003, 630–632), a brazing-related interpretation of the clay stumps should be taken in consideration.

Ceramic slags consist of 11.6 kg of irregular, partially glazed frothy debris generally representing overheated silicates, for instance from the lining or cladding of hearths and furnaces. Ceramic slag is not a direct indicator for ironworking, as it also appears as a by-product of metal casting or pottery production (Brinch Madsen 1984, 30–31; Hauptmann 2020, 245–246). In the context presented here, however, the connection to production-related pyrometallurgical installations is very likely. Therefore, ceramic slag and tuyères bricks are seen both as remnants of hearths and counted together as one single unit termed ‘hearth parts’.

4.2 Debris distribution and workshop identification

Identifying on-site spatial distribution of debris is a standard method to locate production concentrations and to differentiate *chaîne opératoire* stages (Costin 1991, 18–25; 2001, 294; Eschenlohr et al. 2007, 131). Based on the ideal basic assumption that a PCB represents the result of one work unit, the total slag mass is to be seen as a guide value for the minimum production volume of a workshop (Serneels, Perret 2003, 472–473). Recall,

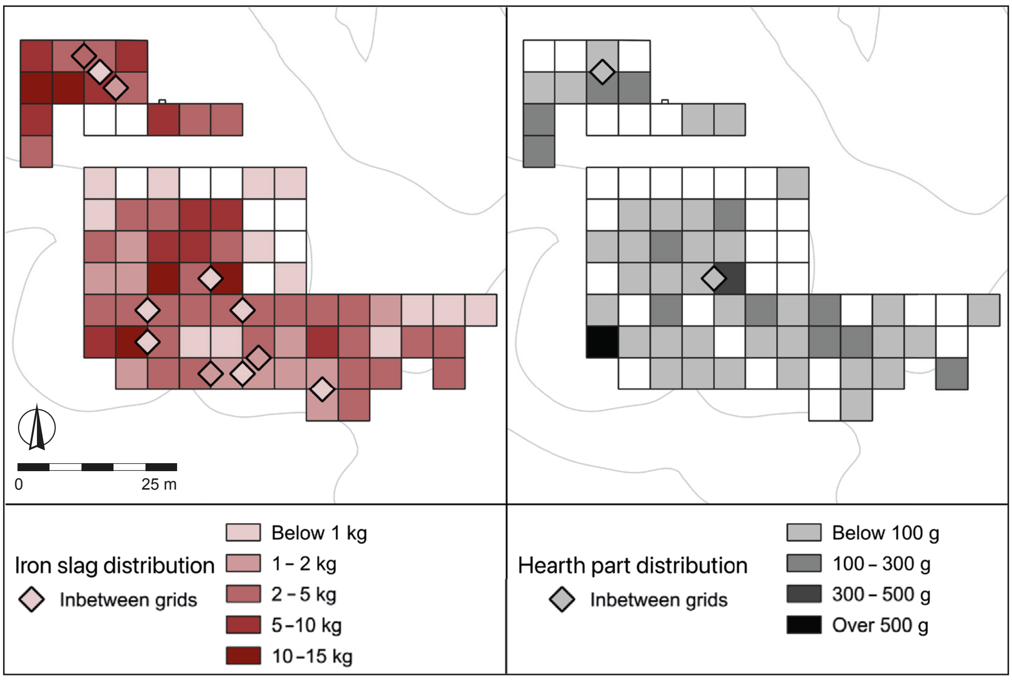


Fig. 11. Iron slag and hearth part distribution per grid in the northern suburbium of the Mikulčice-Valy settlement agglomeration. Graphic by M. Lebsak.

***Obr. 11.** Rozložení železářské strusky a výpalků na síti ze severního suburbia sídelní aglomerace Mikulčice-Valy. Grafika M. Lebsak.*

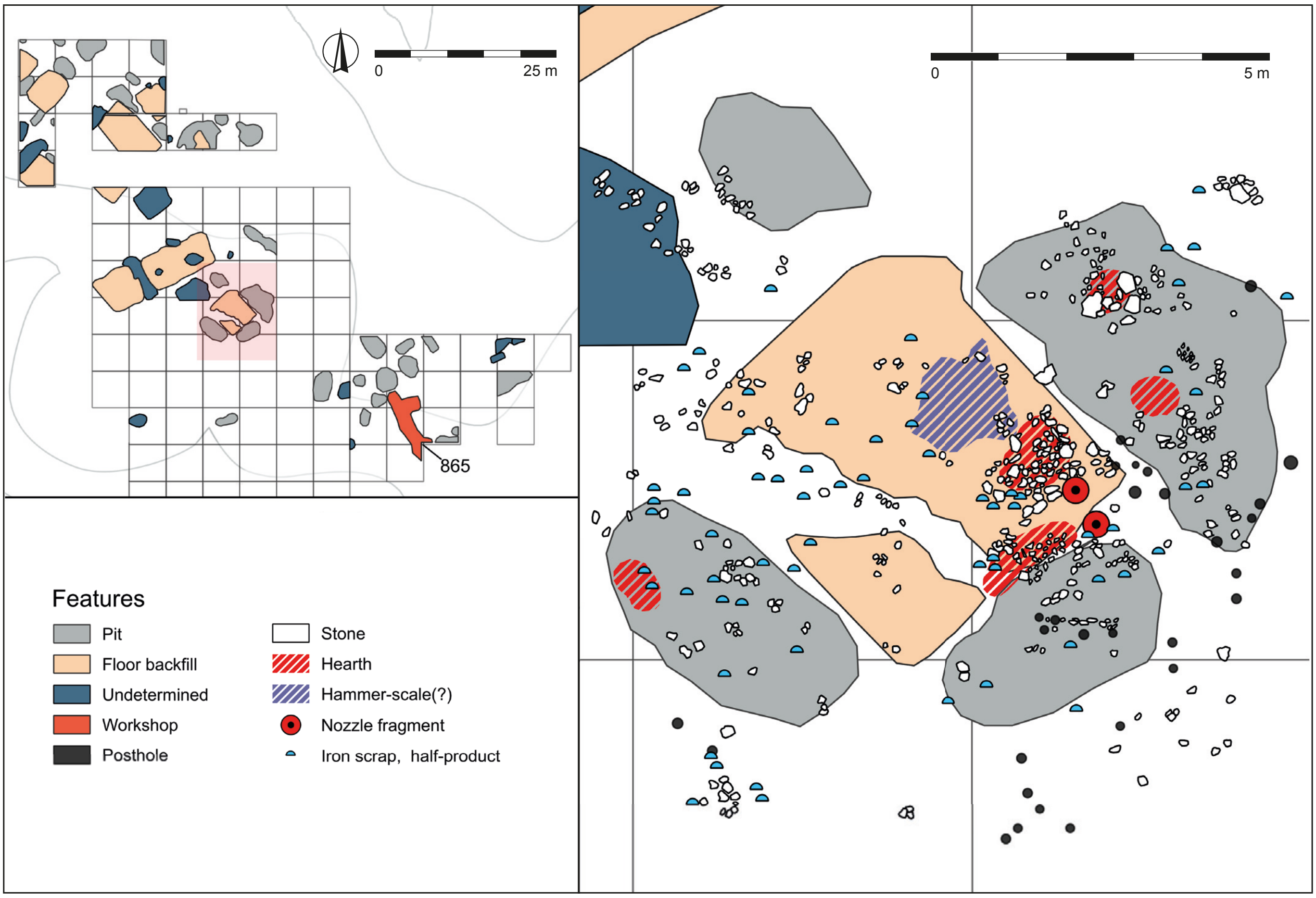


Fig. 12. Overview of the excavated settlement features and possible workshops in the northern suburbium of the Mikulčice-Valy settlement agglomeration. After Klíma 1985, 431, Fig. 2; adaption and graphic by M. Lebsak.

Obr. 12. *Přehled odkrytých sídlištních objektů a možných dílen ze severního suburbia sídelní aglomerace Mikulčice-Valy. Podle Klíma 1985, 431, obr. 2; úprava a grafika M. Lebsak.*

however, that secondary relocation, for instance caused by terrain levelling or specific disposal strategies, is a considerable site formation factor that might lead to an arbitrary distribution and hence a false identification of production areas (Costin 1991, 19; 2001, 294–295; Westphalen 1989, 52–53; Röber 2008, 109; Schäfer 2013, 324; Herdick 2015, 330). In our case, 287.5 kg of pyrometallurgical waste was accumulated on an area of 2000 m^2. The distribution of ironworking debris according to weight per grid shows a congruence between iron slags and hearth fragments in the central part of P 1981-82, in the western part of P 1975-76 and P 1974-I, as well as unevenly in the entire area of P 1974-II (Fig. 11). Such spatial correlations between slags and hearth parts have been observed elsewhere and mentioned as a stark indicator for blacksmithing production loci, although more solid evidence is the combination with pyrometallurgical features (Westphalen 1989, 42, 53; Serneels 2003, 207; Eschenlohr et al. 2007, 131–156, 170; Schäfer 2013, 318).

The Early Medieval archaeological record reveals a heterogeneous range of hearths explicitly connected with blacksmithing, but their constructions might vary significantly in detail and should be verified in case of doubt (Pleiner 2006, 123–131; Röber 2008, 109). Albeit ideal and exemplary workshops therefore do not exist, the minimum requirements for smithing operations are a fire pit, bellows for metal heating and an anvil (e.g. Gassmann 2004, 75; Pleiner 2006, 123).

Four ground-level fire pits or potential hearths with ashy infills, of which at least three may have been enclosed or technically constructed with sandstone slabs and partially situated in sunken features, were reported for the central part of excavation P 1981-82 and correlate with the distribution of slags, hearth fragments, potential hammer-scale concentrations and iron failures or scrap (Fig. 12). Another documented feature is a sandy-clayish floor backfill, partially intermixed with charcoal fragments, which extends between the sunken features. Floor backfills are characteristic for the Mikulčice-Valy settlement agglomeration and considered to be remnants of above-ground buildings (Poulík 1961, 83–85; Mazuch 2020). The archaeological evidence supports the interpretation of the hearths as blacksmith installations, or production residues specifically. However, reconstructions lack clear archaeological evidence, whether in form of a free-standing log cabin (Klíma 1985, 431, Fig. 2) or the possible secondary usage of material extraction pits as separate sunken workshops. It is therefore not possible to give a clear spatial definition of production units or workshops as cohesive entities.

Feature 865 excavated during campaign P 1971-I, by contrast, can be related to craft production based on a verifiable and revised excavation report (Mazuch 2008b). It consists of a ditch-like pit with its southern part bordering an old branch of the River Morava and pairs of post-holes arranged alongside (Fig. 12). The feature contained 26 crucibles, bronze casting debris, several bronze and lead objects as well as a pair of tongs (Tejral 1975, 46; Poláček, Marek 2005, 218–221; Mazuch 2008b, 16, 24–29, 38; 2019, 187). Also noticeable is a considerable concentration of ironworking slags in that area (Fig. 13). Elongated sunken workshop pits with attested blacksmithing are known from other contemporaneous archaeological contexts, such as from the craft-related area Lesní školka in the Břeclav-Pohansko settlement agglomeration, Czech Republic (Dostál 1993, 38–40, Fig. 5: 3; Eschenlohr et al. 2007, 130–132) and in the outer bailey of the royal palace of Tilleda, Saxony-Anhalt, Germany (Grimm 1990, 54–58, Fig. 45–47).

A problem remains the discrepancy between the archaeologists' expectation to reveal in situ preserved, permanent workshop installations, and the excavated metallurgical remains with their inherent potential for *chaîne opératoire* reconstruction (Gustaffson 2011, 99; Callmer 2020, 39). The finds presented here and elsewhere (Westphalen 1989, 74–80; Fig. 26: 3; Schäfer 2013, 312–314) suggest a hearth consisting of a shallow, clay-lined fire pit at ground level with at least a diameter of 10–20 cm and a depth of minimum 5 cm (Fig. 13). Blacksmithing and metal casting therefore must have been executed in squatting or kneeling positions. The air supply was ensured with a bellows made of perishable materials (e.g. Roden, Weisgerber 1998), protected with a refractory tuyère brick made of clay.

Such flexible, non-durable workshop installations are known from different ethnographical sources (e.g. Soulignac, Serneels 2013, 120) and are by its very nature heavily prone to taphonomic processes and destruction by deliberate clean-ups and spatial relocations, leaving no or barely recognizable traces in the archaeological record. Site abandonment strategies are also to be considered for the common absence of the predominantly portable workshop equipment. Stationary anvils, for instance, could have been made of wood and stone and therefore remain undistinguishable from ecofacts.

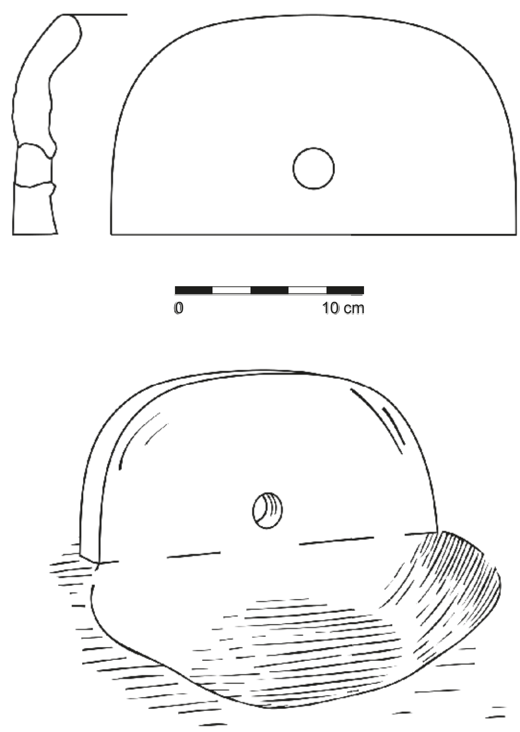


Fig. 13. Possible reconstruction of a ground-level hearth with a clay tuyère brick of semi-circular shape. Partially after Hrubý 1965, 135, Fig. 52. Drawing by M. Lebsak.

Obr. 13. *Možná rekonstrukce přízemního ohniště s dyznovou cihlou půlkruhového tvaru. Částečně podle Hrubý 1965, 135, obr. 52. Kresba M. Lebsak.*

5. Discussion

5.1 Specialisation and the context of production

The results have shown that slags and pyrometallurgical debris in Mikulčice-Valy are predominantly associated with iron processing or blacksmithing, indicating the existence of a production nucleus in the northern suburbium. In what follows, we aim to discuss the organisation of this production, specifically addressing the degree of specialisation as deduced from the archaeological context. We presume that high debris quantities alone do not necessarily equate to large-scale and high-output production, nor are they a reliable indicator of craft specialisation.

Our definition of specialisation as a specific form of production organisation is not based on stereotypical, history-based assumptions on Medieval craftmanship, but on the simple and universal idea postulated by Cathy Costin (2001, 276; also 2005, 1062–1063; Clark 1995), that 'the organization of [specialised] production is variable across space, time, and personnel and that the specialist produces more of some goods than he or she personally uses'. Central to this definition is therefore the reciprocal exchange relationship between producers and consumers, with the latter being in a relative majority. Other possible proxy evidence for craft specialisation are standardisation, proficiency, and technological complexity, as well as a general regularisation and differentiation of production (Costin 1991, 33–43; 2005, 1064–1069).

The descriptive approach to craft specialisation considers production parameters such as spatial organisation (concentration), the organisation and size of production units (scale), the amount of time invested in production (intensity) and the political-economic relations (context) between producers and elites, including the actual objects and how they are produced (Costin 2005, 1038–1039). It is thus necessary to pinpoint our archaeological data within those parameter axes from a regional to intra-site perspective to approach ironworking specialisation in the Mikulčice-Valy settlement agglomeration.

In terms of the spatial organisation on a regional level, Mikulčice-Valy represents a blacksmithing production centre, at least in the context of its waste output. The distribution of blacksmithing debris is noticeably uneven and differential on a regional scale, showing a gradient from rural to proto-urban settlements. Only the latter, such as the Břeclav-Pohansko agglomeration, yielded qualitatively comparable waste assemblages (Tab. 3).

Small-scale blacksmithing slag quantities, on the contrary, can be observed in rural sites with adequately published data, such as Brno-Modřice and Bořitov (Beran et al. 2013, 29; Mikulec et al. 2022) and the satellite settlements of the Mikulčice-Valy hinterland, although clear quantities are not provided for the latter two (Fig. 1: 3; Mazuch 2008a; Hladík et al. 2022, 115, 132).

The relative nucleation of artisans in the settlement agglomeration can be seen when the total slag mass is cautiously equated with the minimum production volume and the aggregation of individual producers (see Chapter 3.2). Such a regional concentration can be explained by the producers' desire to be close to formal marketplaces and therefore to consumers and access to raw materials (Costin 1991, 14–15; also Hirth 1998, 453).

On an intra-site scale, the concentration of 287.5 kg of pyrometallurgical debris on an area of 0.2 ha in the northern suburbium very likely represents a nucleated craft activity zone or a cluster of workshops. However, a more even distribution of debris in the whole agglomeration cannot be ruled out in advance. Since only approximately one-third to one-half of the pyrometallurgical debris from the entire site has been evaluated so far, there is no reason to assume that the northern suburbium represented a singular blacksmithing area.

Dispersed concentrations of different craft activities are known from the Břeclav-Pohansko settlement agglomeration, in particular from the areas Lesní hrúd and Lesní školka, which are ca 370 m apart (Macháček et al. 2007, esp. 176). The latter yielded three ferrous and non-ferrous metalworking activity zones or workshop clusters about 70–80 m apart on an area of 1.9 ha, different (half)products, tools, and 137.5 kg of blacksmithing slags (Tab. 3; Macháček et al. 2007, esp. 176–177). In the 1.6 ha U Víta area of the Staré Město (Uherské Hradiště District) settlement agglomeration, a cluster of 10 precious metal workshops is situated just 30 m away from two potential blacksmithies (Galuška 1989, 407–408, Fig. 2; 1992, esp. 125, Fig. 2). The mapping of pyrometallurgical debris as surface finds in the Viking Age proto-town of Hedeby shows a similar picture. Although scattered over the entire surveyed area, three notable concentrations of blacksmithing slags can be observed in the peripheral areas near the semicircular fortification northwest and south of the settlement (Westphalen 1989, 29, 36, 52–54, 81).

Intra-site concentration or quarterisation of craftsmakers, also of different artisans simultaneously in one place, tends to be connected with emerging urbanity (Costin 2001, 295), especially in High and Late Medieval contexts (Christophersen 2015, 121; Müller 2020, 115–117). In order to avoid too historical references, the dispersed concentration of craft activities within proto-urban communities can also be seen as part of an emergent microscale 'crafting landscape', likely with different organisational components and varying forms of specialisation (Erb-Satullo 2022, 568–569.). Besides the intra-community concentration of craft activities and possible clustering of workshops, the size and internal organisation of production units, or the scale of production, is hardly identifiable due to the missing or poorly interpretable archaeological record.

Moreover, it remains unknown, for instance, if production was family-based and performed in the domestic space or how workers were eventually recruited (Costin 1991, 15–16, 29–30; 2001, 296–297).

The intensity of production, or amount of time (part-time, full-time, seasonal) invested in craftmaking, cannot solely depend on waste quantity or intra-site concentrations. It is even unclear whether craft-related activities in the northern suburbium belong to a single short event or cover the entire proposed occupation phase between the second half of the 9th and early 10th centuries AD (see also Herdick 2015, 330; Kerbler 2019, 206). Therefore, intensity is best approached by carefully considering the debris output and the full spectrum of economic activities carried out, especially when dealing with potential household-based production (Costin 1991, 30–32). Our evaluation of the pyrometallurgical material has shown that it almost completely derives from the processing of iron, or blacksmithing production and repair in particular. Scattered iron scrap and fragments or half-products of knives, arrowheads, axes, fittings, scythes, and other implements near the slag concentrations provide insight into the potential range of finished products (Klíma 1985, 439–440, Fig. 7, 8), although their relation to the ironworking workshops is only presumable. According to metallographic analysis of selected iron artefacts from different areas of the Mikulčice-Valy site, the technological and artistic skills required for their production are manifold (e.g. Pleiner 2006, 53–70). Standardised, probably mass-produced implements like nails and rhomboid arrowheads require few steps of plastic deformation and thus relatively little specialist knowledge (Pleiner 1967, 98–99, 107, Fig. 18). In contrast, specialised tools and battle axes require up to 16 steps of plastic deformation in combination with complex heat-treating operations such as carburisation, quench-hardening and welding of iron and hardenable steel (Pleiner 1967, 98–99, 102, Fig. 17; 2006, 210). A special role is played by objects like scissors, augers, or complex knives, which, due to relatively simple forging operations but advanced heat-treating techniques, are potentially to be regarded as outcomes of extensive production by specialised blacksmiths (Pleiner 1967, 98–99, 107, Fig. 18). It has been argued that routinised production and the production of technically sophisticated objects requiring high skill levels tends to be full-time (Costin 1991, 16–17). Smith's tools that could provide an insight into the *chaîne opératoire* are known in small numbers from the entire site but are still unpublished.

Besides blacksmithing, basic household activities and the archaeologically scarcely traceable production of wood and antler also need to be taken into consideration (Mazuch 2019, 176–177, 185–186). Another evidenced craft in the northern suburbium is the processing of non-ferrous metals. Ferrous and non-ferrous metalworking exhibit a coherence regarding debris concentration, although the overall distribution of crucibles or casting debris requires thorough revision (Poláček, Krupičková 2020, 188–189, Fig. 107). There is nevertheless strong evidence to suggest that both crafts were performed in tandem by the same individuals or at least in spatially very close relation, maybe even in the same workshops, as stated above. The close spatial relation of ferrous and non-ferrous metalworking also has been attested for production loci in the in Scandinavian early towns such as Ribe, Birka, Kaupang, and Hedeby (Callmer 2020, 39–40), prompting scrutiny on unilinear concepts of narrow craft specialisations in Early Medieval peripheral regions as proposed in older literature (e.g. Chropovský 1983, 138, 158–159). The comparably high distribution of iron scythes in the northern suburbium has been brought forward as an indirect evidence of animal husbandry (Poláček 2003, 643–644; Poláček et al. 2019, 453, 469; Mazuch 2019, 177–178). However, its organisational relation to ironworking remains unclear and must be ruled out as evidence for potential part-time work of craft producers. There is evidence to assume that individuals in the northern surburbium were not only primarily engaged in blacksmithing, but also in non-ferrous metalworking, basic household activities, and possibly other crafts like wood or antler-working.

The context of production is a concept that designates the political-economic relationship and dependence between producers and institutions, which can range fluently between independent and attached. Such relationships have a considerable impact on the goods produced and are subject to different forms of demand. Attached systems are defined by the existence of political institutions and their motivation to access prestige goods for the mainly full-time reproduction of social hierarchical orders through variable forms of control over producers, their production, and the distribution of their final goods (Brumfiel, Earle 1987, 5; Clark, Parry 1990, 298; Costin 1991, 11; 2001, 297–300; Earle 1997, 73; Sinopoli 2003, 32–35; Schortman, Urban 2004, 188, Tab. 1).

Especially for the region discussed here and its narrative of a 'Great Moravian' political entity, emerging elites have been emphasised for their potential mobilisation of crafted valuables and influence on commerce. Such ideas, for instance, range from patronised production and redistribution of fine-metal jewellery (Hlavica, Procházka 2020a, 78; Ungerman 2020, 180), bottlenecking of long-distance trade (Poláček 2007; Štefan 2011, 342), to more drastic forms of control, like the direct restriction of non-elites from participating in local market-exchange (Macháček 2021, 39–40; or simply the non-existence of local markets, see Štefan 2011, 343).

There is a growing body of evidence suggesting that iron was in significant demand for the creation and maintenance of hierarchies, distribution of wealth, and the exertion of political control. The production and monopolisation of arms and other military gear made of iron were preconditions for predatory behaviour and are typically mentioned proxies for the identification of status validation (e.g. Earle 1997, 105–110). Swords, for instance, were not only desired as symbols of authoritative dominance *per excellence* (Chropovský 1983, 134; Košta, Hošek 2014, 294–296; Košta 2020, 244), but also because they represent technical hypertrophies, whose value derives from both intense labour expenditure and high production costs (Clark, Parry 1990, 293). Similar high-status objects are luxuriously decorated iron spurs and associated riding gear (Kouřil 2020). The hoarding of iron implements, which constitute a distinctive archaeological phenomenon in Early Medieval south-eastern Europe including the region discussed here, was moreover emphasised as acting a crucial part in the accumulation of wealth and social investment of elite actors (Curta 2011; Macháček, Müllerová 2022, 287–290). Largely known from hoard contexts and mostly discarded in settlement agglomerations are so called axe-shaped ingots (e.g. Pleiner 1961). More recently, they have been attributed as monetary tokens used in commercial market-transactions and issued as well as guaranteed by elite institutions (Hlavica, Bárta 2021; Hlavica et al. 2022, 329–330. The controlled or attached production of iron high-status valuables in higher-order sites like the Mikulčice-Valy settlement agglomeration is therefore probable but hardly provable. Non-commercial attached production of this kind was, despite being highly specialised, very likely of low output and intensity with relatively low demand, leaving little or no noticeable ironworking debris in the archaeological record.

Independent specialised production, by contrast, is noncentralised and determined by demand from an unspecified group of consumers, while the distribution of commodities is not restricted nor directly controlled by political institutions. The production spectrum of independent specialists ideally consists of utilitarian commodities that are indispensable for subsistence and consumable by a large part of society (e.g. Brumfiel, Earle 1987, 5; Sinopoli 1988, 582; Costin 1991, 11; 2001, 298–299). The archaeological record of Mikulčice-Valy indeed yielded a manifold range of iron products of utilitarian nature, covering the entire economic spectrum of Early Medieval labour types expected in a densely crowded settlement, from basic household equipment and implements for agriculture and animal husbandry to sophisticated, highly specialised craft-related tools (Klanica 1974; Klíma 1980; Poláček 2000; 2003; Mazuch 2003). Recall that iron tools are prone to wear and need to be repaired or replaced frequently. Experimental use-wear analysis and ethnographic sources suggest that especially the repair and replacement of agricultural implements like ploughs and scythes stimulated the demand of raw iron and engendered an economic interdependence between individuals engaged in farming activities and specialised ironworkers (e.g. Mothander et al. 1989, 130–150; Lerche 1994; Karlsson 2015, 267–268). Agriculture indeed played a substantial role not only in the rural satellite settlements of Mikulčice but also partially in its suburbia (Poláček et al. 2019, 468–469). It is evident that such a socio-technical entanglement and interdependence also existed with other artisans, or intensive consumers of iron implements respectively. Therefore, it should be argued that the demand for the above-stated utilitarian commodities must have been high and stable, potentially stimulating a large-scale production output by specialised full-time ironworkers.

Large-scale production of commodities must have caused a high demand for resources and therefore required a steady, easily accessible supply of iron and charcoal. The Mikulčice-Valy settlement has not yet yielded convincing indicators for iron smelting, nor charcoal burning pits or anthracological data from metallurgical contexts. Few of the reduction slags introduced here from the northern suburbium can be interpreted as remnants of iron smelting on an insignificant scale, or more likely as flux or even relocated material (Gassmann 2004, 72; Eschenlohr et al. 2007, 66). In fact, this observation is valid for nearly all studied settlement agglomerations or hillforts in Moravia and Slovakia. The exceptional evidence for iron smelting in two cases stems from excavations in Staré Město and its hinterland, Czech Republic (Hrubý 1965, 308–319; Galuška 2001, 131), as well as Pobedim, Slovakia (Vendtová 1969, 217–219, 230–231). The necessity of importing iron to large settlements with evidence of intensive iron processing, yet without any traces of smelting, is moreover known from Viking Age Hedeby and Ribe (Westphalen 1989, 58–67; Brinch Madsen 2004, 220–221).

Only a few extramural iron smelting sites are known from the closer Moravian-Slovakian region for the discussed timeframe, and fewer have been evidenced by thorough archaeological excavations (Fig. 14). For instance, large-scale iron smelting with rows of furnaces in operation has been archaeologically attested for the Jurassic-Cretaceous Rudice formation in the Czech Moravian Karst and constitutes the most important source of its

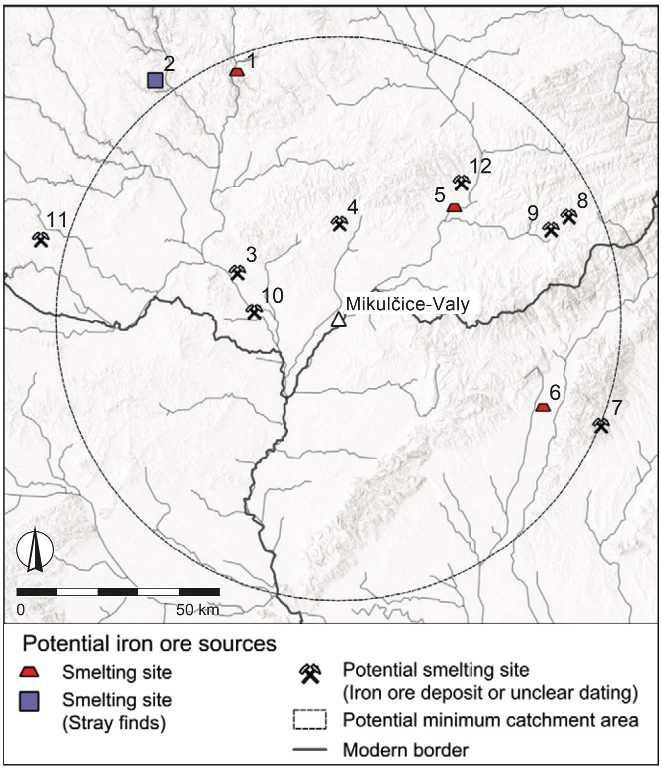


Fig. 14. Smelting sites and potential iron our sources within a catchment area of a radius of 70 km around the Mikulčice-Valy settlement agglomeration. 1 – Moravian Karst (Souchopová 1986); 2 – Brno-Lažánky (Merta, Hlavica 2022); 3 – Šakvice-Pasohlávky (Tišnovský 2012); 4 – Babí lom u Strážovic (Poláček 2008); 5 – Staré Město near Uherské Hradiště (Hrubý 1965; Galuška 2001); 6 – Pobedim (Vendtová 1969); 7 – Považský Inovec (Kohút 2015); 8 – Rudimov-Slavičín (Galuška 2008); 9 – Rudice-Bojkovice (Galuška 2008); 10 – Lednice (Merta 2000); 11 – Znojmo area (Urbanová 2014); 12 – Kudlovice (Galuška 2008). Graphic by M. Lebsak.

Obr. 14. *Hutě a potenciální zdroje železa ve spádové oblasti o poloměru 70 km kolem sídelní aglomerace Mikulčice-Valy. 1 – Moravský kras (Souchopová 1986); 2 – Brno-Lažánky (Merta, Hlavica 2022); 3 – Šakvice-Pasohlávky (Tišnovský 2012); 4 – Babí lom u Strážovic (Poláček 2008); 5 – Staré Město u Uherského Hradiště (Hrubý 1965; Galuška 2001); 6 – Pobedim (Vendtová 1969); 7 – Považský Inovec (Kohút 2015); 8 – Rudimov-Slavičín (Galuška 2008); 9 – Rudice-Bojkovice (Galuška 2008); 10 – Lednice (Merta 2000); 11 – Znojemsko (Urbanová 2014); 12 – Kudlovice (Galuška 2008). Grafika M. Lebsak.*

kind in the discussed region (Souchopová 1986). The datable or potential mining sites are situated within a catchment of approximately 70 km around the Mikulčice-Valy settlement agglomeration, although the distribution of iron from more remote sites or the unverified usage of local bog ores cannot be excluded.

Iron could have been distributed in form of split blooms, of which few are attested to be scattered in the settlement (Merta 2019, 11; Merta et al. 2022), but also indirectly as finished products and scrap. Commercial ingots or stock bars have not been clearly distinguished in the archaeological record yet, if we exclude the main purpose of axe-shaped bars from this context. Given the fact that recycling of metals was a common economic behaviour in many Early Medieval societies (Pleiner 2006, 59; Schwab, Senn 2008; Disser et al. 2016, 159), objects could easily have been made up of a heterogenous material from different sources. Thus, unilinear mechanisms of raw material import, for instance from one specific iron ore deposit, are highly questionable (Pleiner 1967, 101–103). The economic mechanism behind the distribution of iron was probably not unilinear either. There is evidence suggesting that elites controlled the access to local ore deposits as possibly reflected by the noticeable relative spatial proximity between iron smelting loci and high-order sites like hillforts (Měřínský 2014b, 208; Merta, Hlavica 2022; Ruttkay 2014, 258; see also Costin 2001, 299). It has been suggested that the attachment to local elites enabled a relatively uncontrolled circulation of products via local markets (Hlavica 2023, 37, 88), which was moreover mandatory for the supply of a presumed specialised large-scale production with raw materials.

In summary, the descriptive approach connecting our results with production parameters shows that large-scale, specialised blacksmithing it not only nucleated on a regional scale and limited to settlement agglomerations, but also shows signs of potential quarterisation with other craft activities inside proto-urban settlements. While the internal organisation and size of production units remains unknown, the intensity of production can be approached more holistically. The analysis of the pyrometallurgical waste shows that blacksmithing and repair of simple and standardised as well as highly sophisticated iron objects requiring different skill levels was the predominant activity in the northern suburbium. However, also non-ferrous metalworking and household subsistence were part of the production system. Since iron smelting in Mikulčice-Valy has not been yet convincingly proven, the supply of raw materials had to be guaranteed by imports from outside. The production of high-status objects is potentially connected with full-time, attached craftsmen, while the supply with everyday commodities tends to be linked with the production sphere of independent, more dispersed specialists.

5.2 The proto-urban blacksmith

The fact that even the production of utilitarian commodities was carried out by attached craftsmen embedded in strict top-down political economy, and basic subsistence goods like bucket fittings of knives were allocated and raw materials subjected to calculated redistribution, can only be believed if one accepts the picture of the Early Middle Ages drawn by *Annaliste* historians like Georgy Duby in the 1960s, namely as an 'early type of desolate socialist command economy' (Meier 2011, 286). Therefore, a more heterarchical model must be sought for our case that considers bottom-up solution making and the possible autonomy of non-elite commodity producers (Schortman, Urban 2004, 195–199) and involves their access and relation to local or regional market exchange.

According to the so called adaptationist model of specialisation, it is predicted that independent, large-scale producing specialists can develop in urbanized milieus, under increased population densities, with accessibility to distribution flows and stable regional markets. In this context, craft specialisation is not forcefully imposed by political institutions, but facilitated by protection and access to socio-economic privileges (Brumfield, Earle 1987, 2, 5–6 also Costin 1991, 12; Earle 1997, 68). The political integration in such centralised milieus moreover allows specialists to interact with a heterogenous network of consumers, producers, and distributors, while still partaking in innovation and competition and maintaining independence through relative social distance to predatory elites (Sinopoli 1988, 581–582; Oka, Kusimba 2008, 361–363). Recently, the interrelation between urbanisation and craft specialisation was also pointedly articulated for proto-towns in Viking Age Anglo-Scandinavia, emphasizing craft as an emergent urban feature over elite patronage or sponsorship (Ashby, Sindbæk 2020, esp. 21).

As predicted by the adaptationist model, the Mikulčice-Valy case indeed shows political-economic preconditions potentially encouraging the emergence of 'urban' independent specialised production. The existence of a local market and the stable inflow of raw material, a high number of potential consumers, and relative peace and certain securities provided by a local institution formed a nexus within the 'urban organism' (Poláček 2020b, 139) which allowed producers to develop economically and most importantly to produce full-time and large-scale without the direct interference of elites. Since we do not know the exact social obligations and degrees of control exerted on producers, which must have been unequal and could change dynamically, we should in our case therefore not speak about independent, but centralised production as a locational or relational phenomenon (Sinopoli 1988, 581; 2003, 33–34). It should also be proposed that a large part of centralised production was, by its very nature, commercial or demand-oriented, respectively, and large-scale, because it ensured the supply of basic household commodities and substantial working equipment for a majority of the populace. It is very likely that such socio-economic interdependences and mutual obligations as a consequence of centralisation directly fostered relationships within proto-urban communities and especially among craftsmen in particular (Croix et al. 2019; Ashby, Sindbæk 2020, 10; esp. Christophersen 2015, 121).

In summary, there is direct and indirect evidence to propose a preliminary blacksmithing production model for the 'Great Moravian' sphere of influence (Fig. 15), in which largely independent, large-scale centralised production with a high output of consumption commodities is set in relation to high pyrometallurgical waste quantities, of course only in ideal cases of preservation and archaeologically recognizable deposition strategies, which are fairly rare. The supply of raw iron is exclusively market based. This mode of production organisation is confined to proto-urban settlement agglomerations.

In contrast, noncentralised blacksmithing in rural or peripheral areas, where neither attachment nor centralisation exist as organisational forms, is mainly confined to subsistence or only to little extent market based. Part-time or seasonal production is manufacturing of simple commodities or tool maintenance. The output is low, and iron can been smelted simultaneously. The autonomy of production is comparably high, but the degree of independence can vary depending on the context.

Elite-sponsored production of exclusive valuables is noncommercial by nature and most probably of low output, yet of high intensity and control. It is to be localised in the sphere of influence of the elites, for example in higher-order settlement agglomerations or hillforts.

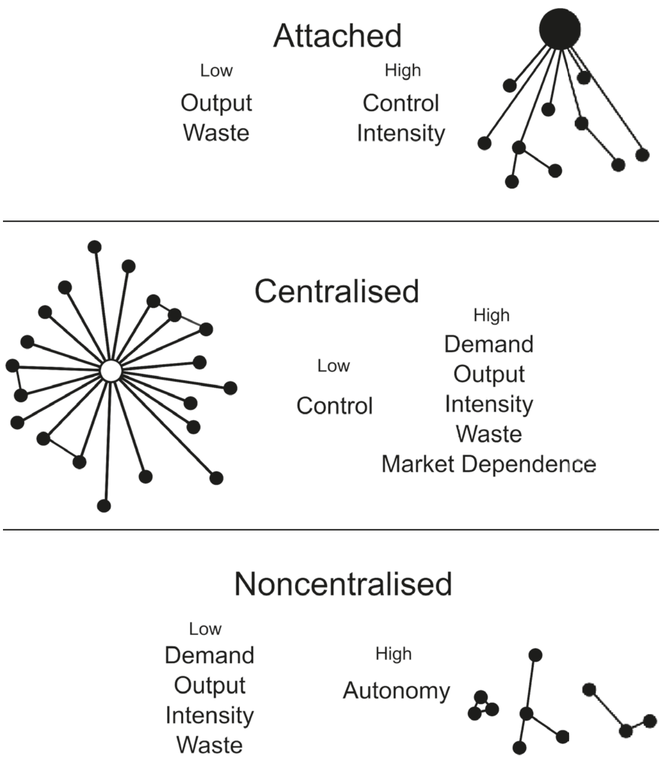


Fig. 15. Ideal model of blacksmith production as deduced from the Mikulčice-Valy case study. Centralised production in settlement agglomerations is characterised by high-intensity, output, market dependence and comparably low control by elites. Non-centralised production in rural or peripheral areas is comparably independent, but low regarding output and intensity, as it is probably practised part-time or seasonal. Attached or elite sponsored production in higher-order sites creates prestige goods and shows a high degree of intensity and control. It is non-commercial. Graphics by M. Lebsak.

***Obr. 15.** Ideální model kovářské výroby odvozený z případové studie Mikulčice-Valy. Centralizovaná výroba v sídelních aglomeracích se vyznačuje vysokou intenzitou, produkcí, závislostí na trhu a poměrně nízkou kontrolou ze strany elit. Nestředisková výroba ve venkovských nebo periferních oblastech je srovnatelně nezávislá, ale nízká, pokud jde o produkci a intenzitu, protože je pravděpodobně provozována na částečný úvazek, nebo sezónně. Připojená nebo elitou sponzorovaná výroba v lokalitách vyššího řádu vytváří prestižní zboží a vykazuje vysoký stupeň intenzity a kontroly. Je nekomerční. Grafika M. Lebsak.*

The latter two types therefore ideally leave comparably low quantities of production waste, if not accumulated over time. It should be noticed that such production modes are neither static nor exclusive, monolithic typologies. Rather, they describe relations between individuals and groups, producers, and consumers, which can exist simultaneously and develop, vary, or change, in response to dynamic economic and social factors. Therefore, in the case of Mikulčice-Valy, attached and centralised modes of production organisation could have existed simultaneously and successively, with the latter being hypothetically the economic majority. Satellite settlements in close proximity of the agglomeration probably already were independent regarding their iron economy. However, this model needs to be tested in the future on similar proto-urban production loci and compared with rural sites in detail.

6. Conclusion

The study presented here analysed and reviewed nearly 300 kg of pyrometallurgical remnants from the northern suburbium of the Early Medieval Mikulčice-Valy settlement agglomeration, particularly slags and technical ceramic fragments. The material evidence was contextualised with inquiries regarding craft specialisation and socio-economic relations in proto-urban environments.

Using macroscopic and microscopic methods (SEM-EDS, WD-XRF), four types of debris were distinguished: ironworking slag, smelting slag, technical ceramics, and ceramic slag. Ironworking slag constitutes the majority of the debris, and its spatial distribution evidently marks a production locus within the extramural settlement in connection to both permanent and highly mobile workshop installations.

However, a high quantity of ironworking debris does not, by itself, serve as evidence for either the degree of craft specialisation or as a reliable proxy for the production output level. In discussing the archaeological evidence within a broader range of specialisation parameters, we considered the regional and intraspatial debris concentration, the production intensity, and especially the context of production, or the relationship between elite sponsorship and autonomy, respectively. The confrontation of those parameters with an adaptationist specialisation model suggests that independent, large-scale production of commodities emerged due to the site's urbanised characteristics, such as high population density, steady demand for iron implements, and access to regional markets for raw materials. This form of centralised craft specialisation is not or only loosely attached to political institutions. Therefore, we assume that specialised craft production shaped early urbanised milieus as a bottom-up driver of socioeconomic interdependencies between producers and consumers, encompassing both elite and non-elite actors. However, this model needs to be tested on comparable archaeological sites.

While our analysis shed light on possible degrees of craft specialisation in proto-urban environments, a more holistic understanding of the dynamics of the Early Medieval iron economy requires continued interdisciplinary research. In this context, the application of methodological tenets such as on-site documentation of slags and sieving for hammer-scales, along with future provenance studies considering ores and iron objects, is inevitable.

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References

Ashby, S. P., Sindbæk, S. M. 2020: Crafting the urban network. In: S. P. Ashby, S. M. Sindbæk (eds.): *Crafts and social networks in Viking towns*. Oxford, Havertown: Oxbow Books, 1–29.

Baumhauer, M. 2003: *Archäologische Studie zu ausgewählten Aspekten der mittelalterlichen Handwerkstopographie im deutschsprachigen Raum. Bestandsaufnahme der Handwerksbefunde vom 6.-14. Jahrhundert und vergleichende Analyse* [online]. Manuscript of the dissertation. Eberhard Karls Universität, Tübingen. Philosophische Fakultät. Stored in: TOBIAS-lib – Publikationen und Dissertationen [Accessed 2024-06-19]. Available from: https://publikationen.uni-tuebingen.de/xmlui/handle/10900/46233.

Beran, V., Hajnalová, M., Kos, P., Lisá, L., Parma, D. 2013: Geoarcheologický výzkum raně středověké kovárny z Modřic u Brna. *Živá archeologie. (Re)konstrukce a experiment v archeologii* 15(2), 25–31. Available also from: https://uni.uhk.cz/zivaarcheologie/index.php/ziva/article/view/153/140.

Borzová, Z., Pieta, K., Jakubčinová, M. 2020: *Bojná 3. Poľnohospodárske náradie z hradiska valy a jeho zázemia*. Archaeologica Slovaca Monographiae XXIX. Nitra: Archeologický ústav SAV.

Brather, S. 2008: *Archäologie der westlichen Slawen. Siedlung, Wirtschaft und Gesellschaft im früh- und hochmittelalterlichen Ostmitteleuropa*. 2. überarbeitete und erweiterte Auflage. Ergänzungsbände zum Reallexikon der Germanischen Altertumskunde 61. Berlin, New York: Walter de Gruyter. DOI: 10.1515/9783110209952.

Brinch Madsen, H. 1984: Metal-casting. Techniques, production and workshops. In: M. Bencard (ed.): *Ribe Excavations 1970-76. Volume 2*. Esbjerg: Sydjysk Universitetsforlag, 25–189.

Brinch Madsen, H. 2004: Smithing Debris. In: M. Bencard et al. (eds.): *Ribe Excavations 1970-76. Volume 5*. Højbjerg, Aarhus: Jutland Archaeological Society, University Press, 187–222.

Brumfiel, E. M., Earle, T. K. 1987: Specialization, exchange and complex societies. An introduction. In: E. M. Brumfiel, T. K. Earle (eds.): *Specialization, exchange and complex societies*. New directions in archaeology. Cambridge: University Press, 1–9.

Callmer, J. 2020: Craft. Some pragmatic notes on the study of craft production and craftspeople in early medieval northern Europe. In: S. P. Ashby, S. M. Sindbæk (eds.): *Crafts and social networks in Viking towns*. Oxford, Havertown: Oxbow Books, 31–49.

Cech, B., Walach, G. 1998: Feldmethoden zur Bestimmung historischer Schmiedeschlacken. Methodik und erste Ergebnisse. *Archäologie Österreichs* 9(2), 72–78.

Christophersen, A. 2015: Performing towns. Steps towards an understanding of medieval urban communities as social practice. *Archaeological Dialogues* 22(2), 109–132. DOI: 10.1017/S1380203815000161. Available also from: https://1url.cz/p1i5v.

Chropovský, B. 1983: Zur Problematik der Entstehung und Entfaltung spezialisierter Handwerkszweige in Großmähren. In: H. Jankuhn et al. (Hrsg.): *Das Handwerk in vor- und frühgeschichtlicher Zeit. Teil II – Archäologische und philologische Beiträge. Bericht über die Kolloquien der Kommission für die Altertumskunde Mittel- und Nordeuropas in den Jahren 1977 bis 1980*. Abhandlungen der Akademie der Wissenschaften in Göttingen, Phil.-Hist. Kl. 3, Nr. 123. Göttingen: Vandenhoek & Ruprecht, 120–159.

Clark, J. E. 1995: Craft specialization as an archaeological category. *Research in Economic Anthropology* 16, 267–296.

Clark, J. E., Parry, W. J. 1990: Craft specialization and cultural complexity. *Research in Economic Anthropology* 12, 289–364.

Costin, C. L. 1991: Craft specialization. Issues in defining, documenting, and explaining the organization of production. *Archaeological Method and Theory* 3, 1–56. Available also from: https://www.jstor.org/stable/20170212.

Costin, C. L. 2001: Craft production systems. In: G. M. Feinman, T. D. Price (eds.): *Archaeology at the millennium. A sourcebook*. New York: Springer, 273–327. DOI: 10.1007/978-0-387-72611-3.

Costin, C. L. 2005: Craft Production. In: H. Maschner, C. Chippindale (eds.): *Handbook of Methods in Archaeology*. Lanham: AltaMira, 1032–1105.

Coupland, S. 1990: Carolingian Arms and Armour in the Ninth Century. *Viator. Medieval and Renaissance Studies* 21, 29–50. DOI: 10.1484/J.VIATOR.2.301331. Available also from: https://1url.cz/v1i5y.

Croix, S., Neiß, M., Sindbæk, S. M. 2019: The réseau opératoire of Urbanization. Craft Collaborations and Organization in an Early Medieval Workshop in Ribe, Denmark. *Cambridge Archaeological Journal* 29(2), 345–364. DOI: 10.1017/S0959774318000525. Available also from: https://1url.cz/r1ib1.

Curta, F. 2011: New Remarks on Early Medieval Hoards of lron Implements and Weapons. ln: J. Macháček, Š. Ungerman (Hrsg.): *Frühgeschichtliche Zentralorte in Mitteleuropa. Internationale Konferenz und Kolleg der Alexander von Humboldt-Stiftung zum 50. Jahrestag des Beginns archäologischer Ausgrabungen in Pohansko bei Břeclav 5.–9.10.2009, Břeclav, Tschechische Republik*. Studien zur Archäologie Europas 14. Bonn: Verlag Dr. Rudolf Habelt GmbH, 309–332.

Disser, A., Dillmann, P., Leroy, M., Merluzzo, P., Leroy, S. 2016: The bridge of Dieulouard (Meurthe-et-Moselle, France). A fresh perspective on metal supply strategies in Carolingian economy. *ArcheoSciences* 40(1), 149–161. DOI: 10.4000/archeosciences.4830. Available also from: https://journals.openedition.org/archeosciences/4830.

Dostál, B. 1993: Velkomoravský řemeslnický areál v Břeclavi--Pohansku. *Jižní Morava* 29(32), 31–53. Available also from: https://1url.cz/M1ibU.

Drescher, H. 1983: Metallhandwerk des 8.-11. Jahrhunderts in Haithabu auf Grund der Werkstattabfälle. In: H. Jankuhn et al. (Hrsg.): *Das Handwerk in vor- und frühgeschichtlicher Zeit. Teil II – Archäologische und philologische Beiträge. Bericht über die Kolloquien der Kommission für die Altertumskunde Mittel- und Nordeuropas in den Jahren 1977 bis 1980*. Abhandlungen der Akademie der Wissenschaften in Göttingen, Phil.-Hist. Kl. 3, Nr. 123. Göttingen: Vandenhoek & Ruprecht, 174–192.

Dungworth, D., Wilkes, W. 2009: Understanding Hammerscale. The use of high-speed film and electron microscopy. *Historical Metallurgy* 43(1), 33–46. Available also from: https://www.hmsjournal.org/index.php/home/article/view/177/172.

Dunster, J., Dungworth, D. 2012: *Blacksmiths' Fuel. The analysis of slags from archaeological and contemporary iron-working. Technology Report*. Research report 16. Coalbrookdale: English Heritage, 1–19. DOI: 10.5284/1037501. Available also from: https://1url.cz/H1ib9.

Düwel, K. 1988: On the Sigurd representations in Great Britain and Scandinavia. In: M. A. Jazayery, W. Wintey (eds.): *Languages and Cultures. Studies in honor of Edgar C. Polomé*. Trends in Linguistics. Studies and Monographs 36. Berlin, New York: De Gruyter Mouton, 133–156. DOI: 10.1515/9783110864359.133.

Earle, T. 1997: *How Chiefs Come to Power. The Political Economy in Prehistory*. Stanford: University Press.

Erb-Satullo, N. L. 2022: Towards a Spatial Archaeology of Crafting Landscapes. *Cambridge Archaeological Journal* 32(4), 567–583. DOI: 10.1017/S095977432200004X. Available also from: https://1url.cz/g1i9a.

Eschenlohr, L., Friedli, V., Linder, C. R.-C., Senn, M. 2007: *Develier-Courtételle, un habitat rural mérovingien. 2. Métallurgie du fer et mobilier métallique*. Cahier d'archéologie jurassienne 14. Porrentruy: Office de la culture et Société jurassienne d'Emulation. Available also from: https://doc.rero.ch/record/31761.

Galuška, L. 1989: Výrobní areál velkomoravských klenotníku ze Starého Města-Uherského Hradište. *Památky archeologické* LXXX(2), 405–454. Available also from: https://1url.cz/euFHt.

Galuška, L. 1992: Dvě velkomoravské kovárny s depoty ze Starého Města. *Acta Musei Moraviae, Scentiae sociales* LXXVII(1), 123–161.

Galuška, L. 2001: Staroměstsko-uherskohradišťská aglomerace – vývoj osídlení a přírodní podmínky v 6.–10. století. In: L. Galuška et al. (eds.): *Velká Morava mezi východem a západem. Sborník příspěvků mezinárodní vědecké konference Uherské Hradiště, Staré Město 28. 9.–1. 10. 1999*. Spisy Archeologického ústavu AV ČR Brno 17. Brno: Archeologický ústav AV ČR Brno, 123–137.

Galuška, L. 2008: A contribution to the structure and character of the landscape of the Great Moravian agglomeration Staré Město – Uherské Hradiště. In: L. Poláček (Hrsg.): *Das Wirtschaftliche Hinterland der frühmittelalterlichen Zentren*. Internationale Tagungen in Mikulčice VI. Spisy Archeologického ústavu AV ČR Brno 31. Brno: Archäologisches Institut der Akademie der Wissenschaften der Tschechischen Republik, Brno, 249–256.

Gassmann, G. 2004: Schmiedeabfälle. Aspekte ihrer naturwissenschaftlichen Untersuchung. In: W. Melzer (Hrsg.): *Schmiedehandwerk in Mittelalter und Neuzeit. Beiträge des 6. Kolloquiums des Arbeitskreises zur archäologischen Erforschung des mittelalterlichen Handwerks*. Soester Beiträge zur Archäologie 6. Soest: Mocker & Jahn, 71–80.

Glob, P. V. 1959: Avlsten. Nye typer fra Danmarks jernalder. *Kuml* 9(9), 69–83. Available also from: https://tidsskrift.dk/kuml/article/view/103043/152103.

Grimm, P. 1990: *Tilleda. Eine Königspfalz am Kyffhäuser. Teil 2: Die Vorburg und Zusammenfassung*. Schriften zur Ur- und Frühgeschichte 40. Berlin: Akademie-Verlag.

Gustaffson, N. B. 2005: On Norse padlocks – production and use. Examples from the Birka Garrison. *Journal of Nordic Archaeological Science* 15, 19–24. Available also from: https://1url.cz/C1imz.

Gustaffson, N. B. 2009: Vikingatida blästerskydd av sten och lera från Mälardalen. *Fornvännen* 104(4), 253–261. Available also from: https://www.diva-portal.org/smash/get/diva2:1226456/FULLTEXT01.pdf.

Gustaffson, N. B. 2011: Beyond Wayland – thoughts on early medieval metal workshops in Scandinavia. *Historical Metallurgy* 45(2), 90–101. Available also from: https://hmsjournal.org/index.php/home/article/view/131.

Hauptmann, A. 2020: *Archaeometallurgy. Materials Science Aspects*. Natural science in archaeology 1613–9712. Cham: Springer. DOI: 10.1007/978-3-030-50367-3.

Herdick, M. 2015: *Ökonomie der Eliten. Eine Studie zur Interpretation wirtschaftsarchäologischer Funde und Befunde von mittelalterlichen Herrschaftssitzen*. Monographien des Römisch-Germanischen Zentralmuseums, Band 124. Mainz: Verlag des Römisch-Germanischen Zentralmuseums. DOI: 10.11588/propylaeumdok.00005297. Available also from: https://archiv.ub.uni-heidelberg.de/propylaeumdok/5297/.

Hirth, K. G. 1998: The Distributional Approach. A New Way to Identify Marketplace Exchange in the Archaeological Record. *Current Anthropology* 39(4), 451–476. DOI: 10.1086/204759. Available also from: https://www.journals.uchicago.edu/doi/10.1086/204759.

Hladík, M., Mazuch, M., Látková, M. 2022: *Great Moravian Settlement in Mikulčice-Trapíkov and Economic Hinterland of the Power Centre. Rural Economy, Centres and Organisational and Functional Principles of Great Moravia*. Studien zum Burgwall von Mikulčice XIII. Spisy Archeologického ústavu AV ČR Brno 62. Brno: Czech Academy of Sciences, Institute of Archaeology, Brno. Available also from: https://www.arub.cz/wp-content/uploads/spisy_arub_62_SBM_XIII_web.pdf.

Hlavica, M. 2023: *Fragmenty Velké Moravy. Hrnčířské značky jako nástroj výzkumu společenské a politické komplexity Moravy 9. století*. Spisy Archeologického ústavu AV ČR Brno 75. Brno: Archeologický ústav AV ČR, Brno, v. v. i. DOI: 10.47382/arub2023-05. Available also from: https://www.arub.cz/wp-content/uploads/Spisy_75.pdf.

Hlavica, M., Bárta, P. 2021: The evolution of early medieval Moravian axe-shaped currency bars through the perspective of an archaeological experiment. *Přehled výzkumů* 62(2), 11–21. DOI: 10.47382/pv0622-01. Available also from: https://www.arub.cz/wp-content/uploads/PV-62_2_01.pdf.

Hlavica, M., Kouřil, P., Mikulec, R. 2022: Moravian Iron Money. Model of the 9th-Century Axe-Shaped Bars' Genesis and Its Testing with the Assemblage from Staré Zámky near Brno-Líšeň. *Slovenská archeológia* LXX(2), 327–350. DOI: 10.31577/slovarch.2022.70.14. Available also from: https://archeol.sav.sk/files/SlovArch-70-2-2022_text_na-web.pdf.

Hlavica, M., Procházka, R. 2020a: Basic Principles of the Great Moravian Economy. In: L. Poláček et al.: *Great Moravian Elites From Mikulčice*. Brno: Czech Academy of Sciences, Institute of Archaeology, Brno, 75–78. Available also from: https://www.arub.cz/wp-content/uploads/ARUB_Great_Moravian_Elites_From_Mikulcice_2020.pdf.

Hlavica, M., Procházka, R. 2020b: Market System. In: L. Poláček et al.: *Great Moravian Elites From Mikulčice*. Brno: Czech Academy of Sciences, Institute of Archaeology, Brno, 79–81. Available also from: https://www.arub.cz/wp-content/uploads/ARUB_Great_Moravian_Elites_From_Mikulcice_2020.pdf.

Hlavica, M., Procházka, R. 2020c: Axe-shaped currency bars. In: L. Poláček et al.: *Great Moravian Elites From Mikulčice*. Brno: Czech Academy of Sciences, Institute of Archaeology, Brno, 82–85. Available also from: https://www.arub.cz/wp-content/uploads/ARUB_Great_Moravian_Elites_From_Mikulcice_2020.pdf.

Hrubý, V. 1965: *Staré Město. Velkomoravský Velehrad*. Monumenta archaeologica 14. Praha: Nakladatelství ČSAV.

Janssen, W. 1983: Gewerbliche Produktion des Mittelalters als Wirtschaftsfaktor im ländlichen Raum. In: H. Jankuhn et al. (Hrsg.): *Das Handwerk in vor- und frühgeschichtlicher Zeit. Teil II – Archäologische und philologische Beiträge. Bericht über die Kolloquien der Kommission für die Altertumskunde Mittel- und Nordeuropas in den Jahren 1977 bis 1980*. Abhandlungen der Akademie der Wissenschaften in Göttingen, Phil.-Hist. Kl. 3, Nr. 123. Göttingen: Vandenhoek & Ruprecht, 317–394.

Jentgens, G. 2009: *Von Bauern und Schmieden im Mittelalter. Archäologie im Kreis Steinfurt*. Münster: Landschaftsverband Westfalen-Lippe.

Kalhous, D. 2020: Moravia Under the Mojmirid Dynasty in the 9th Century. In: L. Poláček et al.: *Great Moravian Elites From Mikulčice*. Brno: Czech Academy of Sciences, Institute of Archaeology, Brno, 15–21. Available also from: https://www.arub.cz/wp-content/uploads/ARUB_Great_Moravian_Elites_From_Mikulcice_2020.pdf.

Karlsson, C. 2015: *Förlorat järn. Det medeltida jordbrukets behov och förbrukning av järn och stål*. Jernkontorets Bergshistoriska Skriftserie 49. Acta Universitatis agriculturae Sueciae 38. Stockholm: Jernkontoret. Available from: https://pub.epsilon.slu.se/11435/1/karlsson_c_140415.pdf.

Kempa, M. 2003: Archäologische Untersuchungen an früh- und hochmittelalterlichen Verhüttungsplätzen. In: A. Hauptmann, Ü. Yalçin (Hrsg.): *Abbau und Verhüttung von Eisenerzen im Vorland der mittleren Schwäbischen Alb. Die Eisenproduktion im frühen und hohen Mittelalter. Archäologie, Metallurgie, Landesgeschichte. Internationales Kolloquium am 4.-5. November 1994 in Schwäbisch Gmünd*. Forschungen und Berichte zur Vor- und Frühgeschichte in Baden-Württemberg 86. Stuttgart: Konrad Theiss, 9–116.

Kerbler, L. J. 2019: Eisengewinnung und -verarbeitung auf den mittelalterlichen Burgen Feinfeld und Sachsendorf, Niederösterreich. *Beiträge zur Mittelalterarchäologie in Österreich* 34, 205–224.

Klanica, Z. 1973: Předběžná zpráva o výsledcích devatenácté sezóny výzkumu v Mikulčicích (okr. Hodonín). Vorläufiger Bericht über die Ergebnisse der neunzehnten Grabungssaison in Mikulčice (Bez. Hodonin). *Přehled výzkumů* 1972, 51–53. Available also from: https://www.arub.cz/wp-content/uploads/pv_17_1972.pdf.

Klanica, Z. 1974: *Práce klenotníků na slovanských hradištích*. Studie Archeologického ústavu ČSAV v Brně II(6). Praha: Academia.

Klíma, B. 1980: *Zámečnická práce staromoravských kovářů v Mikulčicích*. Studie Archeologického ústavu ČSAV v Brně VIII(3). Praha: Academia.

Klíma, B. 1985: Velkomoravská kovárna na podhradí v Mikulčicích. *Památky archeologické* LXXVI(2), 428–455. Available also from: https://1url.cz/r1iy7.

Kohút, M. 2015: Geologické predispozície vzniku sídiel pri Bojnej. In: K. Pieta, Z. Robak (eds.): *Bojná 2. Nové výsledky výskumov včasnostredovekých hradísk*. Archaeologica Slovaca Monographiae. Fontes XX. Nitra: Archeologický ústav SAV, 145–151.

Košta, J. 2020: Ninth- and Tenth-Century Swords in Moravia. Weapons, Top Smithery Products and Symbols of Power. In: L. Poláček et al.: *Great Moravian Elites From Mikulčice*. Brno: Czech Academy of Sciences, Institute of Archaeology, Brno, 231–244. Available also from: https://www.arub.cz/wp-content/uploads/ARUB_Great_Moravian_Elites_From_Mikulcice_2020.pdf.

Košta, J., Hošek, J. 2014: *Early Medieval Swords from Mikulčice*. Studien zum Burgwall von Mikulčice X. Spisy Archeologického ústavu AV ČR Brno 42. Brno: Institute of Archaeology of the Academy of Sciences of the Czech Republic, Brno.

Kouřil, P. 2020: Ostentatious Spurs From Mikulčice. In: L. Poláček et al.: *Great Moravian Elites From Mikulčice*. Brno: Czech Academy of Sciences, Institute of Archaeology, Brno, 255–267. Available also from: https://www.arub.cz/wp-content/uploads/ARUB_Great_Moravian_Elites_From_Mikulcice_2020.pdf.

Lerche, G. 1994: *Ploughing implements and tillage practices in Denmark from the Viking period to about 1800. Experimentally substantiated*. The Royal Danish Academy of Sciences and Letters' Commission for Research on the History of Agricultural Implements and Field Structures 8. Herning: Poul Kristensen.

Leroy, M., Cabboï, L., Bauvais, S., Berranger, M., Blaising, J.-M., Boulanger, K., Brkojewtisch, G., Coubel, S., Deffressigne, S., Disser, A., Dunikowski, Ch., Dupont, R., Folzan, M., Frauciel, M., Gazenbeek, M., Georges-Leroy, M., Lagadec, J.-P., Lambert, M.-P., Lorquet, P., Merluzzo, P., Peytremann, É., Prévot, M., Prouteau, R., Riquier-Bouclet, Ch., Séquier, J.-M., Schembri, F., Tikonoff, N. 2019: *Produire et travailler le fer. Les ateliers de l'est du Bassin parisien du ve siècle av. J.-C. au xe siècle apr. J.-C*. Recherches archéologiques 16. Paris: INRAP, CNRS Editions. Available also from: https://hal-inrap.archives-ouvertes.fr/hal-02295821.

Loveluck, C. 2013: *Northwest Europe in the Early Middle Ages, c. AD 600-1150. A comparative archaeology*. Cambridge: Cambridge University Press.

Macháček, J. 2009: Disputes over Great Moravia. Chiefdom or state? the Morava or the Tisza River? *Early Medieval Europe* 17(3), 248–267. Available also from: https://1url.cz/11wMm.

Macháček, J. 2015: O Velké Moravě, archeologii raného středověku i o nás samých. *Archeologické rozhledy* LXVII(3), 464–494. Available also from: https://archeologickerozhledy.cz/index.php/ar/article/view/184/167.

Macháček, J. 2021: Großmähren im neuen Diskurs. Die Suche nach alternativen Erklärungsmodellen. In: S. Albrecht (Hrsg.): *Großmähren und seine Nachbarn*. Forschungen zur Geschichte und Kultur der böhmischen Länder 5. Berlin, Bern, Wien: Peter Lang, 29–58.

Macháček, J., Gregerová, M., Hložek, M., Hošek, J. 2007: Raně středověká kovodělná výroba na Pohansku u Břeclavi. *Památky archeologické* XCVIII, 129–184. Available also from: https://1url.cz/l1w1G.

Macháček, J., Müllerová, M. 2022: Phänomen Hacksilberschätze – die südmitteleuropäische Perspektive. In: F. Biermann et al. (Hrsg): *Frühmittelalterliches Hacksilber im nördlichen westslawischen Raum. Archäologie und Archäometallurgie. Beiträge der internationalen Konferenz im Kulturhistorischen Museum Görlitz 18./19. Oktober 2019*. Studien zur Archäologie Europas 36. Bonn: Dr. Rudolf Habelt, 281–392.

Mazuch, M. 2003: Fischereigerät aus Mikulčice und die Frage des Fischanteils an der Ernährung der Bewohner des Burgwalls. In: L. Poláček (Hrsg.): *Studien zum Burgwall von Mikulčice V*. Spisy Archeologického ústavu AV ČR Brno 21. Brno: Archäologisches Institut der Akademie der Wissenschaften der Tschechischen Republik, Brno, 355–399. Available also from: https://mikulcice.arub.cz/wp-content/uploads/2016/06/SBM5_10_Mazuch.pdf.

Mazuch, M. 2008a: Slovanské sídliště v poloze Mikulčice „Podbřežníky". *Přehled výzkumů* 49, 165–181. Available also from: https://www.arub.cz/prehled-vydanych-cisel/PV49_studie_9.pdf.

Mazuch, M. 2008b: *Mikulčice-Valy (okr. Hodonín). Plocha P 1974 - I (č. 45), areál severní podhradí*. Manuscript of the field report, id. MTX201405470 [2024-06-18]. Stored in: Archive of the Institute of Archaeology of the Czech Academy of Siences, Brno. Available also from: Digital Archive of the Archeological Map of the Czech Republic https://digiarchiv.aiscr.cz/id/M-TX-201405470.

Mazuch, M. 2019: Die Besiedlung im nördlichen Suburbium des Burgwalls von Mikulčice (Grabungsflächen P 1974-II und P 2005). In: L. Poláček (Hrsg.): *Das Suburbium des Burgwalls von Mikulčice*. Studien zum Burgwall von Mikulčice IX. Spisy Archeologického ústavu AV ČR Brno 40. Brno: Archäologisches Institut der Akademie der Wissenschaften der Tschechischen Republik, Brno, 157–238. Available also from: https://www.arub.cz/wp-content/uploads/ARUB_Das_Suburbium_des_Burgwalls_von_-Mikulcice_2019.pdf.

Mazuch, M. 2020: Floor backfills as an evidence of surface buildings. In: L. Poláček et al.: *Great Moravian Elites From Mikulčice*. Brno: Czech Academy of Sciences, Institute of Archaeology, 152–153. Available also from: https://www.arub.cz/wp-content/uploads/ARUB_Great_Moravian_Elites_From_Mikulcice_2020.pdf.

McCormick, M. 2003: *Origins of European Economy. Communication and Commerce, A.D. 300-900*. Cambridge: Cambridge University Press. DOI: 10.1017/CBO9781107050693.

Meier, T. 2011: A farewell to the market. Constructing a Carolingian subsistence economy east of the Rhine. In: J. Klápště, P. Sommer (eds.): *Processing, storage, distribution of food. Food in the medieval rural environment. Ruralia VIII, 7th-12th September 2009, Lorca, Spain*. Turnhout: Brepols, 285–300.

Měřínský, Z. 2012: Die ersten Stadtformationen in der Welt der Slawen mit speziellem Augenmerk auf Großmähren. *Archaeologia historica* 37(1), 7–58. Available also from: https://hdl.handle.net/11222.digilib/128239.

Měřínský, Z. 2014a: Production, crafts and trade in the pre-Great Moravian and Great Moravian periods in Moravia and Silesia. In: P. Kouřil (ed.): *Great Moravia and the Beginnings of Christianity*. Brno: Institute of Archaeology of the Academy of Sciences of the Czech Republic, Brno, 105–131.

Měřínský, Z. 2014b: The Staré Zámky near Brno-Líšeň. In: P. Kouřil (ed.): *Great Moravia and the Beginnings of Christianity*. Brno: Institute of Archaeology of the Academy of Sciences of the Czech Republic, Brno, 200–208.

Merta, J. 2000: Polní náčrt baterie železářských pecí z Lednice (okr. Břeclav). *Archeologia technica* 11, 92–93. Available also from: http://archeologiatechnica.cz/sites/default/files/2019-01/at_11_12.pdf.

Merta, O. 2019: Známé nálezy raně středověkých železářských naseknutých lup z území Moravy. *Archeologia technica* 30, 3–13. Available also from: http://archeologiatechnica.cz/sites/default/files/2020-06/AT_30_2019_03_13_Merta_0.pdf.

Merta, O., Hlavica, M. 2022: Doklady středověkého železářství z Lažánek u Veverské Bítýšky. *Archeologia technica* 33, 21–32. Available also from: http://archeologiatechnica.cz/sites/default/files/2023-03/AT_33_2022_21_32_Merta_Hlavica.pdf.

Merta, O., Hlavica, M., Lebsak, M., Přichystal, M., Mikulec, R. 2022: Známé nálezy raně středověkých železářských naseknutých lup z území Moravy 2. *Archeologia technica* 33, 3–8. Available also from: http://archeologiatechnica.cz/sites/default/files/2023-03/AT_33_2022_03_08_Merta_Hlavica_Lebsak_et_al.pdf.

Mikulec, R., Hlavica, M., Kmošek, M. 2022: Archaeological evidence of independent iron production from the 9th-century rural settlement of Bořitov (Blansko District, Czechia). *Archaeologia historica* 47(2), 763—794. DOI: 10.5817/AH2022-2-14. Available also from: https://digilib.phil.muni.cz/handle/11222.digilib/digilib.76769.

Milo, P. 2014: *Frühmittelalterliche Siedlungen in Mitteleuropa. Eine vergleichende Strukturanalyse durch Archäologie und Geophysik*. Studien zur Archäologie Europas 21. Bonn: Dr. Rudolf Habelt GmbH.

Mittelstädt, K., Himmelmann, U., Berthold, C., Schwab, R. 2022: Slag characterization from the Roman vicus of Eisenberg (Germany). *Archaeological and Anthropological Sciences* 14(8), 155. DOI: 10.1007/s12520-022-01614-2. Available also from: https://link.springer.com/article/10.1007/s12520-022-01614-2.

Mothander, B., Kjærby, F., Havenvik, K. 1989: *Farm implements for small-scale farmers in Tanzania*. Uppsala: Scandinavian Institute of African Studies.

Müller, U. 2020: Medieval Urbanscapes. Observations on the high and late medieval city in the German-speaking regions. *Zeitschrift für Archäologie des Mittelalters* 48, 81–126. Available also from: https://1url.cz/j1wER.

Müllerová, M. 2021: *The theory of early medieval hoards from the area of western and southern Slavs* [online]. Manuscript of the dissertation. Masarykova universita. Filozofická fakulta. Ústav archeologie a muzeologie. Stored in: Archiv závěrečných prací Masarykovy univerzity [Accessed 2024-06-19]. Available from: https://is.muni.cz/th/ix3lf/?studium=467595;lang=en.

Nordisk familjebok: Sigurd.svg [online]. Digitalized version from Nordisk familjebok 1876–1937. In: *Wikimedia commons*. Last edited on 18 July 2024, at 07:54. [Accessed 2024-01-08]. Available from: https://commons.wikimedia.org/wiki/File:Sigurd.svg.

Oka, R., Kusimba, C. M. 2008: The Archaeology of Trading Systems, Part 1. Towards a New Trade Synthesis. *Journal of Archaeological Research* 16(4), 339–395. DOI: 10.1007/s10814-008-9023-5. Available also from: https://www.jstor.org/stable/41053254.

Ottawa, P., Rogers, N. 2002: *Craft, Industry and Everyday Life. Finds from Medieval York*. The Archaeology of York. The Small Finds 17/15. York: Council for British Archaeology. Available also from: https://1url.cz/h1wEO.

Pleiner, R. 1961: Slovanské sekerovité hřivny. *Slovenská archeólogia* IX(1–2), 405–450. Available also from: https://cevnad.sav.sk/aktivita_1_1/slovenska_archeologia_1961_1_2.pdf.

Pleiner, R. 1967: Die Technologie des Schmiedes in der großmährischen Kultur. *Slovenská archeólogia* XV(1), 77–188. Available also from: https://cevnad.sav.sk/aktivita_1_1/slovenska_archeologia_1967_1.pdf.

Pleiner, R. 2000: *Iron in archaeology. The European bloomery smelters*. Praha: Archeologický ústav AV ČR.

Pleiner, R. 2006: *Iron in archaeology. Early European blacksmiths*. Praha: Archeologický ústav AV ČR.

Poláček, L. 2000: Holzbearbeitungswerkzeug aus Mikulčice. In: L. Poláček (Hrsg.): *Studien zum Burgwall von Mikulčice IV*. Spisy Archeologického ústavu AV ČR Brno 18. Brno: Archäologisches Institut der Akademie der Wissenschaften der Tschechischen Republik, Brno, 303–361.

Poláček, L. 2003: Landwirtschaftliche Geräte aus Mikulčice. In: L. Poláček (Hrsg.): *Studien zum Burgwall von Mikulčice V*. Spisy Archeologického ústavu AV ČR Brno 21. Brno: Archäologisches Institut der Akademie der Wissenschaften der Tschechischen Republik, Brno, 591–709.

Poláček, L. 2007: Ninth-century Mikulčice: the "market of the Moravians"? The archaeological evidence of trade in Great Moravia. In: J. Henning (ed.): *Post-Roman Towns, Trade and Settlement in Europe and Byzantium 1. The Heirs of the Roman West*. Millenium Studies 5(1). Berlin: De Gruyter, 499–524. Available also from: https://www.degruyter.com/document/doi/10.1515/9783110218848/html#contents.

Poláček, L. 2008: Das Hinterland des frühmittelalterlichen Zentrums in Mikulčice. Stand und Perspektiven der Forschung. In: L. Poláček (Hrsg.): *Das Wirtschaftliche Hinterland der frühmittelalterlichen Zentren*. Internationale Tagungen in Mikulčice VI. Spisy Archeologického ústavu AV ČR Brno 31. Brno: Archäologisches Institut der Akademie der Wissenschaften der Tschechischen Republik, Brno, 257–297.

Poláček, L. 2019: Das Suburbium des Burgwalls von Mikulčice – grundlegende Charakteristika, Topographie und naturräumliche Bedingungen. In: L. Poláček (Hrsg.): *Das Suburbium des Burgwalls von Mikulčice*. Studien zum Burgwall von Mikulčice IX. Spisy Archeologického ústavu AV ČR Brno 40. Brno: Archäologisches Institut der Akademie der Wissenschaften der Tschechischen Republik, Brno, 9–19. Available also from: https://www.arub.cz/wp-content/uploads/ARUB_Das_Suburbium_des_Burgwalls_von_-Mikulcice_2019.pdf.

Poláček, L. 2020a: Settlement development and Chronological criteria: In: L. Poláček et al.: *Great Moravian Elites From Mikulčice*. Brno: Czech Academy of Sciences, Institute of Archaeology, 114–117. Available also from: https://www.arub.cz/wp-content/uploads/ARUB_Great_Moravian_Elites_From_Mikulcice_2020.pdf.

Poláček, L. 2020b: Princely residence and proto-town. In: L. Poláček et al.: *Great Moravian Elites From Mikulčice*. Brno: Czech Academy of Sciences, Institute of Archaeology, 139–147. Available also from: https://www.arub.cz/wp-content/uploads/ARUB_Great_Moravian_Elites_From_Mikulcice_2020.pdf.

Poláček, L. 2020c: Palace: Excavations in 1957 and 2010. In: L. Poláček et al.: *Great Moravian Elites From Mikulčice*. Brno: Czech Academy of Sciences, Institute of Archaeology, 148–151. Available also from: https://www.arub.cz/wp-content/uploads/ARUB_Great_Moravian_Elites_From_Mikulcice_2020.pdf.

Poláček, L. 2020d: Ecclesiastical Centre and Place of Worship. In: L. Poláček et al.: *Great Moravian Elites From Mikulčice*. Brno: Czech Academy of Sciences, Institute of Archaeology, 163–171. Available also from: https://www.arub.cz/wp-content/uploads/ARUB_Great_Moravian_Elites_From_Mikulcice_2020.pdf.

Poláček, L., Bartošková, A., Mazuch, M., Hladík, M. 2019: Das siedlungsarchäologische Bild des Suburbiums von Mikulčice. In: L. Poláček (Hrsg.): *Das Suburbium des Burgwalls von Mikulčice*. Studien zum Burgwall von Mikulčice IX. Spisy Archeologického ústavu AV ČR Brno 40. Brno: Archäologisches Institut der Akademie der Wissenschaften der Tschechischen Republik, Brno, 437–485.

Poláček, L., Krupičková, Š. 2020: Fine-Metal Workshop Near Church 5. In: L. Poláček et al.: *Great Moravian Elites From Mikulčice*. Brno: Czech Academy of Sciences, Institute of Archaeology, 187–189. Available also from: https://www.arub.cz/wp-content/uploads/ARUB_Great_Moravian_Elites_From_Mikulcice_2020.pdf.

Poláček, L., Marek, O. 2005: Grundlagen zur Topographie des Burgwalls von Mikulčice. Die Grabungsflächen 1964-1992. In: L. Poláček (Hrsg.): *Studien zum Burgwall von Mikulčice VII*. Spisy Archeologického ústavu AV ČR Brno 24. Brno: Archäologisches Institut der Akademie der Wissenschaften der Tschechischen Republik, Brno.

Poulík, J. 1961: Übersicht der Entdeckungen auf dem grossmährischen Burgwalle in Mikulčice im Jahre 1960. *Přehled výzkumů* 1960, 83–86. Available also from: https://www.arub.cz/wp-content/uploads/pv_5_1960.pdf.

Poulík, J. 1975: *Mikulčice. Sídlo a pevnost knížat velkomoravských*. Praha: Academia.

Procházka, R. 2009: *Vývoj opevňovací techniky na Moravě a v českém Slezsku v raném středověku*. Spisy Archeologického ústavu AV ČR Brno 38. Brno: Archeologický ústav AV ČR, Brno, v. v. i. Available also from: https://www.arub.cz/wp-content/uploads/Vyvoj_opevnovaci_techniky_na_Morave_a_v_ceskem_Slezsku_v_ranem_stredoveku.pdf.

Resi, H. G. 1979: *Die Specksteinfunde aus Haithabu*. Berichte über die Ausgrabungen in Haithabu 14. Neumünster: Karl Wachholtz Verlag.

Riksantikvaren: *Norwegian Directorate for Culturage Heritage (Riksantikvaren)*. [Accessed 2024-01-08]. Availabe from: https://kulturminnebilder.ra.no/fotoweb/archives/5022-Foto-fri-bruk-(CC-BY)/RA1/RA1/Topnummer/T201_01/T201_01_0031.tif.info#c=%2Ffotoweb%2Farchives%2F5022-Foto-fri-bruk-%28CC-BY%29%2F%3Fq%3Dhylestad.

Röber, R. 2008: Das mittelalterliche Schmiedehandwerk. Quellensituation und Forschungsstand. In: W. Melzer (Hrsg.): *Archäologie und mittelalterliches Handwerk – Eine Standortbestimmung. Beiträge des 10. Kolloquiums des Arbeitskreises zur archäologischen Erforschung des mittelalterlichen Handwerks*. Soester Beiträge zur Archäologie 9. Soest: Mocker & Jahn. 97–127.

Roden, C., Weisgerber, G. 1998: Gebläse. In: H. Beck et al. (Hrsg.): *Reallexikon der germanischen Altertumskunde 10. Friesen, Otto von – Gelübde.* 2., völlig neu bearbeitet Auflage. Berlin: De Gruyter. 510–513.

Roesdahl, E. 1977: *Fyrkat. En Jysk vikingeborg. II. Oldsageme og gravpladsen*. Nordiske Fortidsminder. Serie B. 4. København: Det Kongelige Nordiske Oldskriftselskab.

Ruttkay, A. T. 2014: Pobedim. In: P. Kouřil (ed.): *Great Moravia and the Beginnings of Christianity*. Brno: Institute of Archaeology of the Academy of Sciences of the Czech Republic, Brno, 257–258.

Schäfer, A. 2013: Zur Eisenverarbeitung auf dem Oppidum von Manching. Schlacken und Herdfragmente der Ausgrabung Altenfeld 1996-1999. In: S. Sievers et al. (Hrsg.): *Ergebnisse der Ausgrabungen in Manching-Altenfeld 1996-1999*. Ausgrabungen in Manching 19(2). Wiesbaden: Reichert Verlag, 295–335.

Schoknecht, U. 1977: *Menzlin. Ein frühgeschichtlicher Handelsplatz an der Peene*. Beiträge zur Ur- und Frühgeschichte der Bezirke Rostock, Schwerin und Neubrandenburg 10. Berlin: VEB Deutscher Verlag der Wissenschaften.

Schortman, E. M., Urban, P. A. 2004: Modeling the Roles of Craft Production in Ancient Political Economies. *Journal of Archaeological Research* 12(2), 185–226. DOI: 10.1023/B:JARE.0000023712.34302.49. Available also from: https://link.springer.com/article/10.1023/B:JARE.0000023712.34302.49.

Schwab, R., Senn, M. 2008: Recycling von Alteisen. *Berliner Beiträge zur Archäometrie* 21, 207–226. Available also from: https://1url.cz/91wGQ.

Selskienė, A. 2007: Examination of smelting and smithing slags formed in bloomery iron-making process. *Chemija* 18(2), 22–29. Available also from: https://mokslozurnalai.lmaleidykla.lt/publ/0235-7216/2007/2/Che_022_028.pdf.

Senn-Luder, M. 1997: Die Weiterverarbeitung von Eisen. Le travail post-réduction du fer. In: Vereinigung des Archäologisch-technischen Grabungspersonals der Schweiz (ed.): *Technique des fouilles. Minerai, scories, fer. Cours d'initiation à l'étude de la métallurgie du fer ancienne et à l'identification des déchets de cette industrie*. Einführungskurs zum Studium der frühen Eisenmetallurgie. 2nd revised edition. Basel: VATG, 29–37.

Serneels, V 1993: *Archéométrie des scories de fer. Recherches sur la sidérurgie ancienne en Suisse occidentale*. Cahiers d'archéologie romande 61. Lausanne: Cahiers d'Archéologie Romande.

Serneels, V. 1995: Du minerai à l'objet. Un village de sidérurgistes du VIIème au XIIème siècle à Liestal Rósernta1 (BL/Suisse). In: M. Schmaedecke (Hrsg.): *Ländliche Siedlungen zwischen Spätantike und Mittelalter. Beiträge zum Kolloquium Liestal 1995*. Archäologie und Museum 33. Liestal: Archäologie und Kantonsmuseum Baselland, 35–43.

Serneels, V. 2003: La sidérurgie sur le site carolingien de Liestal-Röserntal (BL): les vestiges matériels, premiers résutats. In: Th. Engel et al.: *Abbau und Verhüttung von Eisenerzen im Vorland der mittleren Schwäbischen Alb*. Forschungen und Berichte zur Vor- und Frühgeschichte in Baden-Württemberg, Band 86. Stuttgart: Konrad Theiss Verlag, 205–212.

Serneels, V., Perret. S. 2003: Quantification of smithing activities based on investigation of slag and other material remains. In: Associazione italiana di metallurgia (ed.): *Archaeometallurgy in Europe. International conference. 24-25-26 September 2003, Milan, Italy. Proceedings 1*. Milan: Associazione Italiana di Metallurgia, 469–478.

Sinopoli, C. M. 1988: The organization of craft production at Vijayanagara, South India. *American Anthropologist* 90(3), 580–597. Available also from: https://www.jstor.org/stable/678225.

Sinopoli, C. M. 2003: *The Political Economy of Craft Production. Crafting Empire in South India, c. 1350–1650*. Cambridge: University Press. DOI: 10.1017/CBO9780511489648.

Söderberg, A. 2008: Metallurgic clay packages. In: H. Clark, K. Lemm (eds.): *Excavations at Helgö XVII. Workshop Part III*. Stockholm: Kungl. Vitterhets Historie och Antikvitets Akademien, 159–169.

Söderberg, A. 2014: The brazing of iron and the metalsmith as a specialised potter. *The Old Potter's Almanack* 19(2), 23–29. Available also from: https://journals.ub.uni-heidelberg.de/index.php/opa/article/view/18270/12073.

Souchopová, V. 1986: *Hutnictví železa v 8.–11. století na západní Moravě*. Studie Archeologického ústavu ČSAV v Brně XIII(1). Praha: Academia.

Soulignac, R., Serneels, V. 2013: Forging with Dogon smiths (Mali). In: D. Dungworth, R. C. P. Doonan (eds.): *Accidental and Experimental Archaeometallurgy*. London: Historical Metallurgic Society, 119–126.

Sperl, G. 1980: *Über die Typologie urzeitlicher, frühgeschichtlicher und mittelalterlicher Eisenhüttenschlacken*. Studien zur Industrie-Archäologie 7. Wien: Verlag der Österreichischen Akademie der Wissenschaften.

Starley, D., Loveluck, C. 2009: Ironworking debris and manufacturing processes. In: D. H. Evans, C. Loveluck (eds.): *Life and Economy in Early Medieval Flixborough c. AD 600-1000. The Artefact Evidence*. Excavations at Flixborough 2. Oxford: Oxbow, 322–328. DOI: 10.2307/j.ctt1cfr8pw.20.Available also from: https://www.jstor.org/stable/j.ctt1cfr8pw.20?seq=1.

Štefan, I. 2011: Great Moravia, Statehood and Archaeology. The 'Decline and Fall' of One Early Medieval Polity. In: L. Macháček, Š. Ungerman (Hrsg.): *Frühgeschichtliche Zentralorte in Mitteleuropa. Internationale Konferenz und Kolleg der Alexander von Humboldt-Stiftung zum 50. Jahrestag des Beginns archäologischer Ausgrabungen in Pohansko bei Břeclav 5.–9.10.2009, Břeclav, Tschechische Republik*. Studien zur Archäologie Europas 14. Bonn: Verlag Dr. Rudolf Habelt GmbH, 333–354.

Tejral, J. 1975: Vorbericht über die Ergebnisse der einundzwanzigsten Grabungssaison in Mikulčice (Bez. Hodonín). *Přehled výzkumů* 1974, 46. Available also from: https://www.arub.cz/wp-content/uploads/pv_19_1974.pdf.

Tišnovský, J. 2012: *Oxid-hydroxidová mineralizace v sedimentech u Pasohlávek* [online]. Manuscript of the thesis. Masarykova univerzita. Přírodovědecká fakulta. Ústav geologických věd. Stored in: Archiv závěrečných prací Masarykovy univerzity [Accessed 2024-06-19]. Available from: https://is.muni.cz/th/ng59h/.

Ungerman, Š. 2020: Specialised craft production. In: L. Poláček et al: *Great Moravian Elites From Mikulčice*. Brno: Czech Academy of Sciences, Institute of Archaeology, 179–186. Available also from: https://www.arub.cz/wp-content/uploads/ARUB_Great_Moravian_Elites_From_Mikulcice_2020.pdf.

Urbanová, S. 2014: *Fe-mineralizace v geologických jednotkách okolí Znojma* [online]. Manuscript of the thesis. Masarykova univerzita. Přírodovědecká fakulta. Ústav geologických věd. Stored in: Archiv závěrečných prací Masarykovy univerzity [Accessed 2024-06-19]. Available from: https://is.muni.cz/th/tgby1/.

Vendtová, V. 1969: Slovanské osídlenie Pobedima a okolia. *Slovenská archeológia* XVII(1), 119–232. Available also from: https://cevnad.sav.sk/aktivita_1_1/slovenska_archeologia_1969_1.pdf.

Verhulst, A. E. 2002: *The Carolingian Economy*. Cambridge medieval textbooks. Cambridge: University Press. DOI: 10.1017/CBO9780511817083. Available also from: https://www.cambridge.org/core/books/carolingian-economy/BD0A5C21D952CA5CACEE83291991DAC7.

Westphalen, P. 1989: *Die Eisenschlacken von Haithabu. Ein Beitrag zur Geschichte des Schmiedehandwerks in Nordeuropa*. Bericht über die Ausgrabungen in Haithabu 26. Neumünster: Karl Wachholtz Verlag.

Westphalen, P. 2002: *Die Eisenfunde von Haithabu*. Die Ausgrabungen in Haithabu 10. Neumünster: Karl Wachholtz Verlag.

Württembergische Digitale Bibliothek: Stuttgarter Psalter. Cod.bibl. fol. 23 [online]. In: *Württembergische Digitale Bibliothek*. © 2024 [Accessed 2024-01-08]. Available from https://digital.wlb-stuttgart.de/sammlungen/sammlungsliste/werksansicht?tx_dlf%5Bid%5D=8680&tx_dlf%5Border%5D=title&tx_dlf%5Bpage%5D=10&cHash=d9fed011e397797f6e01f1f5c7a65cd7.

Zachrisson, T. 2020: Viking Age society, its realms and the importance of iron. Reflections on the historical background and emerging networks. In: C. Karlsson, G. Magnusson (eds.): *Iron and the Transformation of Society. Reflexion of Viking Age Metallurgy*. Jernkontorets bergshistoriska skriftserie 51. Stockholm: Jernkontoret, 89–140. Available also from: https://www.diva-portal.org/smash/get/diva2:1517360/FULLTEXT01.pdf.

Resumé

Předkládaná studie se zabývá významem železářství v kontextu raně středověké střední Evropy se zaměřením na sídelní aglomeraci Mikulčice-Valy v České republice. Poukazuje na možnost, že předchozí studie přehlížely ekonomicko-historický význam konkrétních kovářských činností na raně středověkých sídlištích. Toto přehlédnutí se připisuje předpokladu, že kovářství bylo činností všudypřítomnou; tento přístup však vede k přílišnému zjednodušení složitosti řemeslné výroby a jejích sociálních důsledků. Autoři zdůrazňují rozmanitost praktické výroby a zpracování železa v raném středověku, která sahala od domácké výroby až po řemeslnou činnost ve velkém rozsahu, obzvláště v urbanizovaných oblastech.

Lokalita Mikulčice-Valy je významné proto-urbánní sídliště s intenzivním zpracováním železa i neželezných kovů, přesto však bylo dosud vyhodnocování metalurgického materiálu převážně nesystematické. Mikulčice-Valy jsou jako centrální sídliště doloženy na konci 8. století; v 9. století se vyvinuly do formy opevněné sídelní aglomerace s charakteristickými urbánními prvky a komplexním půdorysem (obr. 1: 1). Severní suburbium hradiště bylo krátkodobě osídleno v druhé polovině 9. a na počátku 10. století. Z celkové rozlohy 5 ha byla dosud archeologicky prozkoumána plocha 0,2 hektaru (obr. 1: 2). Archeologickými výzkumy bylo získáno 287,5 kg pyrometalurgického odpadu, jako je například železná struska a strusková hlína, což ukazuje na důležitost lokality ve specializované řemeslné výrobě.

V rámci této studie byla provedena makroskopicko-typologická a mikroskopická (SEM-EDS, WD-XRF) analýza pyrometalurgických pozůstatků ze severního suburbia lokality Mikulčice-Valy (tab. 1, 2), která identifikovala čtyři materiálové skupiny (tab. 1). První skupina představuje kovářskou strusku o celkové hmotnosti 268,6 kg, z níž 81,5 kg tvoří nepoškozená planokonvexní dna výhně (PCB), 24,3 kg PCB zachovaná z 25–75 % a 163 kg malé fragmenty PCB a kusy strusky nepravidelného tvaru (obr. 2: 1–6, 8, 9; 3; tab. 2, 3; graf 1–3). Morfologické a chemické charakteristiky těchto materiálů napomáhají našemu porozumění železářským procesům, včetně dokladů opakovaných cyklů ohřívání a ochlazování během výroby (tab. 4–8; obr. 4–7; tab. 10). Strusky z tavby železa o hmotnosti 2,69 kg vykazují významně vysoký obsah oxidu fosforečného a oxidu manganatého (obr. 2: 7, 8; tab. 9, 10). Obohacení P_2O_5 je zřetelným znakem tavby bahenních rud bohatých na fosfor. Ostatní pyrometalurgické pozůstatky mají formu technické keramiky o celkové hmotnosti 4,4 kg. Lze je dále rozdělit na pozůstatky dyznových cihel (obr. 9: 1–6; tab. 11; graf 4) na ochranu měchů (obr. 10), jednu trubicovitou dyznu (obr. 9: 7) a dvě hliněné ucpávky (obr. 9: 8, 9). Poslední skupinou je pak 11,6 kg amorfní keramické strusky představující přežhavené silikáty z obložení či oplášťování výhní a pecí.

Za účelem identifikace případných umístění dílen bylo analyzováno rozložení metalurgického odpadu (obr. 11, 12), přičemž autoři poukazují na skutečnost, že interpretace dílenských zařízení in situ mohou komplikovat sekundární relokace materiálu. Zjištěné skutečnosti naznačují, že kování a obrábění neželezných kovů se pravděpodobně provádělo v prostředí flexibilních, nestálých dílen. To podtrhuje složitost identifikace trvalých dílenských struktur vzhledem k charakteru archeologického fondu a zdůrazňuje potřebu pečlivého zvážení procesů utváření lokality.

V rámci diskuse organizace železářské výroby autoři argumentují, že velké množství odpadu nemusí být nutně znakem rozsáhlé výroby nebo řemeslné specializace. Navrhují definici specializace na základě recipročního vztahu mezi výrobci a spotřebiteli s důrazem na důležitost sledovaných parametrů, jako jsou prostorové uspořádání (koncentrace), organizace a velikost výrobních jednotek (rozsah), množství času vynaloženého na výrobu (intenzita) a politicko-ekonomické vztahy (kontext).

Příspěvek navrhuje model organizace výroby, který odráží socioekonomickou dynamiku proto-urbánních sídel, kde v podmínkách zvýšené hustoty osídlení a dostupnosti trhu mohla prosperovat nezávislá výroba velkého rozsahu (obr. 15). Surové železo bylo třeba na místo dovážet (obr. 14). Vztahy mezi výrobci a politickými institucemi lze charakterizovat jako pružné, umožňující inovace a konkurenci mezi řemeslníky. Po zasazení dosavadních zjištění do kontextu docházejí autoři k závěru, že Mikulčice-Valy jsou příkladem lokality s formou centralizované výroby, která je převážně založena na trhu, s doklady jak nezávislé řemeslné činnosti, tak činnosti podporované elitou, které mohly v rámci sídliště existovat i souběžně. Autoři navrhují návazný interdisciplinární výzkum dynamiky raně středověkého železářského hospodářství s důrazem na důležitost metodologických přístupů, které budou brát v úvahu širší kontext výroby a vztahy mezi výrobci a spotřebiteli.

Contacts

Michael Lebsak
Institute of Archaeology of the Czech Academy of Sciences, Brno
Čechyňská 19
CZ-602 00 Brno
lebsak@arub.cz
ORCID: 0000-0003-4836-6071
&
Masaryk University Brno
Department of Archaeology and Museology
Arna Nováka 1
CZ-602 00 Brno
&
Albert-Ludwigs University Freiburg
Institut für Archäologische Wissenschaften
Belfortstraße 22
D-790 98 Freiburg

Jaroslav Kapusta
Palacký University Olomouc
Department of Geology
17. listopadu 12
CZ-771 46 Olomouc
jaroslav.kapusta@upol.cz
ORCID: 0000-0003-1764-1173