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Archaeologia historica. 2022, vol. 47, iss. 2, pp. 763-794

ISSN 0231-5823 (print); ISSN 2336-4386 (online)

Stable URL (DOI): https://doi.org/10.5817/AH2022-2-14
Stable URL (handle): https://hdl.handle.net/11222.digilib/digilib.76769

Archaeologia historica 47, 2, 2022, 763–794
https://doi.org/10.5817/AH2022-2-14

ARCHAEOLOGICAL EVIDENCE OF INDEPENDENT IRON PRODUCTION FROM THE 9TH-CENTURY RURAL SETTLEMENT OF BOŘITOV (BLANSKO DISTRICT, CZECHIA)

ROMAN MIKULEC – MICHAL HLAVICA – MATĚJ KMOŠEK

Abstract: *The study attempts to show the potential of iron slags to answer questions about the organization of iron production in 9th-century Moravia. As a case study, it evaluates a small archaeological assemblage from the contemporary rural settlement of Bořitov, where basic contextual and macroscopic evaluation in combination with various archaeometric analyses (pXRF, ED-XRF, XRD, SEM/EDS) of iron slags made it possible to recognize the smelting of iron ore, as well as its further processing in a reheating hearth and smithy. Taking into account some other finds connected with iron production as well as the specific geographic position of Bořitov, these results also indicate that the community in Bořitov could have been beyond the reach of regional elites and might thus have acted as independent producers with the main purpose to saturate their own demand and/or exchange the surplus.*

Key words: *Early Middle Ages – Great Moravia – iron smelting – smithy – slags – XRF – XRD – SEM/EDS.*

Archeologické doklady nezávislé produkce železa z venkovské osady 9. století v Bořitově (okres Blansko)

Abstrakt: *Studie se pokouší ukázat potenciál železářských strusek pro zodpovězení otázek spjatých s organizací železářské produkce na Moravě 9. století. Jako případovou studii vyhodnocuje menší archeologický soubor z dobové venkovské osady v Bořitově. Kontextuální a makroskopická analýza strusek v kombinaci s jejich analýzou archeometrickými metodami (pXRF, ED-XRF, XRD, SEM/EDS) umožnila na lokalitě potvrdit tavbu železa, stejně jako jeho následné zpracování ve vyhřívací výhni či kovárně. S přihlédnutím k některým dalším dobovým nálezům z Bořitova, jež jsou s produkcí železa spojeny, a ke geografickému umístění lokality tyto výsledky též naznačují, že místní komunita se již nacházela mimo bezprostřední dosah dobových regionálních elit, a místní řemeslníci tak mohli fungovat coby nezávislí producenti s hlavním cílem saturovat vlastní potřeby, případně nadbytek příležitostně směňovat.*

Klíčová slova: *raný středověk – Velká Morava – tavba železa – kovárna – struska – archeometrie – XRF – XRD – SEM/EDS.*

1 Introduction

The understanding of the organization of craft production and of distribution of goods and commodities in the Early Middle Ages[1] is one of the ways an archaeologist is able to learn about the character of contemporary social organization including the shape and structure of central power (Hlavica–Procházka 2020). By focusing on production and distribution of commodities, it is possible to infer changes in the political economies of contemporary elites and thus to understand the processes of political centralisation within them and their overall internal dynamics. In this manner, 9th-century Moravia is not an exception. The current unfamiliarity with its economic and organizational principles (cf. Štefan 2011; 2014; Macháček 2012; 2015; Kalhous 2014; Profantová–Profant 2014) still needs be overcome, and studies which aim to acquire new knowledge about the economics of this society can contribute to it.

In this respect, an analysis of the organization of the production and distribution of regionally demanded commodities, such as iron, seems to be particularly promising. During the existence of the Great Moravian polity, iron production ensured crucial means for two linchpins of the contemporary economy – the intensifying agricultural production (Měřínský 2014, 105–110) and the mobilization of resources from outside Great Moravian territory through looting raids

1 In multiple parts of the text, we use terms traditionally used by domestic archaeology in reference to the dating. For dividing the Czech and Moravian Early Middle Ages, we accepted following periodization: Early Slavic Period (c. 550–680 AD), Early Hillfort Period (c. 680–800 AD), Middle Hillfort Period (c. 800–950 AD, including the Great Moravian Period, c. 833–907 AD), Late Hillfort Period (c. 950–1200 AD).

(Třeštík 2001, 104–107; for summarization, see also Macháček 2021). Wide demand for ore in combination with uneven distribution of ore sources made iron a scarce resource the distribution of which across Great Moravia's territory had to be systematically ensured and thus also offered opportunities for the elite's control (Hlavica–Procházka 2020, 76).

Despite the importance of iron for the understanding the dynamics of the Great Moravian economy, the state of knowledge, especially in the sphere of primary evidence of contemporary iron production, remains rather uneven (see Pleiner 1958; 1962; 2000; Souchopová 1986; 1995; Souchopová–Stránský 2008). Research is faced with an insufficient understanding of the specifics of the iron operational chain, mainly the part ranging from the extraction and smelting of the

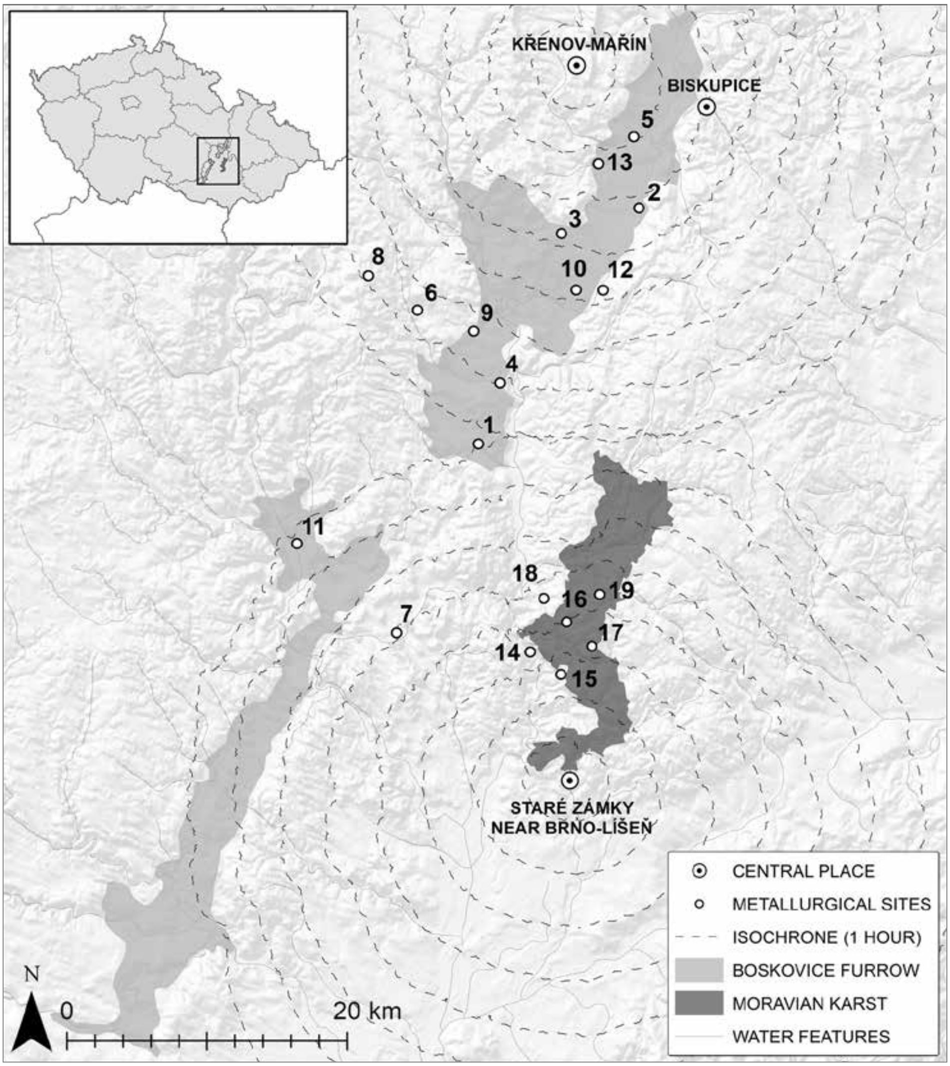

Fig. 1. The Boskovice Furrow and the Moravian Karst with localization of the sites with documented early medieval iron production or processing (for the list of the individual sites, see Tab. 1).

Obr. 1. Boskovická brázda a Moravský kras s lokalizací míst s doloženou raně středověkou produkcí železa či jeho zpracováním (pro soupis jednotlivých lokalit viz tab. 1).

ores near their deposits to the production of final iron products in smithies, and their consequent distribution.

On the other hand, archaeological research has yielded rather significant, although not yet quite adequately evaluated, artefact assemblages so far. Two distinctive early medieval production regions, the Moravian Karst and the Boskovice Furrow (Fig. 1), differing both in the natural environment and the archaeological remnants of past production activities, were situated in the southern part of central Moravia, the peripheral region of the presumed power core of the Great Moravian polity (for more detail, see Poulík 1957, 348; Kalhous 2020, Fig. 1 on p. 16). Despite their relative geographic proximity, these regions differ considerably environmentally, but both were suitable for mining and iron smelting as they contained deposits of mostly iron oxide ore (Souchopová 1995, 45). Numerous field surveys and excavations within them however have shown that the character of the archaeological remnants of production activities also differs.

2 Main iron production areas in 9th-century Moravia

2.1 Moravian Karst

The Moravian Karst, part of the Drahany Uplands, is a flat highland region with an area of approximately 92 km^2 stretching from the northern part of Brno as far as the small town of Sloup (Demek et al. 2006, 305). It is an infertile land that was forested also in the Early Middle Ages (Souchopová 1986, 8). Iron smelting was carried out from the 5th century BC to the end of the 19th century. In contrast to the Boskovice Furrow region, however, no evidence for a permanent early medieval settlement has been known so far.

Finds related to early medieval iron production have been documented at a minimum of 19 sites in this region (Tab. 1). Numerous extensive workshops with multiple furnaces and characteristic refuse piles have been detected archaeologically (Souchopová 1986, 16–37, 39–45).

Besides iron smelting furnaces, as-yet undated mining relics have also been detected in the region. Mining sinkholes situated near contemporary smelting sites are possibly of early medieval origin (Merta–Merta 2000, 33; Souchopová 1986, 63–64; Souchopová–Stránský 2008, 145–146). The archaeological record also evidences that reheating, i.e., initial refining of raw iron blooms (for more details, see Pleiner 2000, 215–216), was most probably carried out at the Middle Hillfort Period (Souchopová–Stránský 2000, 23; 2008; see also Merta 2019) as well as late the Late Hillfort Period sites (Souchopová 1986, 55, 75; Souchopová–Stránský 2008, 64, 75–76). However, smithing activities exceeding the reheating and basic processing of blooms is only evidenced from the Late Hillfort Period (Souchopová 1979, 97; 1986, 49–50, 77–78; Souchopová–Stránský 2008, 80–82, 143–144).

Based on the current state of archaeological research of the Moravian Karst, the development of early medieval smelting workshops in the region can thus be summarized as follows:

- First early medieval smelting activities appeared in the Moravian Karst in the late 8th and early 9th centuries AD. Underground furnaces of the Želechovice type (Fig. 2:1), that were also able to produce high-carbon steel, were used at that time (Pleiner 1969, 485–486; see also Pleiner 2000, 190–193). The setting of smelting sites was planned during this period (Pleiner 1955, 28; Souchopová 1986, 16–23; Souchopová–Stránský 2008, 37–38).

- During the Middle Hillfort Period, the furnace design was changed in favour of types that allowed their better operation, maintenance, and slightly higher production effectivity. Two types of these furnaces were used: embanked furnaces with a thin front wall and free-standing shaft furnaces with a shallow hearth (Figs. 2:2, 3). Workshops in the Moravian Karst are systematically organized during this period (Souchopová 1986, 23–37). Thin-walled tuyeres predominate at these sites.

Tab. 1. Overview of early medieval sites in the Boskovice Furrow and the Moravian Karst with documented early medieval iron production or processing.

Tab. 1. Přehled raně středověkých lokalit Boskovické brázdy a Moravského krasu s doloženou raně středověkou výrobou či zpracováním železa.

No. (Fig. 1)	Site	Region	Dating
1	Bořitov	Boskovice Furrow	Middle Hillfort Period
2	Cetkovice	Boskovice Furrow	Middle Hillfort Period – Late Hillfort Period?
3	Drválovice/Vanovice	Boskovice Furrow	Middle Hillfort Period – Late Hillfort Period
4	Jabloňany	Boskovice Furrow	Middle Hillfort Period – Late Hillfort Period
5	Jevíčko	Boskovice Furrow	Late Hillfort Period
6	Kunštát region	Boskovice Furrow	Middle Hillfort Period or Late Hillfort Period
7	Kuřim	Boskovice Furrow	Middle Hillfort Period or Late Hillfort Period
8	Rozseč nad Kunštátem	Boskovice Furrow	Unknown (High Middle Ages?)
9	Sebranice	Boskovice Furrow	Early Hillfort Period, Late Hillfort Period
10	Sudice	Boskovice Furrow	Unknown
11	Tišnov region	Boskovice Furrow	Unknown
12	Vážany	Boskovice Furrow	Early Hillfort Period – Late Hillfort Period?
13	Velké Opatovice	Boskovice Furrow	Late Hillfort Period
14	Adamov	Moravian Karst	Late Hillfort Period
15	Babice nad Svitavou	Moravian Karst	Late Hillfort Period
16	Habrůvecká bučina	Moravian Karst	Late Hillfort Period
17	Habrůvka	Moravian Karst	Unknown
18	Olomučany, plot No. 171	Moravian Karst	Late Hillfort Period
18	Olomučany – Růžová Street, plots Nos. 951/2 and 951/3	Moravian Karst	Late Hillfort Period
18	Padouchov (Forest District Habrůvka)	Moravian Karst	Late Hillfort Period
18	Forest District Olomučany, forest units Nos. 86/1 and 86/2	Moravian Karst	Middle Hillfort Period – Late Hillfort Period
18	Forest District Olomučany, forest unit No. 98/1	Moravian Karst	Middle Hillfort Period
18	Forest District Olomučany, forest unit No. 98/3	Moravian Karst	Early Hillfort Period
18	Forest District Olomučany, forest unit No. 100	Moravian Karst	Late Hillfort Period
18	Forest District Olomučany, forest unit No. 107	Moravian Karst	Unknown
18	Forest District Olomučany, forest unit No. 38 A	Moravian Karst	Middle Hillfort Period
18	Forest District Olomučany, forest unit No. 84	Moravian Karst	Late Hillfort Period
18	Forest District Olomučany, forest unit No. 89	Moravian Karst	Late Hillfort Period
18	Forest District Olomučany, forest unit No. 98/2	Moravian Karst	Early Hillfort Period
18	Forest District Olomučany, forest unit No. 98/4	Moravian Karst	Late Hillfort Period
19	Forest unit No. 53 south of Rudice	Moravian Karst	Late Hillfort Period
19	Rudice	Moravian Karst	Unknown

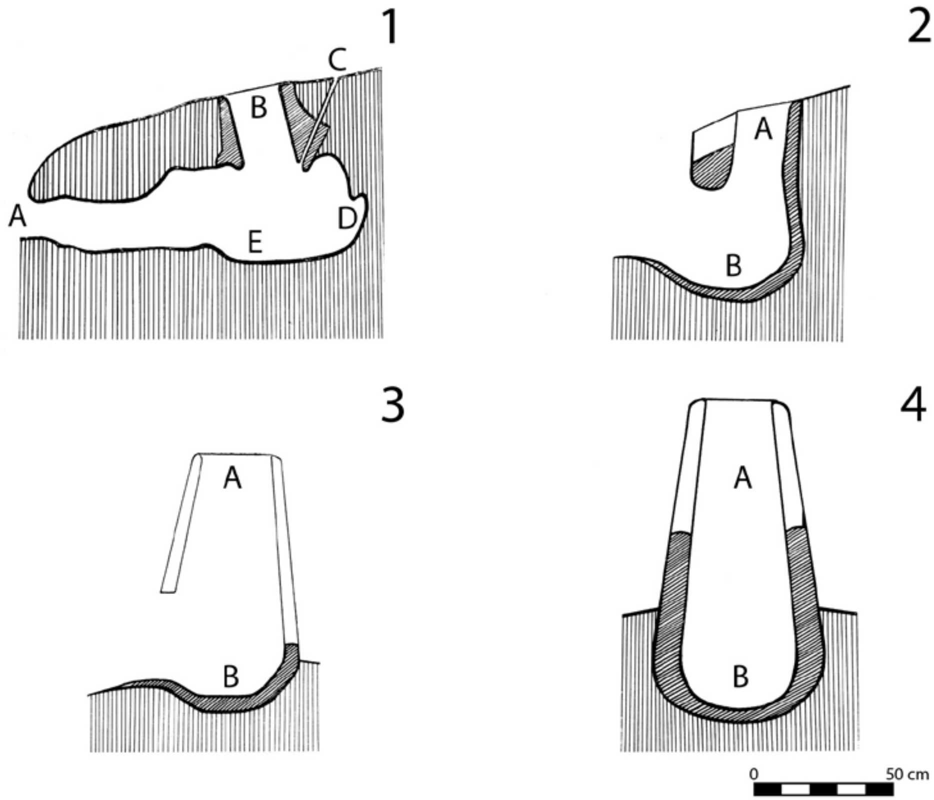

Fig. 2. Cross-section of the individual types of furnaces. 1) Underground furnace of the Želechovice type. A – tunnel-like front aperture; B – bulb-shaped shaft; C – rear air blowing form; D – horseshoe-shaped cavity; E – furnace hearth. 2) Embanked furnace with a thin front wall. A – chimney-like shaft; B – furnace hearth. 3) Free-standing shaft furnaces with shallow hearth. A – presumed shape and height of the shaft; B – shallow hearth. 4) Slag-pit furnace. A – presumed shape and height of the shaft; B – slag pit. After Souchopová 1986, Fig. 28, modified.

Obr. 2. Průřez jednotlivými typy pecí. 1) Pec želechovického typu. A – tunelovitý hrudní otvor; B – baňkovitá šachta; C – týlová forma pro vhánění vzduchu; D – podkovovitá dutina; E – nístěj pece. 2) Vestavěná pec s tenkou hrudí. A – komínovitá šachta; B – nístěj pece. 3) Nadzemní šachtová pec s mírně zahloubenou nístějí. A – předpokládaný tvar a výška šachty; B – mírně zahloubená nístěj. 4) Nadzemní šachtová pec s kotlovitě zahloubenou nístějí. A – předpokládaný tvar a výška šachty; B – kotlovitě zahloubená nístěj. Podle Souchopová 1986, Fig. 28, upraveno.

- Smelting workshops in the Moravian Karst were abandoned after the fall of Great Moravia in the early 10th century. The hiatus lasted there at least into the middle of the century (Souchopová 1979, 81–82; 1986, 80–81; Souchopová–Stránský 2008, 39), and iron production was re-established in the region during the second half of the 10th century. However, ironworks during this time are minor and unorganized compared to the previous periods. The use of free-standing slag-pit furnaces (Fig. 2:4) accompanied by finds of thick-walled tuyeres is documented (Souchopová 1986, 39–45). This is proof of a decline in the technological level of production. Local production thus most probably supplied only a small circle of consumers in this period (Souchopová 1979, 81–82; 1986, 32, 80–82; Souchopová–Stránský 2008, 40).

2.2 Boskovice Furrow

In contrast to the Moravian Karst, iron production in the Boskovice Furrow (Fig. 1) is still much less researched to this day. The region is a part of the Brno Highlands, and it can be characterized as a distinctive strip of currently unwooded terrain surrounded by forested positions in higher altitudes divided into two parts: the southern Oslavany Furrow and the more northerly Smaller Haná (Demek et al. 2006, 79). In contrast to the forested Moravian Karst, the Boskovice Furrow is a fertile region that was not considerably forested even in the Early Middle Ages. A steppe landscape rather predominated there (Souchopová 1986, 8) and an important north-south trade route denoted also as the Trstenice Road (Vermouzek 1971; Měřínský–Zumpfe 1998, 178) ran through the region. This probably also contributed to the higher level of occupation of the region (Souchopová 1976, 153).

As for the Early Middle Ages, ten iron smelting sites are currently known. Three more have not been precisely dated yet but most probably also are from the Early Middle Ages or the beginning of the High Middle Ages (Tab. 1). Most of these sites probably had a settlement character and yielded modest slag assemblages thanks to the field survey. Unfortunately, they together yielded no more than six early medieval metallurgical facilities, and of those only two facilities have been identified. They represent a type of embanked furnaces with a thin front wall (Procházka 1992, 321).

More intensive iron smelting has thus not been proven in this region, as it lacks characteristic evidence in the form of large refuse piles and smelting furnace batteries. Some archaeological finds, such as the above-mentioned embanked furnaces with a thin front wall, on the other hand show that more intensive iron smelting in this region cannot be completely ruled out. A considerable quantity of mining remnants has been also detected in some parts of the region, even though they cannot be unambiguously dated yet. They also provided sporadic additional evidence of early medieval iron production in the form of slag, tuyere pieces, and charcoal finds approximately dated to the Late Hillfort Period (Pleiner 1958, 262–263; Stránský et al. 1996, 45; Stránský et al. 2002, 57).

The character of early medieval iron production within the Boskovice Furrow region is thus still rather unclear. However, more precise evaluation of some of the already obtained archaeological assemblages from the region can help to extend the knowledge about the contemporary regional economics. This is especially the case of Bořitov, the early medieval rural settlement located in the northern part of the Boskovice Furrow (Fig. 1), which offers quite numerous archaeological finds connected to iron production and processing.

2.2.1 Bořitov

Multiple parts of the Bořitov municipality and its surrounding have yielded archaeological evidence of early medieval origin (Fig. 3; Tab. 2). Namely it was a settlement beginning in the Great Moravian Period or even in the Early Slavic Period identified in the Badálek and Nepluště fields (Štrof 1989), and in the Zádvoří and Niva fields. A field survey also revealed a Middle Hillfort Period or possibly even earlier occupation in the area of Bořitov-Krchůvky (Štrof 1979, 69; after Malach 2011, 21). Late Hillfort occupation was then detected in several places in the Bořitov cadastral area, especially in the built-up area of the municipality, in Podsedky field, Úvoz and Trávníky Streets, or Záhumenky field. Late Hillfort Period burials were examined between Školní and Nepomucká Streets (Skutil 1931, 47). The early medieval occupation in Bořitov thus lasted continually from the Early Slavic to the Late Hillfort Periods (Malach 2011, 19–22; Procházka–Štrof 1983; Souchopová 1976, 153).

As for the evidence of early medieval iron production from Bořitov, four unspecified features were detected in the Badálek and Nepluště fields. In view of the accompanying finds in the form of iron slag, iron ore, iron sheet and two whetstones, they were supposedly directly connected with iron production. The assemblage also contained pottery (Figs. 4 and 5) dated to the Middle

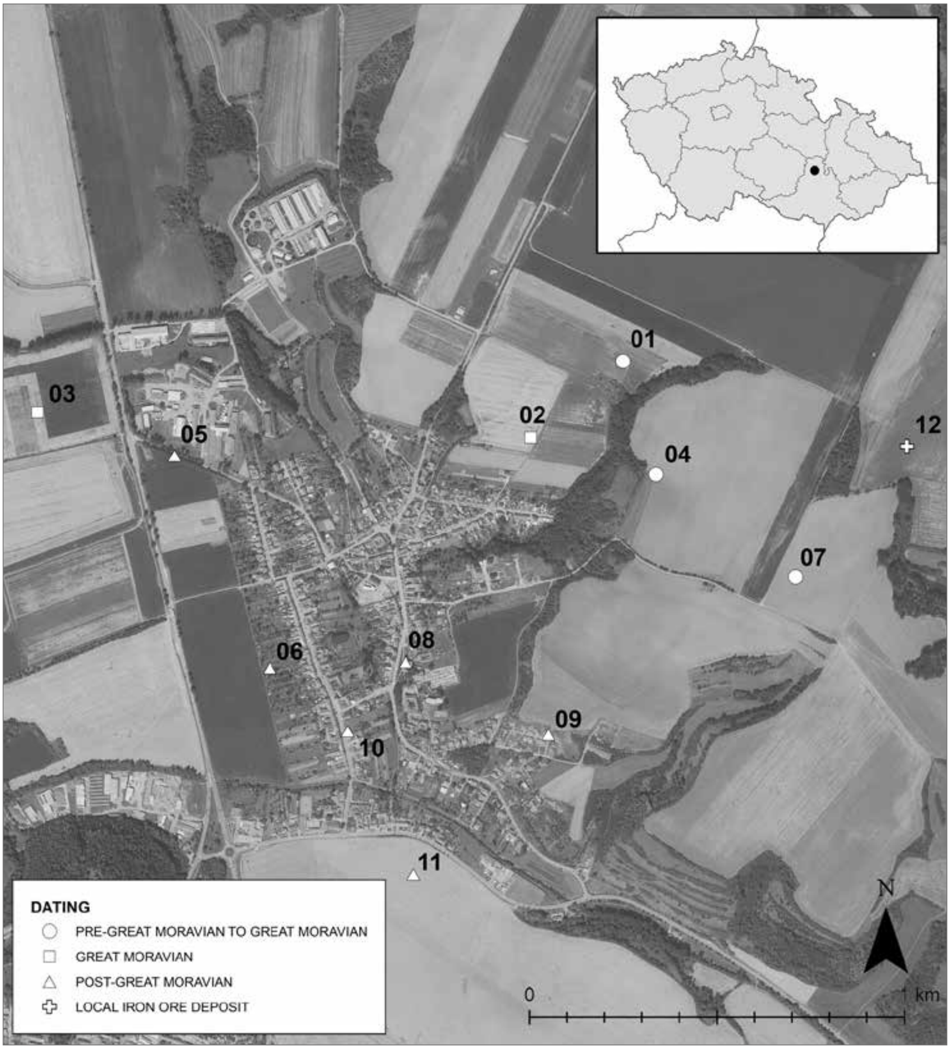

Fig. 3. Aerial photograph of Bořitov with positions of early medieval archaeological finds. 01 – Niva; 02 – Zádvoří; 03 – Krchůvky; 04 – Nepluště; 05 – Úvoz Street; 06 – Podsedky Street; 07 – Badálek; 08 – parish hill, nursery school, U Plhoňů; 09 – Záhumenky; 10 – Sokolská Street (Ekobioprogres); 11 – Trávníky Street; 12 – Horky. Source of the base data State Administration of Land Surveying and Cadastre (ČÚZK).

Obr. 3. Letecký snímek obce Bořitov s vyznačenými polohami s doklady raně středověkého osídlení. 01 – Niva; 02 – Zádvoří; 03 – Krchůvky; 04 – Nepluště; 05 – ulice Úvoz; 06 – ulice Podsedky; 07 – Badálek; 08 – Farský kopec, mateřská školka, U Plhoňů; 09 – Záhumenky; 10 – ulice Sokolská (Ekobioprogres); 11 – ulice Trávníky; 12 – Horky. Zdroj podkladových dat ČÚZK.

Hillfort Period (Malach 2011, 21; Štrof 1989). But as it is long-term inaccessible, this part of the Bořitov assemblage is not further evaluated in this study.

The strongest evidence of iron production and processing still partially available for further evaluation came from the Zádvoří and Niva fields. A slightly sunken rectangular feature (Fig. 6) detected in Zádvoří was interpreted as a smithy based on the large quantity (reportedly over 100 pieces) of predominantly plano-convex iron slags (cf. Hauptmann 2021, 244; Serneels–Perret 2003, Fig. 4; Pleiner 2000, 255). Based on the pottery (Fig. 7), this feature can be generally dated to the Middle Hillfort Period. The feature next to the smithy was interpreted as a refuse

Tab. 2. Individual parts of the municipality of Bořitov with early medieval finds and their dating.

Tab. 2. Jednotlivé části obce Bořitov se zachycenými raně středověkými nálezy a jejich datace.

No.	Field/Street	Dating	Component
01	Niva	Early Hillfort Period/ Middle Hillfort Period	reheathing furnace and adjacent feature
02	Zádvoří	Middle Hillfort Period	smithy, refuse pit
01–02	Niva, Zádvoří	Early Slavic – Middle Hillfort Period	settlement
03	Krchůvky	Middle Hillfort Period	settlement
04	Nepluště	Early Slavic – Middle Hillfort Period	settlement
05–06	Podsedky Street, Úvoz Street	Late Hillfort Period	settlement
07	Badálek	Early Slavic – Middle Hillfort Period	settlement
08	Školní Street, Nepomucká Street (parish hill, nursery school, U Plhoňů)	Late Hillfort Period	settlement, cemetery
09	Záhumenky	Late Hillfort Period	settlement
10	Ekobioprogres (Sokolská Street)	Late Hillfort Period	settlement
11	Trávníky Street	Late Hillfort Period	settlement
12	Horky		possible iron ore source

pit (Souchopová 1975; 1976, 153–155; 1979, 14; 1986, 9, 76; Procházka 2014, 238). A strongly damaged furnace was excavated in the slope of the one of the gullies separating the settlement in Niva from its surroundings, and above it, a reheating hearth was unearthed. No more detailed information about those metallurgical features was provided, except the characterization of the reheating hearth as an elongated pit of a size of 90 × 120 cm and a maximum depth of 60 cm. Based on the pottery found in its fill (Fig. 8), the hearth was dated to the late 8th or early 9th centuries. Next to the reheating hearth, a circular pit of unknown purpose was reportedly detected that belonged to a partially damaged La Tène bronze casting workshop (Procházka 2014, 238; Souchopová 1975; 1976, 153–155; 1979, 14; 1986, 9).

The Niva and Zádvoří fields offer an exceptional opportunity to explore the range of production of activities realized at the site during the Middle Hillfort Period, as part of the excavated assemblage was preserved and has survived to this day. It includes 82 pieces of slag in total with an overall weight of around 30 kg (for more details, see Tab. 3). A total of twenty tuyeres were also present within Niva and Zádvoří (Tab. 4). A relatively rare find of a tuyere block fragment (Fig. 10:1) also comes from the pit adjacent to the reheating hearth and smelting production at the site is also indirectly indicated by seventeen inventoried pieces of iron ore (Fig. 9:4). Ore was reportedly ploughed out of nearby fields in the recent past (Souchopová 1995, 66) and can still be found there today. Even though the area named Horky (Fig. 3:12) was identified as a local surface deposit of iron ore, it is not yet clear where the ore found comes from, as there are several ore outcrops also in the vicinity of Bořitov, e.g., within the cadastral areas of Krhov, Obora or Spešov (Burkart 1953, 138, 358, 518; Kruťa 1966, 238; see also Kučera 1923; Schirmeisen 1903).

Smithing activities are indicated by assemblages that come from the smithy from Zádvoří. Beside characteristic plano-convex slags, it contained a quadrilateral iron bar, which has, unfortunately, not been preserved. According to the documentation, the bar was composed of two rods 56 mm long; the width of the whole object was 20 mm and of one rod 10 mm. Probably a part of the tuyere plate of the smith's furnace was also identified within the remains of the smithy. A fragment of a tuyere was set in its smoothed circular aperture (Fig. 10:2). Another evidence

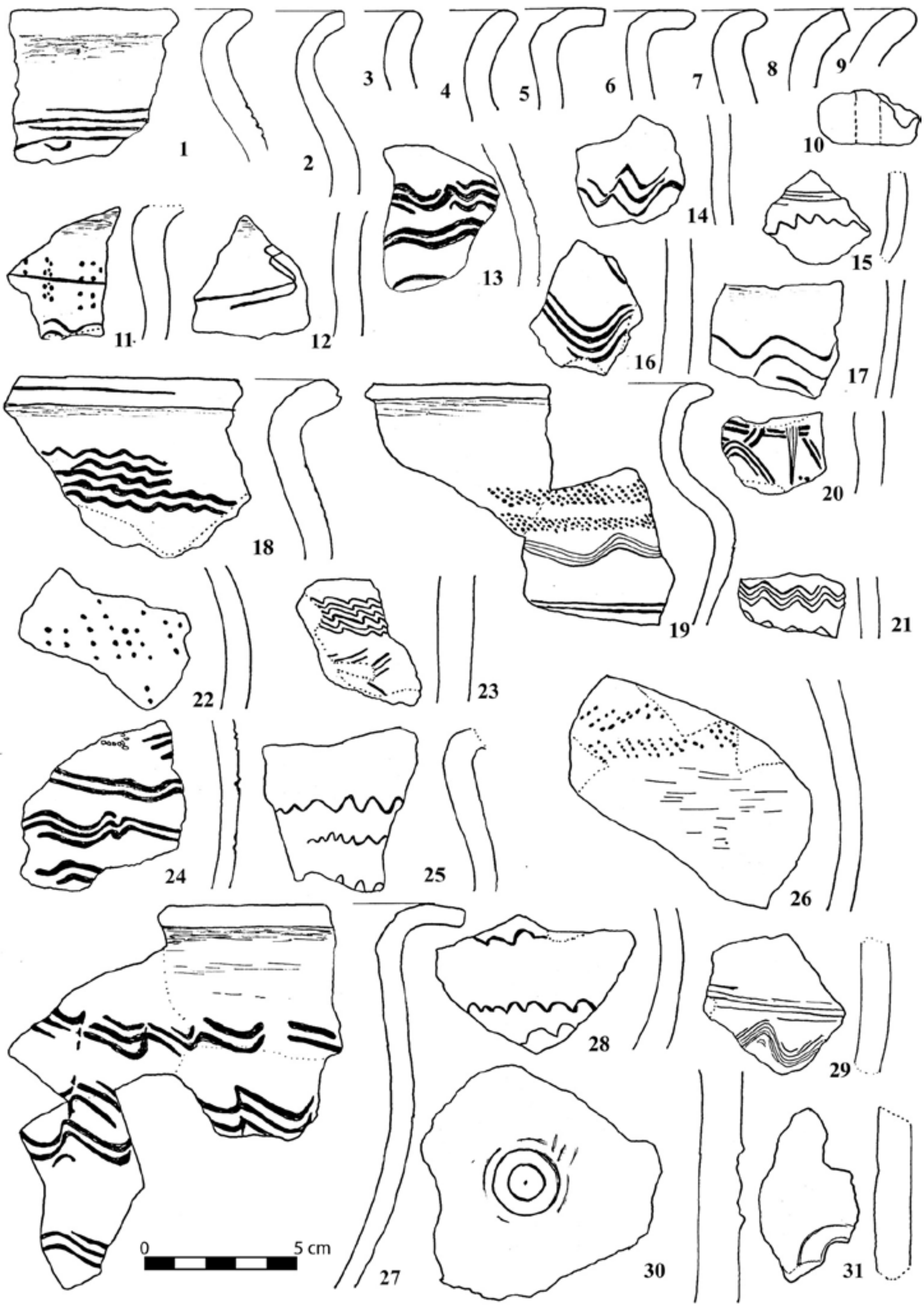

Fig. 4. Middle Hillfort Period pottery from Bořitov-Badálek. After Malach 2011, Tab. 3.

Obr. 4. Středohradištní keramika z Bořitova-Badálka. Podle Malach 2011, tab. 3.

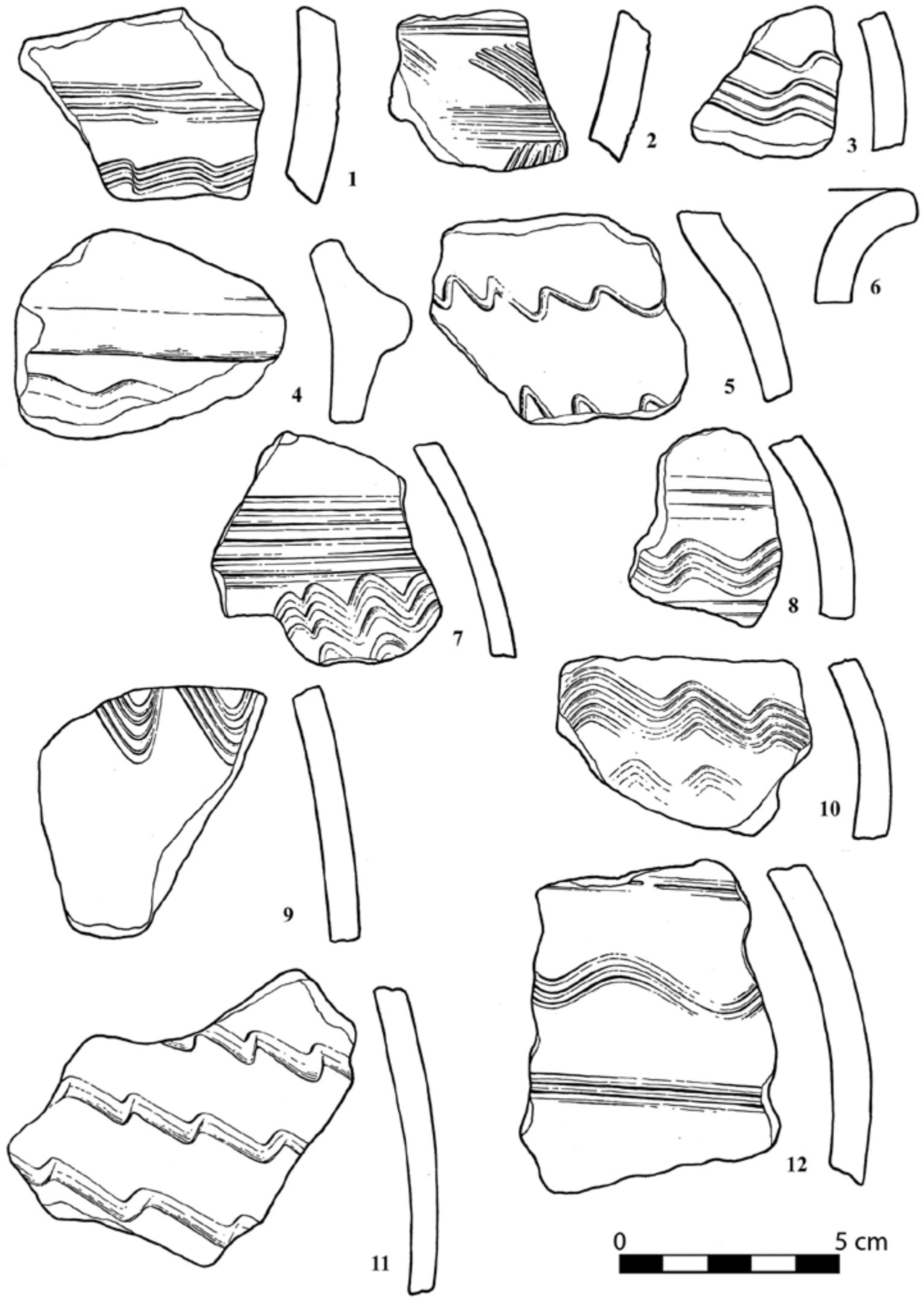

Fig. 5. Middle Hillfort Period pottery from Bořitov-Nepluště. After Malach 2011, Tab. 1.

Obr. 5. Středohradištní keramika z Bořitova-Nepluští. Podle Malach 2011, tab. 1.

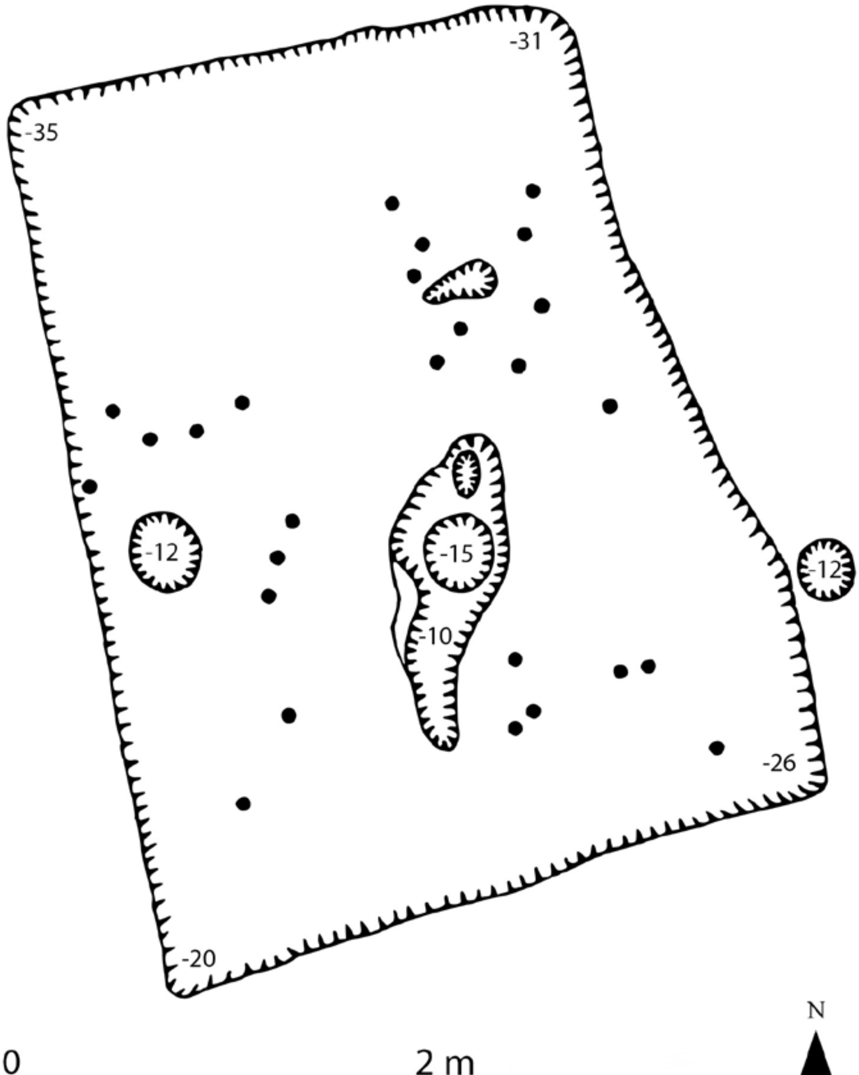

Fig. 6. Bořitov-Zádvoří: ground plan of a presumed smithy. After Souchopová 1976, Fig. 1, modified.

Obr. 6. Bořitov-Zádvoří – půdorys objektu A interpretovaného jako objekt kovárny. Podle Souchopová 1976, obr. 1, upraveno.

Tab. 3. Quantity, weight and preliminary visual classification of slags from the individual iron metallurgy features.

Tab. 3. Počet, hmotnost a předběžná vizuální klasifikace strusek z jednotlivých železářských objektů.

	Preliminary categorization				
Feature	Smithing slags (pcs.)	Smelting slag (pcs.)	Ceramic slag (pcs.)	Uncategorized (pcs.)	Total (pcs.)
Zádvoří – smithy	34	3	3	4	44
Zádvoří – refuse pit	1	0	0	1	2
Niva – reheating hearth	0	2	0	17	19
Niva – adjacent feature	5	2	0	9	16
Niva – smelting furnace	0	0	0	1	1
	Preliminary categorization				
Feature	Smithing slags (g)	Smelting slag (g)	Ceramic slag (g)	Uncategorized (g)	Total weight (g)
Zádvoří – smithy	21,497	468	168	1,329	23,462
Zádvoří – refuse pit	34	0	0	10	44
Niva – reheating hearth	0	139	0	800	939
Niva – adjacent feature	3,471	123	0	2,312	5,906
Niva – smelting furnace	0	0	0	28	28

Tab. 4. List of tuyeres found in the Bořitov-Niva and Bořitov-Zádvoří fields with their sizes.

Tab. 4. Soupis nalezených dyzen z poloh Bořitov-Niva a Bořitov-Zádvoří s rozměry.

Inv. No.	Field	Feature	Wall thickness (mm)	Preserved longitude (mm)
S 3673	Bořitov-Zádvoří	Smithy	8.5–10	65
S 3674	Bořitov-Zádvoří	Smithy	10–15	56
S 3675	Bořitov-Zádvoří	Smithy	13–15	67
S 3727	Bořitov-Zádvoří	Smithy	11–14	70
S 1638	Bořitov-Niva	Adjacent feature	7–10	70
S 3782	Bořitov-Niva	Reheathing hearth	5–10	180
S 3783	Bořitov-Niva	Reheathing hearth	4–10	145
S 3784	Bořitov-Niva	Reheathing hearth	4–12	94
S 3785	Bořitov-Niva	Reheathing hearth	4–8	145
S 3786	Bořitov-Niva	Reheathing hearth	4–8	140
S 3787	Bořitov-Niva	Reheathing hearth	6–11	70
S 3788	Bořitov-Niva	Reheathing hearth	5–7	45
S 3789	Bořitov-Niva	Reheathing hearth	8–9.5	94
S 3790	Bořitov-Niva	Reheathing hearth	11	45
S 3791	Bořitov-Niva	Reheathing hearth	10	46
S 3863	Bořitov-Niva	Reheathing hearth	4–9.6	50
S 3864	Bořitov-Niva	Reheathing hearth	7	30
S 3865	Bořitov-Niva	Reheathing hearth	11	33
S 3866	Bořitov-Niva	Reheathing hearth	6	25
S 3867	Bořitov-Niva	Reheathing hearth	6	40

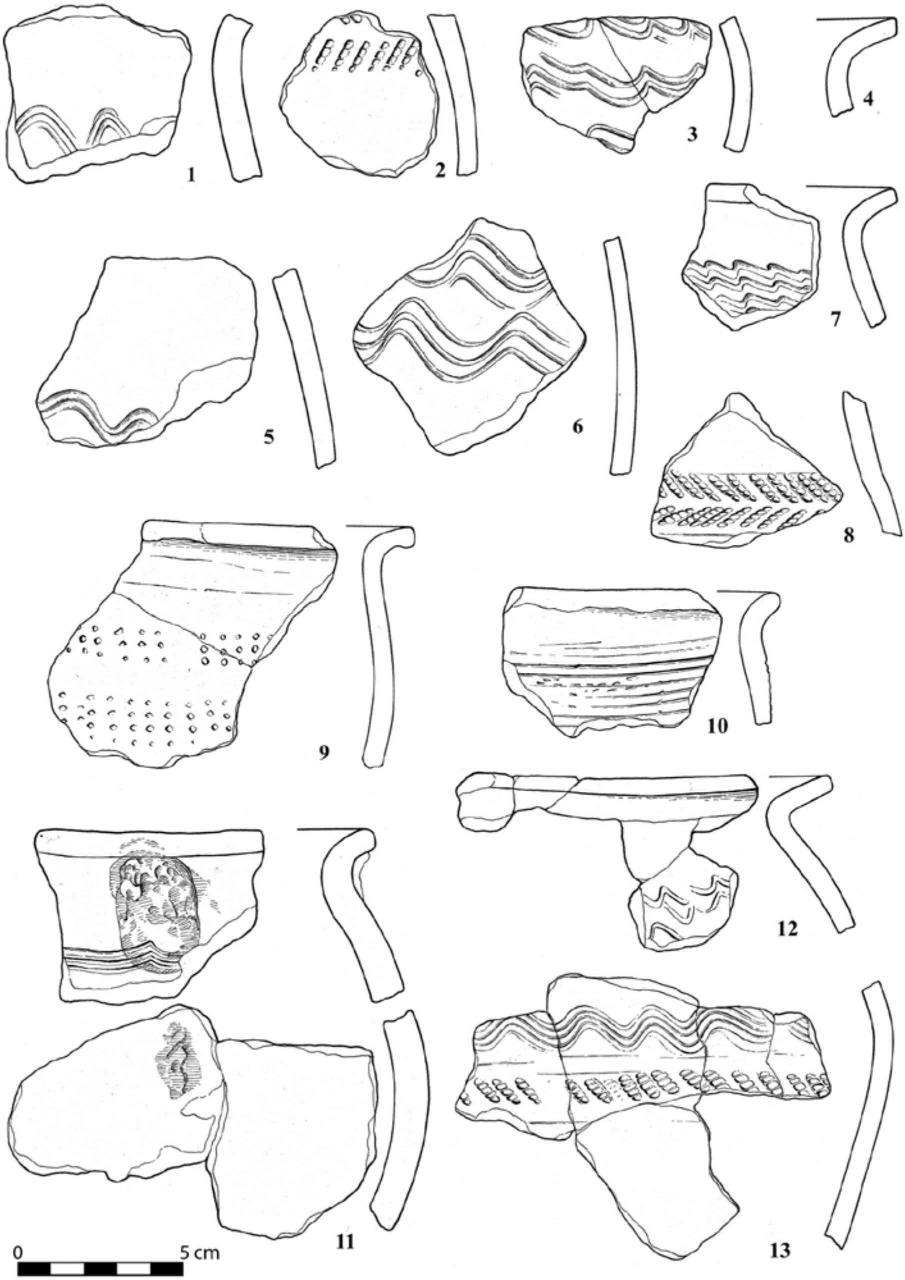

Fig. 7. Middle Hillfort Period pottery from Bořitov-Zádvoří. After Malach 2011, Tab. 2.

Obr. 7. Středohradištní keramika z Bořitova-Zádvoří. Podle Malach 2011, tab. 2.

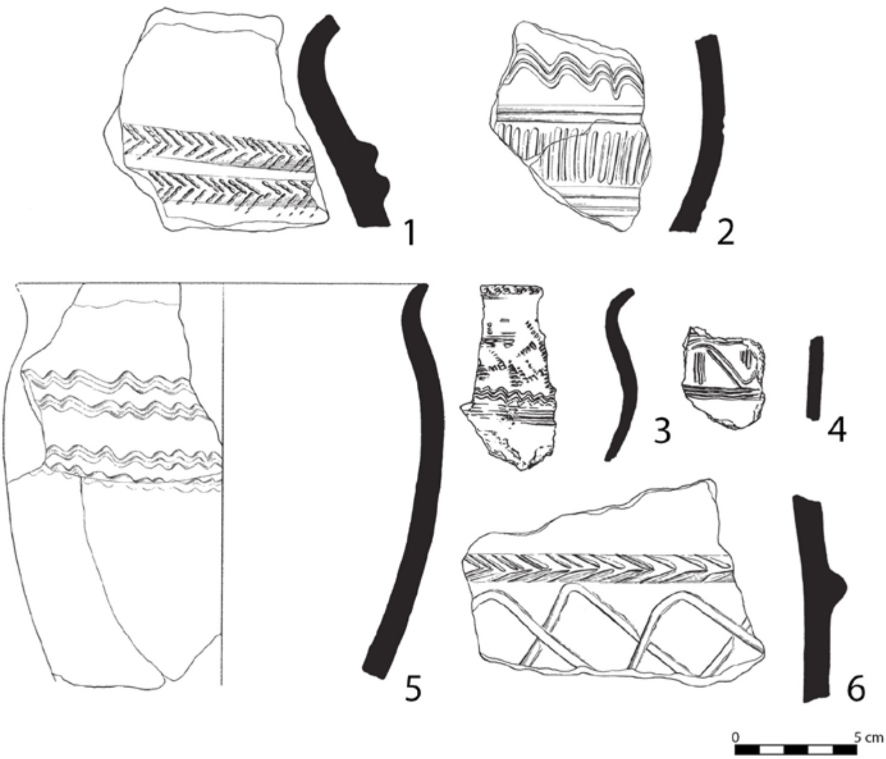

Fig. 8. Late 8th and early 9th-century pottery from Bořitov-Niva. After Procházka 2014, Fig. 98, modified.
Obr. 8. Keramika přelomu 8. a 9. století z Bořitova-Nivy. Podle Procházka 2014, obr. 98, upraveno.

of forging is a flat piece of iron containing numerous slag remnants (Fig. 9:3). The image of the blacksmith production can also be completed by four finds of whetstones within the smithy and fragments of a rotary grindstone, one in the presumed refuse pit next to the smithy and the other in the reheating hearth (Figs. 9:1, 2).

3 Analysis of the production refuse – Material and methods

The archaeometric analysis was focused on morphologically variable assemblage of slags with the goal to determine their origin and to verify presumptions about the presence of multiple stages of iron production and further processing within the studied fields in Bořitov. From the assemblage containing 82 pieces of slags, ten specimens (Tab. 5) were chosen representing the variability of the assemblage in terms of morphology, colouring and archaeological context. These contain three slags with typical flow structure (Figs. 11:1, 2, 3), preliminary interpreted as tap slags (see Hauptmann 2021, 233–235) one fragment of a characteristic plano-convex slag (Fig. 11:4) and two fragments of rusty porous slags (Figs. 11:5, 6), which are together seen as a by-product of smithing or reheating (Serneels–Perret 2003; Hauptmann 2021, 244; Pleiner 2000, 255), two pieces of ceramic slags (Figs. 11:7, 8), which are traditionally interpreted as the result of overheating the metallurgical device lining (Hauptmann 2021, 245–246), and finally two specimens, which could not be classified with certainty based solely on their morphology (Figs. 11:9, 10).

Tab. 5. List of slag samples from the Bořitov-Niva and Bořitov-Zádvoří fields, their preliminary interpretation and final classification based on the results of the archaeometric analysis.

Tab. 5. Soupis vzorků strusek z poloh Bořitov-Niva a Bořitov-Zádvoří, jejich předběžná interpretace a finální klasifikace na základě výsledků archeometrické analýzy.

No.	Field	Feature	Inv. No.	Weight (g)	Density (g/cm^3)	Structure	Colour	Preliminary classification	Final classification
1	Zádvoří	Smithy	S 3712	164	1.9	flow structure	graphitic grey	smelting	cat. 1 (smelting)
2	Niva	Reheathing hearth	S 3840	59	2.2	flow structure	graphitic grey	smelting	cat. 1 (smelting)
3	Niva	Adjacent feature	S 1648	49	2.6	flow structure	graphitic grey	smelting	cat. 1 (smelting)
4	Zádvoří	Smithy	S 3707	219	2.1	plano-convex, porous	brownish red	smithing	cat. 2 (smithing)
5	Niva	Adjacent feature	S 3886	49	2.0	amorphous, porous	brownish red	smithing	cat. 2 (reheating?)
6	Zádvoří	Refuse pit	S 3596	34	1.5	amorphous, porous	brownish red	smithing	cat. 2 (smithing)
7	Zádvoří	Smithy	S 3728	83	1.3	glazy, vitrious	blue/grey/ yellow/white	melted lining	cat. 3 (forge lining)
8	Zádvoří	Smithy	S 3730	19	1.2	glazy, vitrious	blue/grey/ beige	melted lining	cat. 3 (forge lining)
9	Niva	Reheathing hearth	S 3849	13	1.8	porous with aperture	grey	unrecognized	cat. 2 (reheating)
10	Niva	Reheathing hearth	S 3854	11	1.7	amorphous, porous	brownish grey	unrecognized	cat. 2 (reheating)

Tab. 6. Results of the material analysis using a portable X-ray fluorescence spectrometer (pXRF).

Tab. 6. Výsledky materiálové analýzy s využitím ručního rentgen-fluorescenčního spektrometru (pXRF).

Inv. No.	Final classification	LE	Fe	Si	Mn	Al	Cl	Mg	Ca	K	Ti	P	S	Pb	Bi
S 3712	cat. 1 (smelting)	29.2	43.4	9.4	3.3	3.8	0.0	7.0	2.0	0.6	0.1	0.9	0.1	0.0	0.0
S 3840	cat. 1 (smelting)	22.6	53.8	7.5	2.8	2.8	0.0	8.4	0.9	0.2	0.1	0.7	0.0	0.1	0.1
S 1648	cat. 1 (smelting)	19.0	53.7	10.3	3.1	5.1	0.0	6.9	0.6	0.4	0.1	0.6	0.1	0.1	0.1
S 3707	cat. 2 (smithing)	25.8	55.7	4.1	0.5	3.6	0.5	7.7	0.9	0.4	0.0	0.5	0.1	0.1	0.1
S 3886	cat. 2 (reheating?)	44.6	45.5	1.4	0.0	1.3	0.9	4.9	0.6	0.1	0.0	0.3	0.1	0.1	0.1
S 3596	cat. 2 (smithing)	49.3	29.9	6.8	0.1	2.7	0.0	4.4	4.3	0.4	0.1	1.9	0.0	0.0	0.0
S 3728	cat. 3 (forge lining)	60.0	4.5	18.4	0.1	5.7	0.0	4.3	3.3	2.8	0.5	0.3	0.0	0.0	0.0
S 3730	cat. 3 (forge lining)	52.3	9.2	22.0	0.2	6.4	0.0	2.7	0.9	5.6	0.4	0.2	0.0	0.0	0.0
S 3849	cat. 2 (reheating)	32.8	41.4	7.8	0.8	5.4	0.0	5.2	3.1	1.7	0.2	1.3	0.1	0.0	0.0
S 3854	cat. 2 (reheating)	30.1	39.7	6.6	0.7	3.2	0.0	9.7	6.3	0.9	0.2	2.4	0.0	0.0	0.0

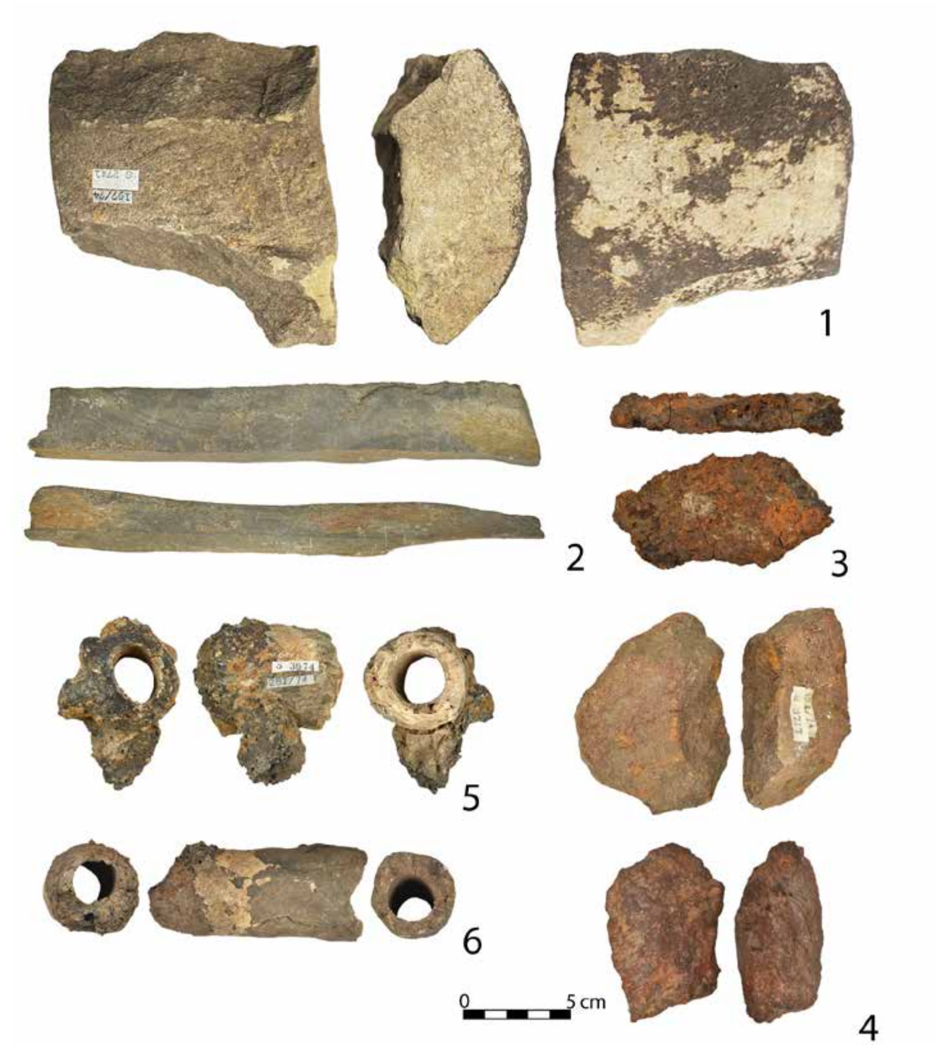

Fig. 9. Early medieval finds from the Niva and Zádvoří fields. 1 – rotary grindstone (Inv. No. S 2741); 2 – whetstone (Inv. No. S 3601); 3 – corroded iron fragment containing slag remnants (Inv. No. S 3715); 4 – iron ore (Inv. Nos. S 3717, S 3857); 5 – tuyere fragment with a distinctive slag pad (Inv. No. S 3674); 6 – tuyere fragment with slag cover (Inv. No. S 3784).

Obr. 9. Raně středověké nálezy z poloh Nivy a Zádvoří. 1 – rotační brus (inv. č. S 2741); 2 – brousek (inv. č. S 3601); 3 – zkorodovaný železný fragment obsahující struskové zbytky (inv. č. S 3715); 4 – železná ruda (inv. č. S 3717, S 3857); 5 – fragment dyzny s výrazným struskovým nálitkem (inv. č. S 3674); 6 – fragment dyzny se struskovým povlakem (inv. č. S 3784).

The utilized methods included pXRF (portable X-ray fluorescence) and ED-XRF (energy dispersive X-ray fluorescence) elemental composition analyses, XRD (X-ray powder diffraction) phase composition analysis and metallographic analyses in combination with the documentation and element analysis using SEM/EDS (scanning electron microscopy with energy dispersive spectroscopy). The utilization focused above all on the detection of possible compositional differences between individual specimens, which allows validation or further specification of their assignment to the individual stages of the production. Conclusions concerning the use of

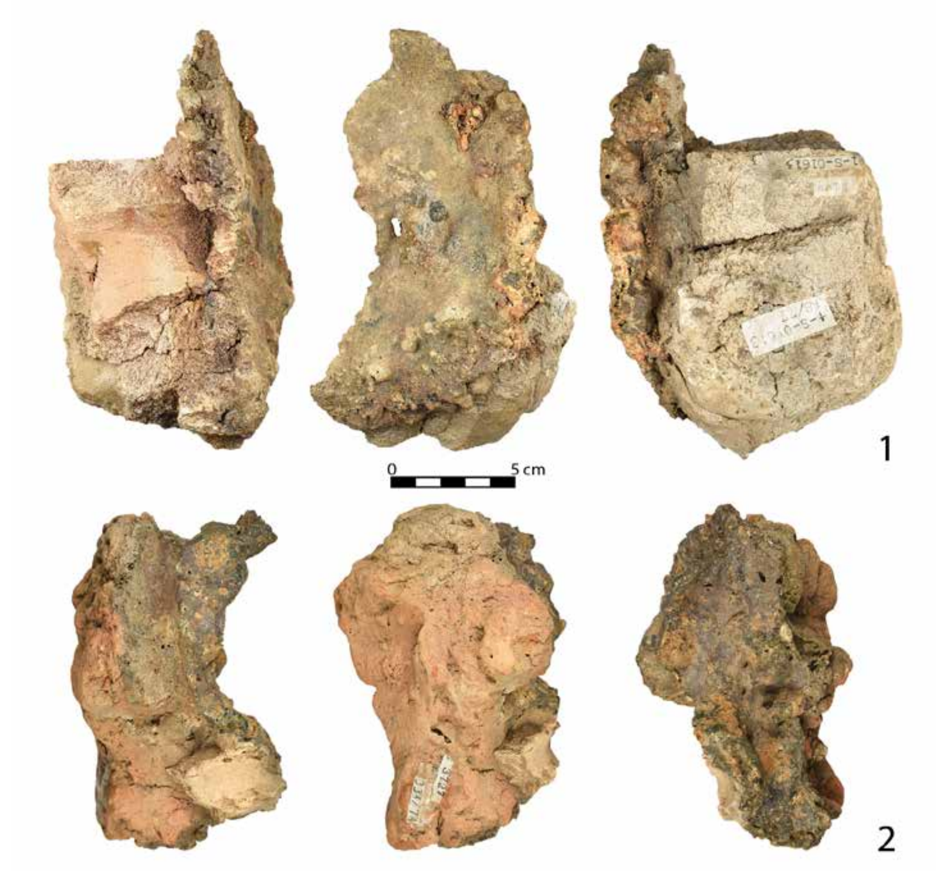

Fig. 10. 1 – Tuyere block fragment from a feature near the reheating hearth in Niva field (Inv. No. S 1613); 2 – tuyere plate fragment from the presumed smithy in Zádvoří field with a remnant of an inserted tuyere (Inv. No. S 3727).

Obr. 10. 1 – Fragment dyznové cihly z objektu u vyhřívací výhně z polohy Niva (inv. č. S 1613); 2 – fragment kovářského štítku se zbytkem vsazené dyzny z kovárny v poloze Zádvoří (inv. č. S 3727).

slag-forming admixtures or fuel were also desired based on the information (elemental composition) provided by these analyses.

Basic elemental composition analysis[2] for tentative characterization and classification of the slags was carried by the pXRF method using a Delta Professional portable spectrometer on fresh fracture surfaces of the slags.[3] Subsequently, a more precise elemental composition analysis was performed by the ED-XRF method using an ElvaX Pro benchtop spectrometer.[4] The ED-XRF method was applied to two types of samples. The first of them were fracture surfaces of the slag (time of measurement: 120 seconds) identical to the above-mentioned pXRF method. The other type consisted of powdered

2 Elemental analyses by pXRF and ED-XRF methods were carried out by Matěj Kmošek at the Institute of Archaeology of the Czech Academy of Sciences, Brno.

3 The measurement was carried out under the following conditions: Rh X-ray tube, Geochem mode, focalization: 8 mm, time of measurement: 150 seconds, integrated automatic evaluation of the spectra.

4 The measurement was carried out under the following conditions: an Ag X-ray tube, Steellow mode, accelerating voltage: 45 and 10 kV, collimator: 4 mm, individual evaluation of the spectra in ElvaX software.

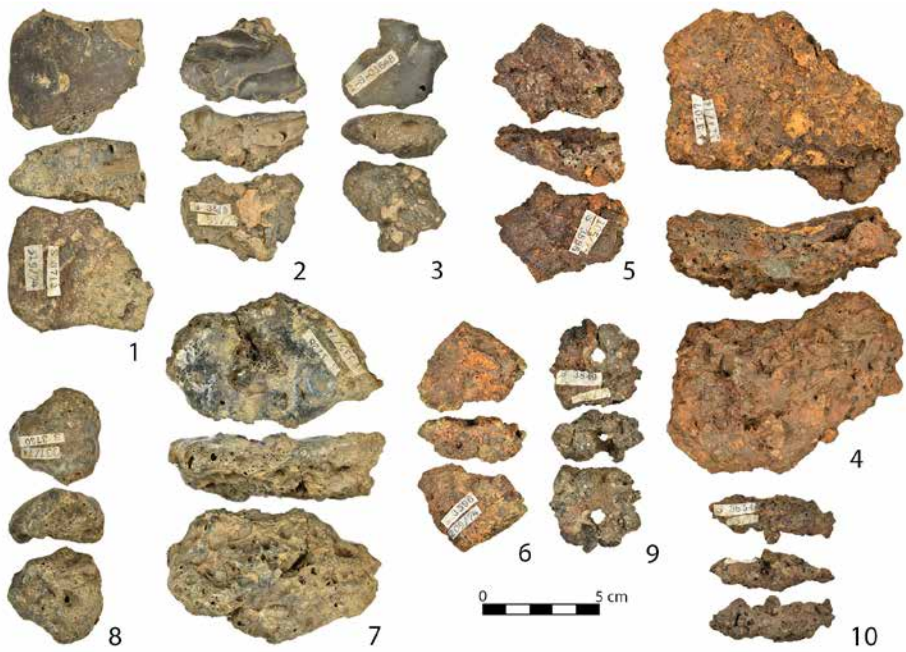

Fig. 11. Overview of slag pieces selected for an archaeometric analysis (for more details, see Tab. 5).
Obr. 11. Přehled strusek vybraných pro archeometrickou analýzu (podrobněji viz tab. 5).

samples (time of measurement: 40 seconds)[5] prepared by grinding for XRD phase analysis (see below). The microstructure[6] of the slag specimens was examined using metallographic thin sections[7] documented and analysed by the SEM/EDS method.[8] Phase composition analyses were performed by the XRD (X-ray Powder Diffraction) method[9] using an Empyrean diffractometer by PANalytical.[10]

4 Results

Based on data obtained by the above-mentioned analytic methods (for the results, see Tabs. 6–9, see also Figs. 12–15), it was possible to classify the analysed specimens into three categories. In view of the absence of minerals of non-ferrous metals, all the analysed specimens can be linked to smelting production and/or processing of iron in the smithy, both using charcoal.[11] The addition of slag-forming admixtures was not proved as the content of CaO is very low.

5 Powdered samples were, moreover, measured by the ED-XRF method including helium micro-flush in order to improve the detection of light elements (Na, Mg).

6 Metallographic thin sections and SEM/EDS analyses were carried out by Jiří Kmošek at the Faculty of Restoration, University of Pardubice.

7 Metallographic samples of slag were embedded in two-component epoxy resin, wet ground on a metallographic grinder (abrasive papers with a coarseness of 120, 200, 400, 800, 1200, 2500 and 4000), polished on polishing canvas using diamond paste with a coarseness of 2 μm, wetted with a mixture of glycerine and ethanol and etched by 2% Nital (2% solution of HNO_3 in ethanol).

8 The observation, documentation and analysis of metallographic thin sections were performed using electronic scanning microscope Tescan Mira3 LMU with a Bruker Quantax 200 energy dispersion analyser (high vacuum regime with an accelerating voltage of 20 kV with electron recoil detection and a data accumulation period of 300 s); the elemental analysis data was evaluated using Bruker Esprit software.

9 X-ray diffraction analyses were carried out by Jiří Másilko at the Institute of Materials Science, Faculty of Chemistry, Brno University of Technology.

10 The measurement was carried out under the following conditions: X-ray tube current: 30 mA, voltage: 40 kV; scan axis gonio; step size: 0.013 Å; step time: 96 s; imaging range: 5–90 °2Th; the results were evaluated using HighScore Plus software.

11 The presence of potassium was detected, and the content of sulphur is rather low.

Tab. 7. Results of the material analysis using energy dispersive X-ray fluorescence (ED-XRF).

Tab. 7. Výsledky materiálové analýzy s využitím energodisperzního rentgen-fluorescenčního spektrometru (ED-XRF).

EDX_XRF_FRACTURE																						
Inv. No.	Final classification	Fe	Si	Mn	Al	Cl	Na	Mg	Ca	K	Ti	P	S	Zr	V	Rb	Sr	Zn	Pb	Co	Ni	Mo	Bi
S 3712	cat. 1 (smelting)	86.4	3.3	7.8	0.3	0.8	< 0.594	0.2	0.6	0.3	0.1	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	< 0.002
S 3840	cat. 1 (smelting)	86.0	5.9	5.0	0.8	0.8	< 0.658	0.3	0.4	0.2	0.2	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	< 0.002
S 1648	cat. 1 (smelting)	90.2	2.5	5.9	0.2	0.3	< 0.560	0.2	0.3	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	< 0.002
S 3707	cat. 2 (smithing)	93.3	3.1	1.1	0.4	0.7	< 0.604	0.2	0.4	0.3	0.1	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	< 0.002
S 3886	cat. 2 (reheating?)	94.5	2.7	0.9	0.3	0.4	< 0.660	0.2	0.5	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	< 0.002
S 3596	cat. 2 (smithing)	94.1	2.8	0.6	0.5	0.7	< 0.619	0.2	0.3	0.3	0.1	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	< 0.002
S 3728	cat. 3 (forge lining)	39.9	39.7	0.6	4.3	1.2	< 1.574	0.8	4.6	4.1	2.6	0.4	0.0	0.8	0.2	0.2	0.2	0.1	0.1	0.1	0.0	0.1	< 0.005
S 3730	cat. 3 (forge lining)	44.3	37.9	1.1	3.3	1.8	< 1.595	0.8	1.0	4.1	2.9	0.8	0.0	0.9	0.2	0.2	0.2	0.0	0.0	0.1	0.1	0.1	< 0.005
S 3849	cat. 2 (reheating)	90.1	3.4	1.9	0.5	0.9	< 0.935	0.3	1.3	0.3	0.3	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	< 0.003
S 3854	cat. 2 (reheating)	91.0	3.4	2.2	0.8	0.6	< 0.762	0.3	0.7	0.4	0.2	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	< 0.003

ED_XRF_POWDER																		
Inv. No.	Final classification	Fe	Si	Mn	Al	Cl	Na	Mg	Ca	K	Ti	P	S	Zr	V	Rb	Sr	Pb
S 3712	cat. 1 (smelting)	73.1	13.0	6.6	2.7	1.6	0.5	0.5	0.6	0.3	0.1	0.8	0.0	0.0	0.0	0.0	0.0	0.0
S 3840	cat. 1 (smelting)	70.5	17.0	4.2	3.9	1.7	0.7	0.6	0.4	0.4	0.2	0.3	0.0	0.0	0.0	0.0	0.0	0.0
S 1648	cat. 1 (smelting)	79.6	10.0	5.3	2.0	1.7	0.3	0.3	0.4	0.1	0.1	0.3	0.1	0.0	0.0	0.0	0.0	0.0
S 3707	cat. 2 (smithing)	83.7	8.3	0.7	2.5	2.1	0.5	0.3	0.5	0.2	0.1	1.0	0.0	0.0	0.0	0.0	0.0	0.0
S 3886	cat. 2 (reheating?)	85.5	7.8	0.7	2.3	1.8	0.4	0.3	0.6	0.2	0.1	0.6	0.0	0.0	0.0	0.0	0.0	0.0
S 3596	cat. 2 (smithing)	81.4	8.3	0.4	1.7	1.6	0.5	0.4	1.7	0.2	0.1	3.4	0.1	0.0	0.0	0.0	0.0	0.0
S 3728	cat. 3 (forge lining)	25.8	49.5	0.4	8.5	2.7	2.2	1.3	3.0	2.5	1.0	2.3	0.1	0.2	0.1	0.1	0.1	0.0
S 3730	cat. 3 (forge lining)	27.1	53.7	0.6	8.1	2.6	1.3	0.9	0.7	2.8	1.1	0.7	0.0	0.2	0.1	0.1	0.0	0.0
S 3849	cat. 2 (reheating)	75.2	12.8	1.2	4.5	1.9	0.8	0.7	0.9	0.5	0.3	0.9	0.1	0.0	0.0	0.0	0.0	0.1
S 3854	cat. 2 (reheating)	72.4	14.0	1.7	4.7	2.2	1.5	0.7	0.8	0.6	0.3	0.9	0.1	0.0	0.0	0.0	0.0	0.0

Category 1 slags (Nos. 1, 2 and 3) are chemically characterized as three-phase slags rich in iron and manganese comprised of fayalite (Fe_2SiO_4), wüstite (FeO) and glass matrix (SiO_2, quartz form) phases. A small quantity of magnetite (Fe_3O_4) is also present. As all the specimens are morphologically characterized by graphite-grey compact fracture and a flow structure that originated from their tapping during their smelting, they can be quite securely identified as smelting tap

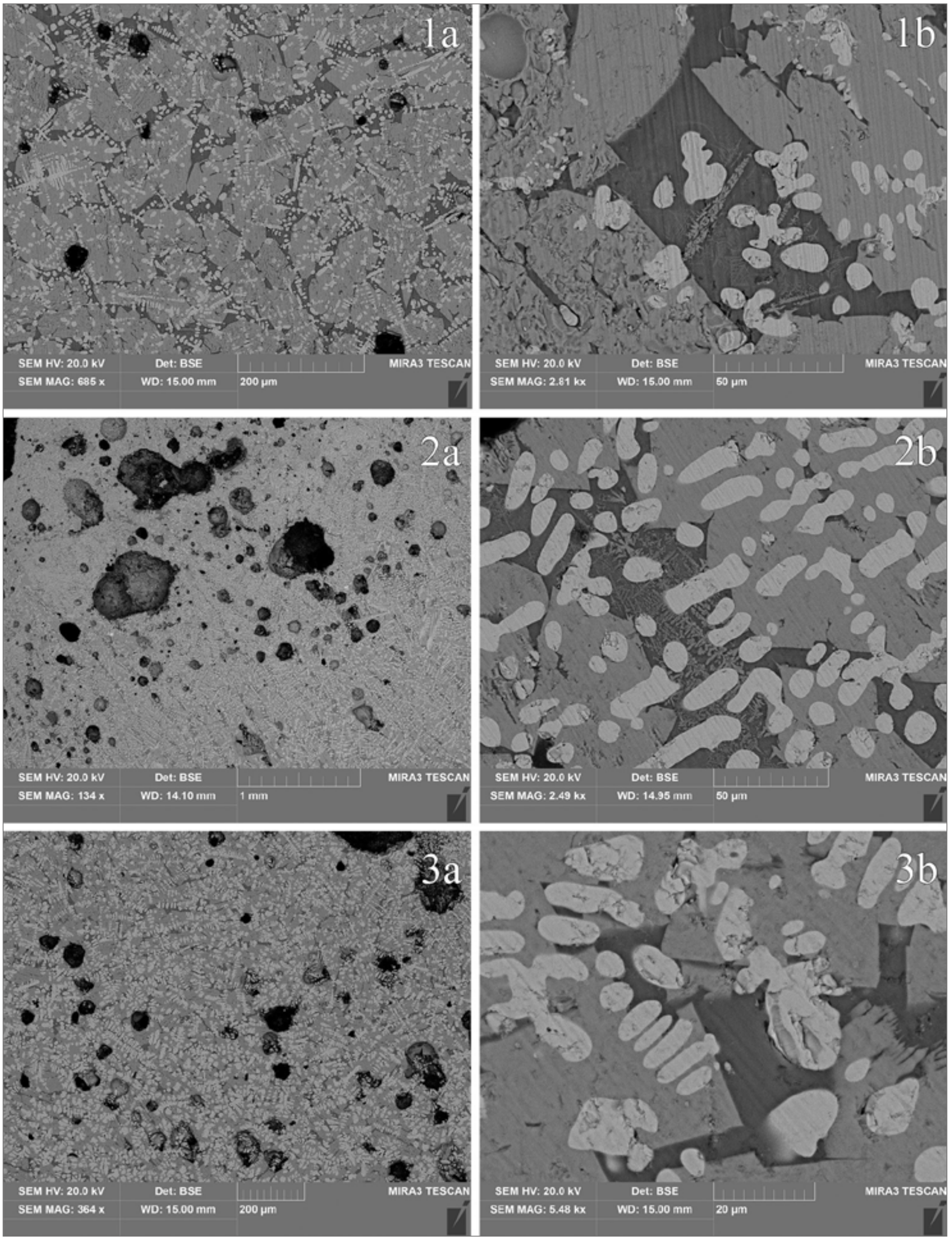

Fig. 12. Photographic documentation of analysed thin sections from a scanning electron microscope (samples Nos. 1–3).
Obr. 12. Snímky analyzovaných výbrusů pořízené skenovacím elektronovým mikroskopem (vzorky 1–3).

slags. They were the by-product of smelting of iron that was rich in manganese using slag tapping furnaces. According to known analogies, these may be contemporary embanked furnaces with a thin front wall or free-standing shaft furnaces with a shallow hearth.

Category 2 slags (Nos. 4, 5, 6, 9 and 10) varied more both chemically and morphologically. The category contains multi-phase slags rich in iron and poor in manganese. They are primarily

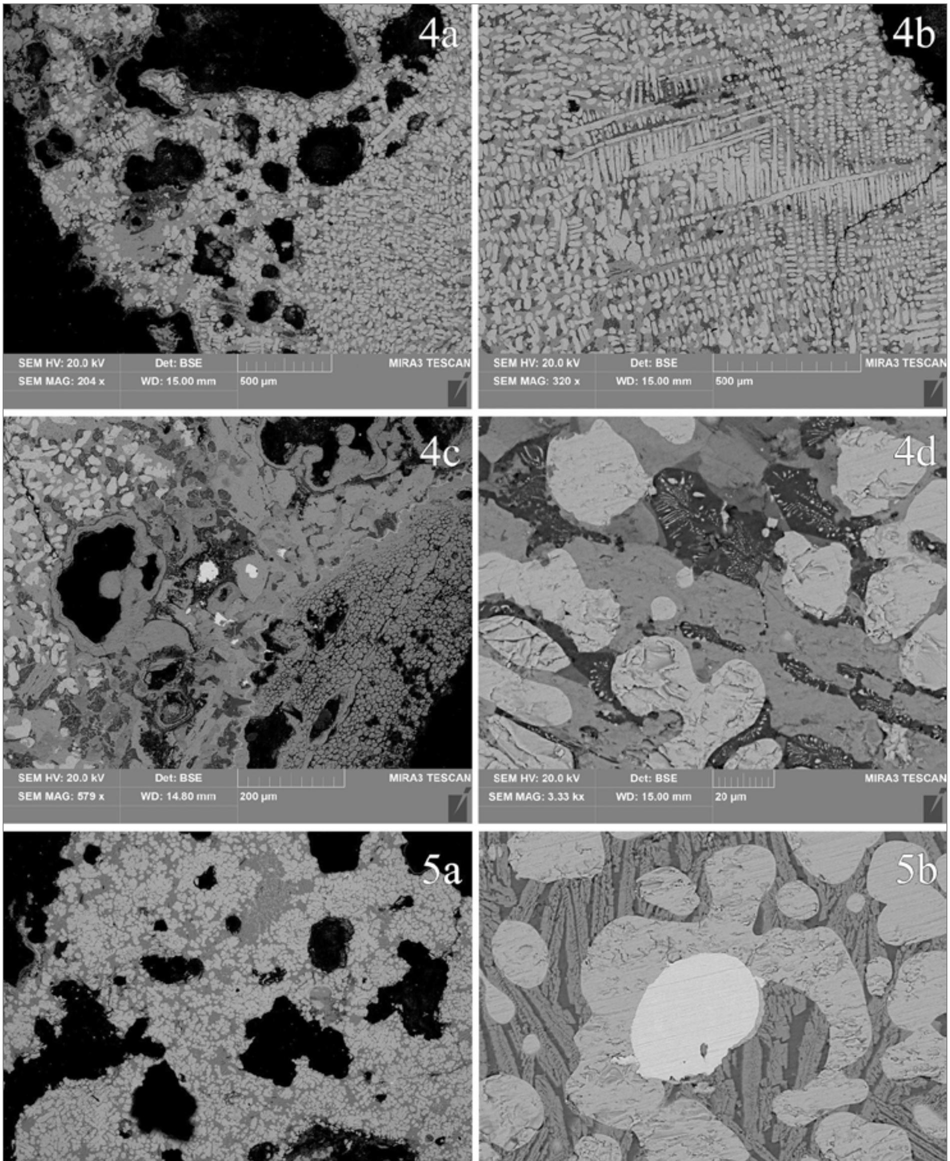

Fig. 13. Photographic documentation of analysed thin sections from a scanning electron microscope (samples Nos. 4–5).
Obr. 13. Snímky analyzovaných výbrusů pořízené elektronovým mikroskopem (vzorky 4–5).

characterized by the presence of fayalite, wüstite, glass quartz matrix and magnetite phases (the content of magnetite is generally higher when compared to Category 1). Other differences from the first group include the presence of iron phases originating from weathering in the form of goethite (present except for slag No. 10) and lepidocrocite (present in slags Nos. 5 and 9). This category most probably contains by-products of the further processing of iron including initial

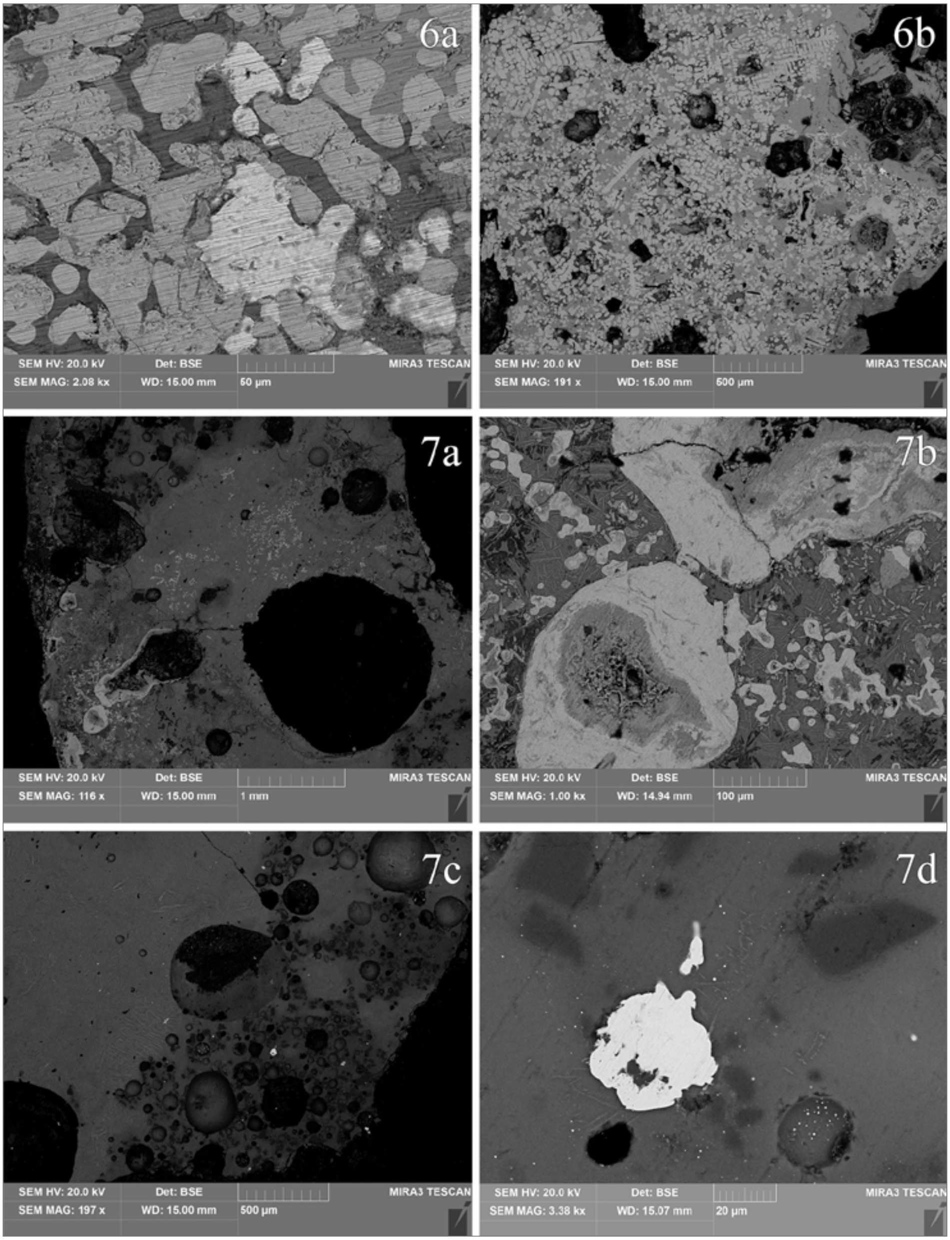

Fig. 14. Photographic documentation of analysed thin sections from a scanning electron microscope (samples Nos. 6–7).
Obr. 14. Snímky analyzovaných výbrusů pořízené elektronovým mikroskopem (vzorky 6–7).

reheating of a bloom using a reheating hearth and its consequent processing in the smithy. This conclusion is supported also by the morphological qualities and find context of the specimens. They included a piece of characteristic plano-convex shape and a rusty porous specimen, both discovered within the smithy, one rusty porous specimen from a feature adjacent to the reheating hearth, and two porous greyish specimens from the reheating hearth itself.

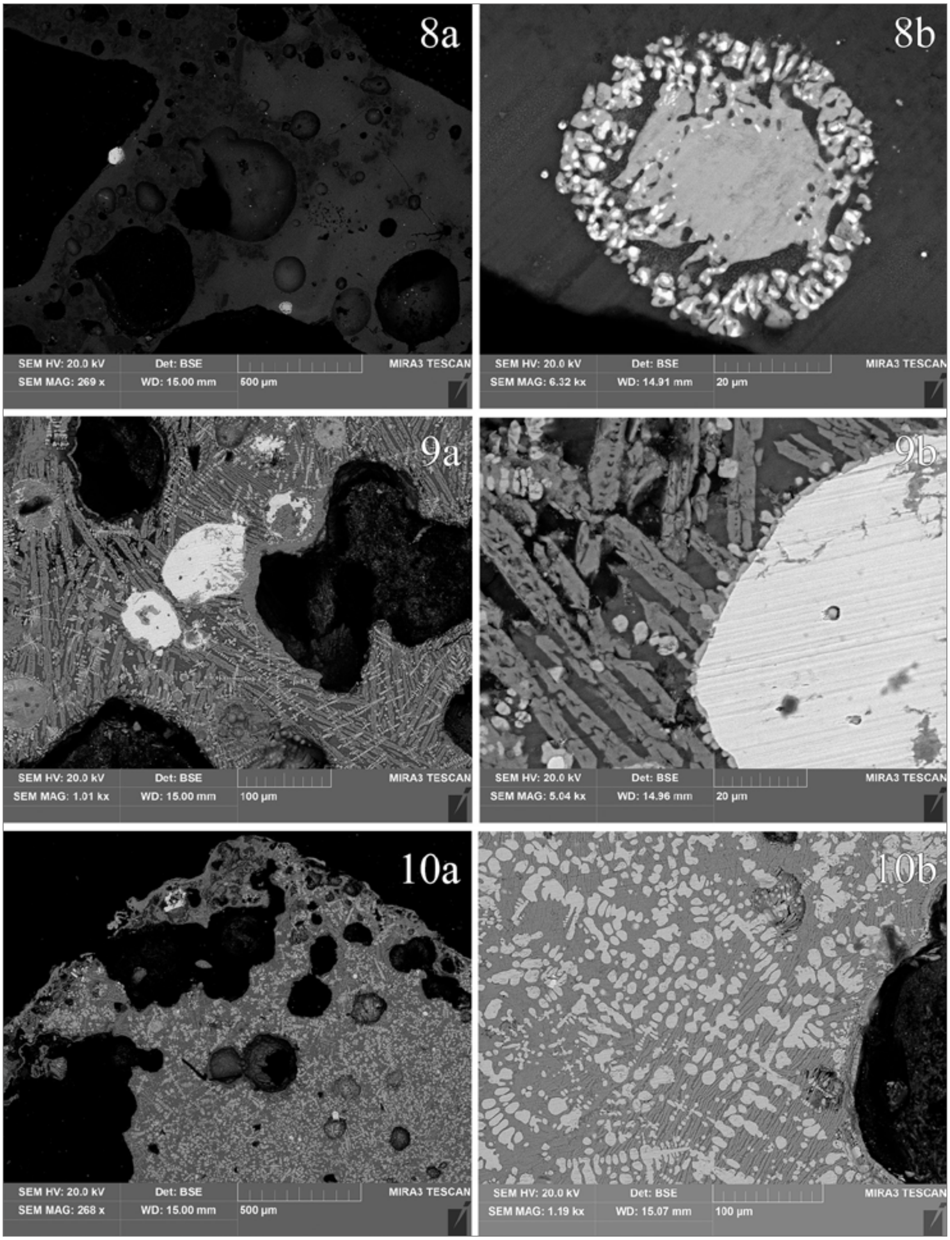

Fig. 15. Photographic documentation of analysed thin sections from scanning electron microscope (samples Nos. 8–10).
Obr. 15. Snímky analyzovaných výbrusů pořízené elektronovým mikroskopem (vzorky 8–10).

Tab. 8. Results of the material analysis using X-ray powder diffraction (XRD).

Tab. 8. Výsledky materiálové analýzy s využitím rentgenové práškové difrakce (XRD).

Inv. No.	Final classification	Fayalite $(FeMn)_2SiO_4$	Wuestite FeO	Goethite FEOOH	Lepidocrocite FeOOH	Magnetite Fe_3O_4	Quartz SiO_2	Cristoballite SiO_2	Spinel $MnFeTiO_4$	Albite $Na(AlSi_3O_8)$	Sanidine $KAlSi_3O_8$	Leucite $KAlSi_2O_6$	Ankerite $Ca(FeMg)(CO_3)_2$	Calcite $CaCO_3$
S 3712	cat. 1 (smelting)	59	28			2	12							
S 3840	cat. 1 (smelting)	68	18			1	13							
S 1648	cat. 1 (smelting)	59	39			2	1							
S 3707	cat. 2 (smithing)	45	27	9		5	8					7		
S 3886	cat. 2 (reheating?)	27	29	4	7	3	11			13	8			
S 3596	cat. 2 (smithing)	27	6	5		12	35							
S 3728	cat. 3 (forge lining)	9				2	85	2	1	3	5			8
S 3730	cat. 3 (forge lining)	3				2	88	8						
S 3849	cat. 2 (reheating)	54	9	4	3	5	20						5	
S 3854	cat. 2 (reheating)	54	29			2	16							

Category 3 slags (Nos. 7 and 8) are composed primarily of silicon with an increased content of aluminium, potassium, sodium, magnesium, chlorine and titanium and a low content of iron and manganese. These slags comprised predominantly of a glass matrix in the form of quartz and its high-temperature modification, cristobalite. Fayalite and magnetite are also present in smaller quantities, as are sporadic phases of iron spinels and oxidic iron particles. The slags come from a strongly oxidizing environment. They are the product of the remelting of material rich in silicone with imprisoned grains of metallic iron or its oxides. As these specimens were found within the smithy, they probably represent slags that originated from overheating the smithing-hearth lining or its ceramic component (cf. Fig. 10:2).

5 Discussion

Besides finds in the Badálek and Nepluště fields, which are currently not available for further evaluation, the production and processing of iron was detected predominantly in the two adjoining fields of Niva and Zádvoří. In Niva field a smelting production has been identified by two metallurgical facilities situated on the periphery of a Middle Hillfort Period settlement (a furnace of an unidentified type and a reheating hearth). Consequent smithing is then evidenced by relicts of contemporary smithy in the neighbouring Zádvoří field. Evaluation of artefactual, and especially the slag assemblage from both production components, helped to clarify the extent of this production during the discussed period.

Tab. 9. Results of the material analysis using scanning electron microscopy with energy dispersive spectroscopy (EDS/SEM).

Tab. 9. Výsledky materiálové analýzy s využitím skenovacího elektronového mikroskopu s energiově-disperzním spektrometrem (EDS/SEM).

EDS_WP														
Inv. No.	Final classification	O	Fe	Si	Mn	Al	Cl	Na	Mg	Ca	K	Ti	P	S
S 3712	cat. 1 (smelting)	29.9	52.3	9.2	2.7	2.4	0.0	0.5	0.5	1.6	0.8	0.1	0.1	0.0
S 3840	cat. 1 (smelting)	29.6	50.6	8.8	4.3	2.1	0.0	0.5	0.7	2.1	1.1	0.1	0.2	0.0
S 1648	cat. 1 (smelting)	28.3	56.2	7.3	3.1	1.7	0.0	0.4	0.5	1.6	0.6	0.1	0.1	0.0
S 3707	cat. 2 (smithing)	28.9	55.7	7.2	0.7	2.7	0.0	0.5	0.7	1.7	1.3	0.1	0.3	0.0
S 3886	cat. 2 (reheating?)	27.0	61.3	5.4	0.6	1.7	0.1	0.3	0.3	1.9	1.1	0.0	0.2	0.1
S 3596	cat. 2 (smithing)	27.7	60.6	6.0	0.4	2.3	0.0	0.3	0.5	1.1	0.8	0.1	0.2	0.0
S 3728	cat. 3 (forge lining)	38.8	22.9	19.8	0.0	5.1	0.2	1.0	1.0	7.0	3.4	0.4	0.2	0.0
S 3730	cat. 3 (forge lining)	46.7	7.1	31.7	0.1	6.3	0.1	1.0	0.8	1.4	4.1	0.6	0.2	0.0
S 3849	cat. 2 (reheating)	33.0	42.3	10.7	0.8	5.9	0.0	0.5	1.1	3.3	1.8	0.2	0.3	0.1
S 3854	cat. 2 (reheating)	31.1	47.8	8.8	0.9	4.8	0.0	0.5	1.0	2.8	1.8	0.1	0.3	0.1

EDS_ST													
Inv. No.	Final classification	FeO	SiO_2	MnO	Al_2O_3	Cl	Na_2O	MgO	CaO	K_2O	TiO_2	P_2O_5	SO_3
S 3712	cat. 1 (smelting)	67.3	19.7	3.5	4.5		0.6	0.9	2.2	1.0	0.1	0.1	0.1
S 3840	cat. 1 (smelting)	65.1	18.8	5.5	4.0		0.7	1.2	2.9	1.3	0.2	0.4	0.1
S 1648	cat. 1 (smelting)	72.3	15.6	4.1	3.3		0.5	0.8	2.3	0.7	0.2	0.2	0.1
S 3707	cat. 2 (smithing)	71.6	15.5	0.9	5.2	0.0	0.7	1.2	2.4	1.6	0.1	0.7	0.1
S 3886	cat. 2 (reheating?)	78.9	11.6	0.8	3.2	0.1	0.4	0.5	2.6	1.3	0.0	0.4	0.2
S 3596	cat. 2 (smithing)	78.0	12.8	0.5	4.3		0.5	0.8	1.5	1.0	0.1	0.4	0.0
S 3728	cat. 3 (forge lining)	29.5	42.3	0.1	9.6	0.2	1.4	1.7	9.9	4.1	0.6	0.5	0.0
S 3730	cat. 3 (forge lining)	9.1	67.8	0.2	12.0	0.1	1.3	1.3	1.9	4.9	1.1	0.4	0.1
S 3849	cat. 2 (reheating)	54.4	22.8	1.1	11.1		0.7	1.8	4.6	2.2	0.3	0.7	0.2
S 3854	cat. 2 (reheating)	61.5	18.8	1.2	9.1		0.7	1.7	3.9	2.2	0.2	0.6	0.1

Analyses of slag confirmed iron smelting at the site. It is evidenced mainly by Category 1 slags, which were determined as refuse of smelting ore that was rich in manganese using a furnace that allows slag tapping. The localization of some of these tap slags within the former smithy is interesting (see Tab. 3). This can be perceived as an indication of further processing or the utilization of smelting refuse by smiths (cf. Pleiner 1969, 472; cf. Bárta–Hlavica in print). Beside relicts of the smelting furnace itself, the smelting is indirectly evidenced also by the find of a tuyere block from a feature adjacent to the reheating hearth (near the smelting furnace) and by multiple iron ore finds recorded in the examined features and within surface finds in the municipality's cadastral area. However, the quantitative extent of the smelting production is still difficult to estimate. The absence of massive refuse piles and the only sporadic presence of remains of smelting facilities suggest much less intensive production compared to Great Moravian workshops in the Moravian Karst. It needs to be considered, however, that existing evidence might have been still partly affected by the current state of research, or later anthropogenic interventions in the landscape, which were presumably more extensive in the Boskovice Furrow than in the Moravian Karst.

More variable Category 2 slags evidence the consequent processing of iron at Bořitov. The category consists of specimens richer in iron and poor in manganese, which distinguish them from the tap slags included in Category 1. Slags from this category can be interpreted as by-products from various stages of iron processing including the reheating of blooms and consequent forging of iron. While specimens found within the smithy and its adjacent feature (Figs. 11:4, 6) are most probably refuse of forging, two previously unclassified specimens (Figs. 11:9, 10) are also included in this category, and taking into account their contexts, those can be quite securely interpreted as reheating slags. One of these specimens also contains a distinct middle aperture, it thus probably formed itself near the tuyere of the reheating hearth. Blacksmithing activity is indicated also by some iron artefacts from the remnants of the presumed smithy, above all a flat piece of iron and a quadrilateral bar connected by rust or welding. Especially the latter was most likely a semi-finished product immediately preceding the forging of the final product (cf. Hlavica–Bárta–Merta 2020, 17, Figs. 18, 19 on p. 23) or the remnant of the faggoting of two iron semi-finished products (for illustration, see Hlavica–Bárta 2021, 16–17, Figs. 6, 7 on pp. 16–17). The Bořitov smithy thus most probably processed iron into products, and it could possibly recycle it there as well.

The approximate assessment of tuyeres has also made it possible to reach interesting conclusions. Their evaluation makes it possible to comment on the issues of their chronological sensitivity, i.e., to specify general presumption based on the tuyeres from Moravian Karst (Souchopová 1979, 81–82; 1986, 32), that thin-walled tuyeres (about 3–4 mm) were more typical of the Middle Hillfort Period and thick-walled (up to 15 mm) ones of the Late Hillfort Period. However, most specimens from the Niva and Zádvoří fields show much more variation (Tab. 4) despite the fact that accompanying pottery material dates their contexts to the Middle Hillfort Period (the smithy), or slightly earlier (the reheating hearth).

It seems, therefore, that certain morphological categories of tuyeres are rather characteristic of a particular type of technological device (see Pleiner 1958, 262) or in this particular case, it may manifest a lower standardization of the ceramic components of metallurgical facilities, which can indicate lower levels of specialization, and organization of iron production in general (see also Costin 2005, 1064–1067). Chronological testimony of tuyeres might have been then valid in the Moravian Karst, an area where the character of iron production of the Middle Hillfort Period went through a considerable qualitative change (including the type of the metallurgical facilities used) after the demise of Great Moravia, but it cannot be used quite reliably in rural areas, especially during the Middle Hillfort Period.

The find of a tuyere block (Fig. 10:1) from the pit adjacent to the reheating hearth is quite enigmatic. Similar cuboid tuyere blocks are usually associated with slag-pit furnaces, in which the slag flows down into the deep hearth during the smelting (e.g. Pleiner 2000, Fig. 35 on p. 150). This is, however, in contradiction with the finds of slags with the flow structure that originated from types of furnaces enabling slag tapping such as a shaft furnace with a thin front wall or with a shallow hearth (Hauptmann 2021, 233–235). Various types of furnaces might have been thus used at the site, or as there are no contemporary analogies for it from the region of Moravia, it may have been a yet unknown variant of a furnace.

The proof of the presence of smelting production in Bořitov during the Middle Hillfort period is important information. This evidence clearly shows that where suitable resources were available, iron production might have been locally organized, i.e., carried out by local settlement communities for the purposes of local consumption and possibly also exchange (cf. Loftsgarden 2019; see also Svenson et al. 2008). The assumption about the independent organization (see also Costin 2005, 1070–1071) of Middle Hillfort Period iron-smelting production in Bořitov is also supported by an analysis of mutual geographical relations between the Moravian Karst, Boskovice Furrow and Middle Hillfort Period centres. The Moravian Karst, with more intensive iron production proved during the existence of Great Moravia, was situated well inside the presumed administrative-market zone of the Staré Zámky centre in Brno-Líšeň (Fig. 1).[12] In view of the absence of more permanent settlements, iron production in the area of the Moravian Karst was probably directly organized from this nearby fortified centre. A higher level of organization is indicated by the systematic arrangement of the contemporary workshops, the uniformity of the components of production facilities (such as the tuyeres) and the subsequent hiatus and deterioration of production after the demise of Great Moravia, when the settlement at Staré Zámky was significantly reduced and probably also lost its central function (Měřínský 2014a, 203).

In contrast, the northern part of the Boskovice Furrow (starting with Bořitov), according to a spatio-temporal accessibility model, was probably outside the direct authority of Staré Zámky. As the northern part of the Boskovice Furrow can then be hypothetically administered by contemporary northern centres such as Křenov-Mařín, or possibly Biskupice (Procházka 2009, 109–110, 147–150), Bořitov itself lies almost precisely between Staré Zámky and these more northerly located centres (Fig. 1). This geographical position of Bořitov was suitable for establishing independent production, as it was probably on the periphery of the administrative reach of contemporary centres, but it was also advantageous for establishing the articulation point between already existing central places, especially taking into account the existence of a nearly south-northern trade route (cf. Christaller 1966, 74–76, Fig. 4; Hodder–Orton 1976, 60, Fig. 4.5b; Minc 2006, 86–87, Fig. 1). The Middle Hillfort Period settlement in Bořitov thus carried the potential to consequently form itself into a lower-level market node (i.e. rural marketplace) interwoven in the Great Moravian market system (cf. Hlavica–Procházka 2020, 78). But the extent of the production within Bořitov identified so far indicates that the gradual bottom-up formation of this new potential articulation node was interrupted by the decline of Great Moravia, as any significant production activities are yet evidenced in the Late Hillfort Period archaeologically.

New knowledge about Bořitov also corrects the previous general assumption that rural smithies were dependent solely on iron obtained through central marketplaces, and the recycling of previously used iron (cf. Hlavica–Procházka 2020, 76). Within suitable conditions, especially the nearby presence of iron ore, the local communities were obviously able to self-supply themselves with iron at least to a certain extent. But this also indicates that the tighter bottlenecking, i.e., constriction of the flow of the iron and its products by contemporary elites could be achieved only with difficulty, as they were not able to fully prevent independent production of iron within the contemporary economic system, especially within rural settlements.

12 Fig. 1 shows an approximate delimitation of the hypothetical administrative-market zones of the centre Staré Zámky in Brno-Líšeň, and of the Křenov-Mařín centre by means of isochrones with the value of a one-hour walking distance through a well passable terrain (road). The isochrones were calculated based on Tobbler's equation (Tobler 1993). The chosen eight-hour radius corresponds to the so-called "administrative limit" model of unspecialized (chieftain) central authority, i.e., the area of a half-day march (c. 30 km) that can be efficiently controlled from the centre without the establishment of additional administrative outposts (Spencer 2010, 7119–7120; Hlavica 2020, 33–36). The thus defined administrative limits around Great Moravia's main central places conspicuously correlate with the presumed spatial distribution of characteristic pottery shape categories defining so-called pottery groups (Hlavica–Procházka 2020a, Fig. 33, see also Vlkolinská 1995, 37). It is likely that professionally made quotidian goods from central workshops also circulated within these zones. This suggests that these administrative zones most probably overlapped with the market zones (on this, see Minc 2006, 82–91) of the Great Moravian market system.

Nevertheless, these assumptions need to be further refined. The evaluation of assemblages and further field research of more northerly situated settlements in the Boskovice Furrow is the most promising path forward. They can uncover the quantitative, as well as qualitative, extent of rural production on rural sites located here. A more detailed investigation of the transformation in the quantity, spatial distribution, and character of iron production at the sites of the two examined regions in the period following the decline of the Great Moravian organizational structure is also desirable. As illustrated already by the existing findings concerning the Moravian Karst, this is one of the ways that may cast light on the role the former Great Moravian elites played in the extent and organization of iron production. Current knowledge about the Moravian Karst shows that changes in the political economies of regional elites may manifest itself through a detectable qualitative change on the local scale, in this particular case between the character of production sites from the Great Moravian period and from the time after the decline of Great Moravia.

6 Conclusion

The presented text aims to characterise iron production in the cadastral area of the present-day municipality of Bořitov, where an early medieval rural settlement with Middle Hillfort Period evidence of iron smelting and forging was located. Based on the newly obtained knowledge, it tries to understand in more detail the specifics of iron production in the northern part of the Boskovice Furrow as compared to the neighbouring Moravian Karst region and ponder the wider background of the organization of production of this crucial commodity during the Middle Hillfort Period. The analysis of material acquired by earlier research of Bořitov made it possible to identify smithing production within the site, as well as remnants of iron smelting and of the reheating of iron blooms. These stages of iron production and processing have been proved by specific categories of slags, whose classification based on the context and morphology of specimens was further supported using advanced material analyses, namely a combination of pXRF, ED-XRF, XRD, metallography and SEM/EDS.

Compared to the smelting sites of the Middle Hillfort Period in the Moravian Karst with their extensive furnace batteries and refuse piles, contemporary iron smelting in Bořitov was most probably performed on a lower level of specialization, and thus probably primarily for the needs of the local community or possibly also some occasional exchange. This conclusion is supported by the evidence of subsequent processing of iron at the site, which is in contrast to the contemporary sites from Moravian Karst, where the forging of iron has not been proved again until the Late Hillfort Period, i.e., the time when Great Moravian organization, its centres and thus also production-distribution networks had declined.

An administrative-geographic model, based on spatio-temporal accessibility analysis, attempts to explain the difference of the organizational complexity of iron production between these two regions. It shows that besides differences in the environmental conditions (the suitability of the landscape for permanent occupation, abundance of ore sources), the character of the organization of iron production is probably also influenced by the direct reach of administrative authority from contemporary power centres. While good controllability of the Moravian Karst region from the nearby Great Moravian centre in Brno-Líšeň with all likelihood made it possible to directly organize more intensive production on a higher level of specialization, the less specialized production in Bořitov, situated on the boundary of the direct administrative reach of the Great Moravian central places, had the opportunity to act more independently.

Naturally, the presented model requires further verification. Promising avenues open especially in the thorough processing of more archaeological assemblages from the Boskovice Furrow region, not only from the period of the existence of Great Moravia but also from the post-Great-Moravian period. New specialized research is desirable in both of the mentioned regions. Attention should also be paid to the extensive – and yet only cursorily evaluated – archaeological assemblages from the contemporary centres. Besides the geographic distance from them, the considerations must also take into account other variables, including the abundance of potential ore sources in the individual regions or the general character of the landscape. The different state of the preservation of archaeological records also needs to be considered. Similar studies carry a significant potential to establish a good base for answering questions connected with the political and economic organization and its transformations in the Early Middle Ages. Through them we can considerably advance our knowledge about the organization of contemporary production and thus also about the role that elites residing in the power centres played in it.

The present work has come into existence with financial support from the Czech Academy of Sciences' research programme Strategy AV21 subtitled "Anatomy of European Society – History, Tradition, Culture, Identity" and with institutional support RVO: 68081758 of The Czech Academy of Sciences, Institute of Archaeology, Brno.

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Shrnutí

Archeologické doklady nezávislé produkce železa z venkovské osady 9. století v Bořitově (okres Blansko)

Zkoumání organizace řemeslné produkce a distribuce zboží a komodit v raném středověku je slibnou cestou, jíž mohou archeologové dosáhnout poznání o charakteru dobové společenské a politické organizace. V kontextu velkomoravské společnosti (ca 833–907) disponují zvláště velkým potenciálem regionálně poptávané komodity, a to především železo, které bylo bází dvou pilířů velkomoravské ekonomiky – zintenzivňující se zemědělské produkce a mobilizace zdrojů vně velkomoravského teritoria skrze kořistění. Do dnešní doby se archeologickými výzkumy podařilo získat množství menších i větších souborů artefaktů spojených s raně středověkou produkcí železa na Moravě, jež pocházejí zejména ze dvou výrazných regionů – Moravského krasu a Boskovické brázdy (obr. 1).

Zalesněná oblast Moravského krasu zachovala početné pozůstatky tavby železa, ovšem bez dokladů permanentního osídlení, a to z období jak středohradištního (ca 800–950), tak mladohradištního (ca 950–1200). Exkavace těchto lokalit naznačují komplexnější organizaci a intenzivnější produkci ve středohradištním období, avšak následovanou hiátem po pádu Velké Moravy, a méně intenzivní produkcí od poloviny 10. století. Region Boskovické brázdy je oproti tomu charakteristický stepní krajinou, s doklady permanentního osídlení s menším rozsahem přilehlé produkce a zpracování železa během obou období. Většina známých lokalit však byla zkoumána pouze prostřednictvím povrchových sběrů či menších sondáží, znalosti o nich jsou tak stále fragmentární.

Jednou z mála výjimek je oblast dnešní obce Bořitov (obr. 3), která poskytla doklady železářských aktivit na několika polohách svého katastru. Nejvýznamnější doklady pochází z polohy Niva, kde byla objevena dvě metalurgická zařízení (podle dochovaných zpráv tavicí pec a vyhřívací výheň), a z polohy Zádvoří, kde se zachovaly pozůstatky kovárny. Vedle ostatních nálezů zahrnujících mimo jiné středohradištní keramiku (obr. 7, 8) či artefakty přímo spojené s produkcí a zpracováním železa (obr. 9, 10, tab. 4) poskytly obě polohy také množství strusky, která byla předběžně klasifikována na základě morfologických atributů (tab. 3), a tato klasifikace byla následně testována několika materiálovými analýzami vybraných vzorků (obr. 11, tab. 5) zahrnujícími metody pXRF, ED-XRF, XRD a SEM/EDS.

Výsledky analýz (tab. 6–9) umožnily ověřit klasifikaci vzorků do několika produkčních fází zahrnujících tavbu železa, jeho vyhřívání, stejně jako následné kovářské zpracování. Ukázaly tak, že během středohradištního období železo nebylo na lokalitě jen produkováno, ale také zpracováváno, pravděpodobně až do podoby finálních produktů. Tyto výsledky kontrastují se současnými znalostmi o Moravském krasu, odkud nepocházejí přímé doklady finálního kovářského zpracování až do mladohradištního období.

Obdržené výsledky nabízejí příležitost zvážit možné rozdíly mezi organizací produkce uvnitř obou regionů. Moravský kras je blíže důležitému středohradištnímu centru ve Starých Zámcích v Brně-Líšni (obr. 1), na jeho území se zachovaly baterie středohradištních tavicích pecí, stejně jako charakteristické odpadové haldy, avšak bez dokladů kovářství či permanentního osídlení v blízkosti tavebních lokalit. Je tak pravděpodobné, že produkce v Moravském krasu byla v tomto období organizována odjinud, pravděpodobně přímo ze Starých Zámků. Tento závěr podporuje předpokládané přerušení produkce po úpadku centra a následná produkce menšího rozsahu zahrnující též kovářství v mladohradištním období.

Na druhé straně kvalitativní rozsah produkčních aktivit uvnitř katastru obce Bořitov ukázal, že místní komunita byla ve středohradištním období v produkci železa zcela soběstačná. S ohledem na pozici Bořitova, který se nachází podstatně dále od centra ve Starých Zámcích (obr. 1), je poměrně oprávněné se domnívat, že řemeslníci této venkovské komunity jednali jako nezávislí producenti s cílem saturovat své vlastní potřeby, či případně směňovat. Tyto závěry, navzdory faktu, že je nelze jednoduše generalizovat kvůli specifickému charakteru Bořitova, jsou důležité pro budoucí úvahy o charakteru středohradištní (zvláště velkomoravské) ekonomiky a úrovni kontroly dobových elit nad ní.

Předkládaná práce vznikla za finančního přispění výzkumného programu Akademie věd České republiky Strategie AV21 s podtitulem: Anatomie evropské společnosti – historie, tradice, kultura, identita a institucionální podpory RVO: 68081758 Archeologického ústavu Akademie věd České republiky, Brno.

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