Abhandlung

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Pottery as a witness of commercialization: The case of 9th-century 'Great Moravia'

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Zusammenfassung: Der vorliegende Artikel präsentiert eine archäologische Methode zum Nachweis marktwirtschaftlichen Austausches anhand von Keramik, die hier als typische Handelsware definiert ist. Ein Keramikkomplex aus dem großmährischen (9. Jh.) Zentralort Staré Město bei Uherské Hradiště wurde archäometrisch (XRF, Petrographie, XRD) untersucht. Das Ergebnis zeigt ein komplexes Handelsnetz zwischen dem Zentrum und Teilen des Hinterlandes. Weiterhin bestätigen die Ergebnisse die These einer Einbindung des Zentrums in ein regionales Marktsystem und helfen, die Kommerzialisierungsprozesse der lokalen frühmittelalterlichen Wirtschaft zu verstehen.

Schlüsselworte: Vermarktung; Märkte; Großmähren; Töpferei; XRF; XRD; Petrographie

Abstract: This paper presents an archaeological method for the detection of market exchange using pottery as an archaeologically well-visible representative of former everyday items. The assemblage from the 9th-century Moravian centre at Staré Město near Uherské Hradiště was evaluated by archaeometric methods (XRF, petrography, XRD) and resulted in the detection of a complex exchange network connecting the centre with multiple parts of its hinterland. Results thus support the previously defined hypothesis about integration of the centre into a regional market system, and helps to refine the knowledge about the degree of commercialization of the period's regional economy.

Keywords: Commercialisation; Markets; Great Moravia; Pottery; XRF; XRD; Petrography

Introduction

In the course of pre-industrial history, the shift of less complex peripheral regions towards a commercial economy was usually initiated when local pre-commercial communities came into contact with commercial mentality often introduced by long-distance traders[1]. Besides the gradual integration of the periphery into the long-distance exchange networks, the contact with the commercial milieu also initiated gradual restructuring of local social and production relationships. The shift towards more intensified production, and changes in elite political economies with the aim to generate and mobilize surplus for long-distant trade includes the introduction of (full-time) production specialists and their concentration in central places forming production and exchange hubs[2]. The increased complexity of production was generally followed by the establishment of mutual relationships based on explicitly numerated debts[3], and the introduction of anonymous market exchange, secured by the network of interconnected marketplaces, i. e., the regional market system[4]. The concomitant effects included stronger inner economic integration and the political centralization of the region[5], increasing social inequality, and the accumulation of wealth within the upper social strata. Higher economic and political complexity, the emergence of complex extractive

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1 E.g. Hudson 1992, see also Graeber 2011.
2 Cf. Costin 2001; Junker 1999.
3 See Innes 2004.
4 See Minc 2006.
5 Cf. Spencer 1998.

institutions, and their long-term sustenance thus directly depended on the presence of the credit-debt relations, and related phenomena of commercialization and market exchange[6].

Among the peripheral regions, we can also include 9th-century Moravia, the frontier of the former Frankish realm, the core of which is located in the territories of today's Czechia and Slovakia. At the beginning of the 9th century, agricultural polities of the region started to organize themselves into the chiefdom confederacy ruled by the house of the Moymirids and labelled by later written sources as *Meghálī Moravía*, i. e. Great Moravia[7]. Not many historical sources exist that are able to clarify the level of economic, and political complexities of the polity, but those existing have illustrated that Great Moravia was able to establish and maintain long-distance trade connections both to Western and Eastern Europe, and also underwent a through inner social and economic transformation. Namely the Raffelstetten customs regulations from the first years of the 10th century testify to long-distance traders punting on salt ships from the Frankish realm to the 'Market of the Moravians'[8]. The trade of salt to Moravia from Southeast Europe, probably the mines in Transylvania controlled by the Bulgarians[9], is evidenced by the Annals of Fulda for AD 892[10]. The mention in the work of the Arabic traveller Ahmad ibn Rustah about a periodic three-day market held in the residential town of the Slavic 'chief of chiefs' called Swentbulk, i. e., probably the Moravian ruler Svatopluk (ruled between AD 871 and 894) from the house of the Moymirids[11] implies that the Great Moravian economy was also at least partially commercialized and had central places with a market function.

Numerous excavations of Moravian sites dated to the Great Moravian period[12] have also supported the image of Great Moravia as having a more complex economy including commercial relations and markets. They have yielded relics of multiple categories of former goods from prestigious to everyday. But contemporary everyday pottery is especially characteristic. Consisting of uniform pottery groups, i. e., stylistically and morphologically standardized assemblages[13] in the surrounding areas around the most important contemporary centres[14] it illustrates the increase of the Great Moravian economic complexity especially in comparison to the previous pre-Great Moravian period[15]. These standardized pottery assemblages reflect the introduction of professional pottery makers[16], and their spatial distribution also indicates the presence of more complex production-distribution networks with nodal points in contemporary centres[17].

As it has been hypothesized elsewhere[18], these nodal points have the geographical predisposition to organize themselves into the 'Great Moravian' market system. The economic and geographic model (Fig. 1) presumes the apical node articulating Moravia with the long-distance trade located in the advantageous geographical position of the fortified settlement of Pohansko near Břeclav[19] near the main power centre in Mikulčice[20]. Both centres shared a similar pottery group, i. e., similar pottery regarding its stylistic and morphological attributes[21], so the model presumes that they also shared a single market and also administrative zones[22], most likely under the direct administrative control of the ruling house of the Moymirids settled in Mikulčice[23]. The existence of additional pottery groups then indicates the presence of additional markets and market zones surrounding this market zone[24]. Their spatial distribution almost precisely mirrored normative spatial distribution of economic central places according to Central Place Theory model[25], which indicates the integration of neighbouring polities into a regional market system with the apical node controlled by the Moymirid rulers[26]. The market system was preliminary modelled as dendritic as the apical node Pohansko near Břeclav offers an opportunity to apply a bottleneck (constriction point in commodity chains) controlled by the ruling house settled in Mikulčice. It's main function was to constrict the inflow of imported goods into Moravian territory – besides prestigious goods such as jewellery from precious metals primarily circulating in a redistribution network[27], possibly also some bulk-luxuries or widely de-

6 Graeber 2011; Hirth 2010; cf. Wright 1977; Flannery 1998; Spencer 2010.
7 Wihoda 2014; Macháček 2019; Kalhous 2020.
8 Pfeffer 1955; Mitterauer 1964; Wolfram 1995.
9 Madgearu 2005.
10 Reuter 2012.
11 Hrbek 1969; Pauliny 1999.
12 See Kouřil 2014; Kouřil/Procházka 2018; Procházka 2009.
13 Mazuch 2020; Galuška 1995; see also Bubeník/Frolík 1995.
14 Macháček 2001; Dresler 2016; Vlkolinská 1995.
15 Hlavica/Procházka 2020a.
16 Cf. Costin 2005.
17 Cf. Stark/Garraty 2010; Knappett 2013.
18 Hlavica/Procházka 2020b; Hlavica in print.
19 See Macháček 2010.
20 See Poláček 2014.
21 Mazuch 2013.
22 Cf. Garraty 2009.
23 See also Hlavica in print.
24 Cf. Hirth 1998; Minc 2006; Garraty 2009.
25 Cf. Christaller 1966.
26 See Hlavica 2020; cf. Gibson 2011.
27 Galuška 2014a.

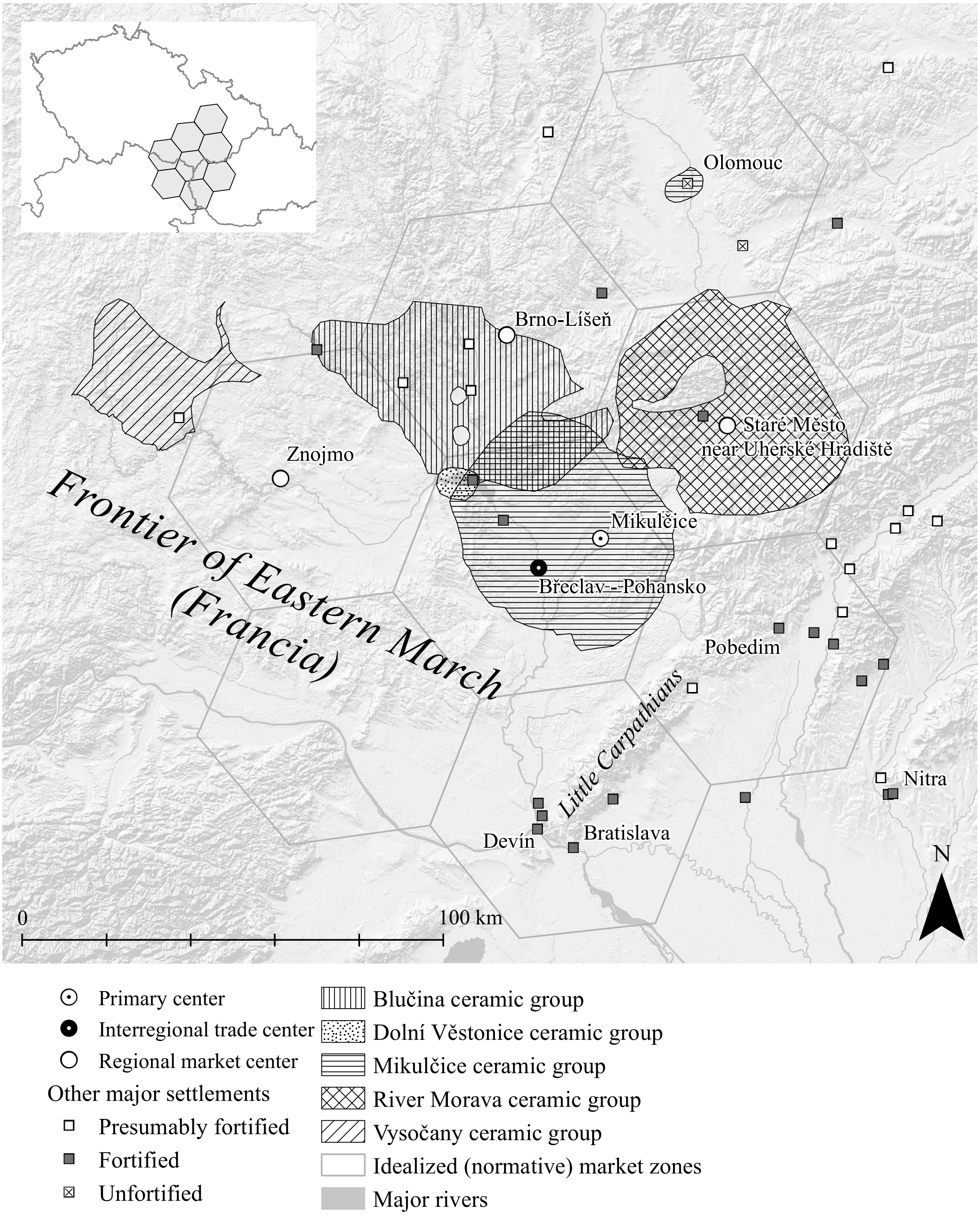

Fig. 1: Model of the presumed 9th century Moravian market system with apical node at Břeclav – Pohansko settlement and including surrounding major strongholds from the power core of the region (after Hlavica in print, modified).

manded consumer goods, such as salt, which is repeatedly mentioned in the written sources[28].

Further research of the Great Moravian market system thus offers opportunities to achieve a better picture of the dynamic changes of the contemporary regional economy. Its deeper understanding can also help elucidate the processes of commercialization, and integration of pre-industrial peripheral regions and polities in general. To achieve this goal, however, it is necessary to develop methods for recognition of the level of economic complexity, i. e., the level of commercialization, and the presence of market exchange. These methods must be able to identify former nodal points (market centres) of the market system, and explore their junctures. For such a research it is especially valuable to investigate the consumption of those consumer groups most dependent of the market. One of the most significant such group would be specialized producers settled in contemporary centres. Since these producers were generally focused on generating the surplus, they were at least partially excluded from the production of food and everyday items. Their self-subsistence was thus lowered, as they needed to be systematically supplied. Because of this dependency, the appearance of professional producers is often seen as directly connected to the emergence of a market exchange, because it is the most effective and stable way to supply producers continually as well as to exchange the surplus they generated[29]. The presumption applies even in the case of attached crafts, i. e., crafts, where resources for parts or the entire production process are controlled by political authorities[30]. The existence of a market provides the simplest distribution of food and variety of everyday items, as well as exchange of the surplus. The only alternative would be to secure local attached production of all the necessary goods, or to mobilize and distribute them via non-market (e. g., tributary) means. Even if these cases were partially possible, the complete elite autonomy in the production to secure the needs of their subjects entirely is highly unlikely due to the high costs of maintaining such a production system (both in terms of resources and workforce) when compared to the market mechanism. The hypothetical subsistence of attached crafts with everyday items based solely on the mobilization and non-market redistribution of everything necessary also suffers from the same problem. The organization and continual maintenance of a network serving for regular mobilization and non-market redistribution of food and multiple categories of everyday items would be extremely difficult, costly and unstable. Most probably for this reason, no evidence for such a redistributional system has yet been found[31].

The main aim of this paper is thus to present the potential of a small-scale analysis using the 9th-century Moravian pottery assemblage as an archaeologically well visible representative of former everyday items to reconstruct the shape and extent of its contemporary exchange network, and consequently to determine the most probable mode of exchange. From the artisan district 'U Víta' located within the former 9th-century Moravian centre at Staré Město near Uherské Hradiště previously modelled as one of the nodal points of 9th-century Moravian market system (Fig. 1), we sampled and evaluated a ceramic assemblage using XRF and XRD compositional analyses and the petrographic examination of thin sections. Using these tools, we have been able to recognize the provenance and production specifics of the pottery consumed by the local specialized artisans. While the material homogeneity of the assemblage would indicate supply from local sources and thus also admit the possibility of the non-market mobilization of pottery, the results described below illustrate the compositional heterogeneity of the assemblage pointing to multiple sources of pottery material outside the centre. This shows the existence of more complex exchange relations at greater distances that were most probably maintained through the local market. The results presented also imply the integration of rural communities into the market located in the centre, and thus at least partial commercialization of rural communities.

2 Material and Methods

2.1 Geological setting

The former Great Moravian centre located on the cadastral areas of today's municipalities Staré Město and Uherské Hradiště was situated at the northern part of the Lower Morava Valley, which is the northernmost section of the Vienna Basin. The valley around the centre forms a narrow corridor of the River Morava's floodplain that deposits on incoherent clastic sediments of the Vienna Basin. The river springs c. 100 km north of the site in area of crystalline rock outcrops (Lugicum and Silesicum) and erodes Palaeozoic (Palaeozoic of Moravian-Silesian region) and Cenozoic (Carpathian Foredeep Basin, Carpathian Flysch) sedimentary complexes before reaching the site. Particles from all

28 Cf. Adshead 1992.
29 Costin 2001; Stark/Garraty 2010.
30 See Costin 2005.
31 Garraty 2009; Stark/Garraty 2010.

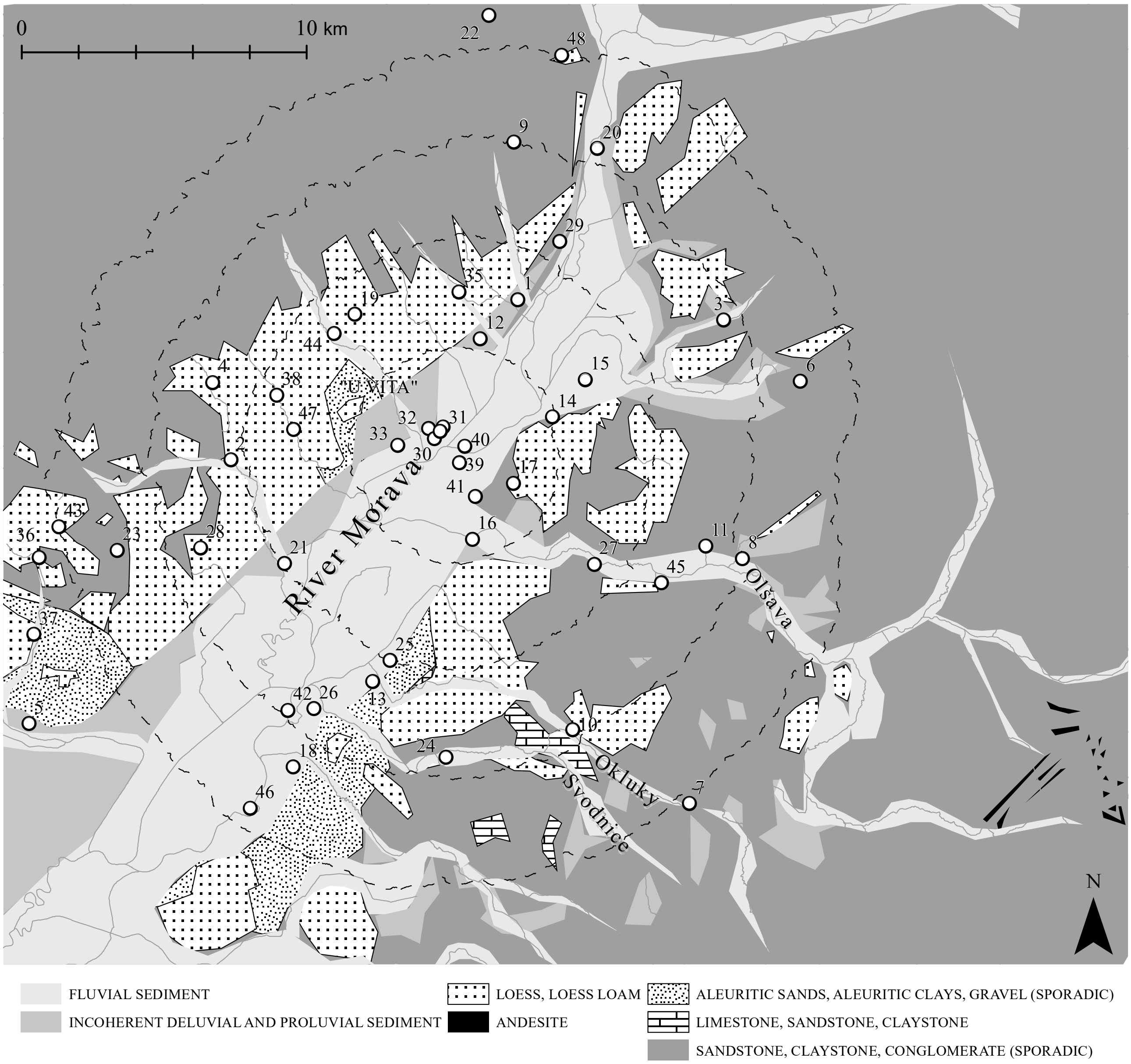

Fig. 2: Geological map of Staré Město's surroundings (Czech Geological Survey 2022, edited). Sites with 9th-century archaeological finds – 1: Babice; 2: Boršice; 3: Březolupy;4: Buchlovice; 5: Bzenec; 6: Částkov; 7: Dolní Němčí; 8: Drslavice; 9: Halenkovice; 10: Hluk; 11: Hradčovice; 12: Huštěnovice; 13: Chylice; 14: Jarošov; 15: Kněžpole; 16: Kunovice; 17: Mařatice; 18: Milokošť; 19: Modrá; 20: Napajedla; 21: Nedakonice; 22: Nová Dědina; 23: Ořechov; 24: Ostrožská Lhota; 25: Ostrožská Nová Ves; 26: Ostrožské Předměstí; 27: Podolí; 28: Polešovice; 29: Spytihněv; 30: Staré Město – "Na Dědině"; 31: Staré Město – "Na Kostelíku"; 32: Staré Město – "Na Valách"; 33: Staré Město – "Špitálky"; 34: Staré Město – "U Víta"; 35: Sušice; 36: Syrovín; 37: Těmice; 38: Tupesy; 39: Uherské Hradiště – Masarykovo nám.; 40: Uherské Hradiště – Rybárny; 41: Uherské Hradiště – Sady; 42: Uherský Ostroh; 43: Újezdec; 44: Velehrad; 45: Veletiny; 46: Veselí nad Moravou; 47: Zlechov; 48: Žlutava.

the regions of the River Morava catchment are expected to form the fluvial sediment in the valley (e. g. presence of amphiboles has been proved 20 km downstream from Staré Město[32]). The valley is surrounded by low hills of Carpathian Flysch formed mainly by sandstone and claystone. Specific geological formations contain limestone – the Hluk Development of the White Carpathian Unit southeast of the site. Volcanic rocks (andesite) of the Middle Miocene form dykes in the Flysch complex 25 km southeast of the site (Fig. 2).

32 Kadlec *et al.* 2009.

Fig. 3: Excavated area of the 9th century artisan district 'U Víta' at Staré Město near Uherské Hradiště (After Hlavica *et al*. 2016, modified).

2.2 Pottery assemblage

The pottery assemblage was collected in the part of the former Great Moravian centre called 'U Víta' located in relative proximity (c. 400 m to the north) to the 9th-century 'palace-type' building[33] during the extensive rescue excavation conducted in the late 1970s. Almost 150 excavated features distributed over the area of about 3000 m^2 and dated from the 9th century to the High Middle Ages[34] also contained multiple features interpreted as relicts of 9th-century ('Great Moravian') artisans' workshops (Fig. 3). These features were connected to goldsmith production[35], ironsmith workshops[36], and probably also two former pottery kilns (Fig. 4). The last-mentioned kilns along with some surrounding features served as refuse pits for broken 9th-century pottery[37]. One of the former kilns (No. 60) contained 673 discarded 9th-century sherds of a total weight of c. 13 kg, whereas the other (No. 63) contained 2,689 pottery sherds of a total weight of c. 64 kg. These two features thus together represent about 19 % of the quantity of the 9th-century ceramic material from the site consisting of nearly of 17,000 pottery fragments with various macroscopically identifiable features and level of fragmentation. The extent of the pottery collection thus makes these features representative as regards the pottery consumption within the artisan district.

2.3 Sampling and archaeometric analyses (XRF, petrography, XRD)

As the artisan district limits itself only to the period of the existence of Great Moravia, the assemblage from refuse pits could be securely dated to the 9th century, when workshops at the district were in operation. For the purpose of covering the whole potential variability of the assemblage, and to include all the potential sources of pottery into the

33 Galuška 2014b.
34 Marešová 1977; Snášil 1978.
35 Galuška 1989.
36 Galuška 1992.
37 Hlavica *et al.* 2016.

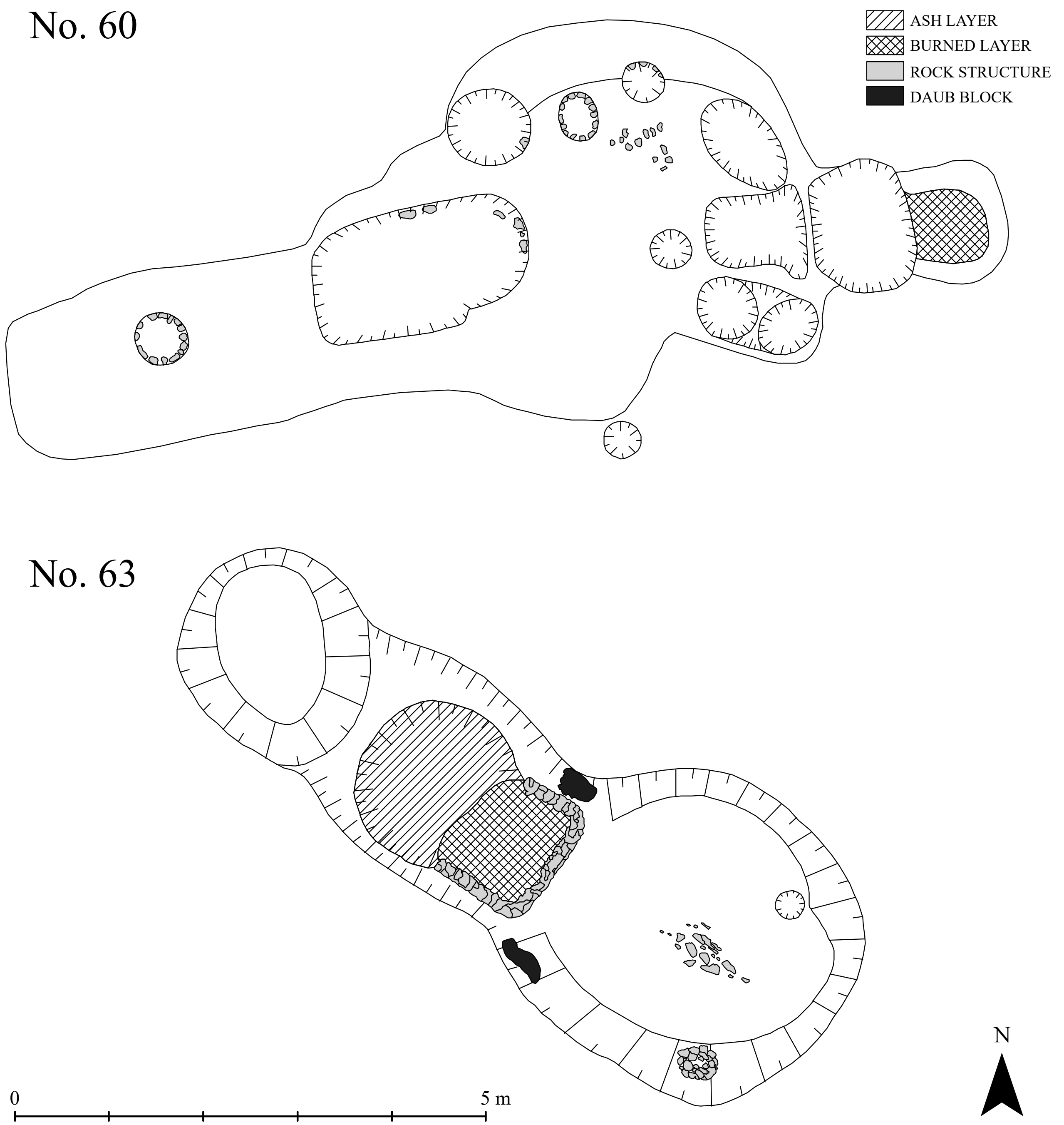

Fig. 4: Features Nos. 60 and 63 from the artisan district 'U Víta' interpreted as former pottery kilns and later served as refuse pits for broken pottery.

further archaeometric analyses respectively, macroscopic classification was conducted. Nevertheless, as is typical for settlement assemblages, even the evaluated assemblage of the ceramic refuse suffered from a high level of fragmentation. Its condition thus made it impossible to include morphologic qualities and more detailed decoration studies of the former vessels. The classification was thus based solely on the material qualities of fragments visible to the naked eye, especially clay and temper properties, including the colour of the fragment and structure of its surface, type and fraction of temper used, and the quality of firing. Regarding the results of this classification (see below), 53 samples including all macroscopic groups were then selected for the subsequent archaeometric analysis (Tab. 1).

A chemical composition analysis of selected samples was then undertaken for further selection of samples for petrographic analysis. The chemical composition analysis

Tab. 1: Samples and analyses used – MG – macroscopic group (see chapter 3.1), XRF – X-ray fluorescence spectrometry, OM – optical microscopy, XRD – X-ray diffraction.

Sample No.	Inv. No.	Feature	MG	XRF	OM	XRD
1	SM10910	63	4	+		
2	SM10778	63	4	+		
3	SM10319	63	4	+		
4	SM10734	63	4	+	+	
5	SM9168	60	4	+		
6	SM8821	60	4	+	+	+
7	SM9172	60	4	+		
8	SM9188	60	4	+	+	
9	SM10984	63	3	+	+	
10	SM10632	63	3	+	+	
11	SM10595	63	3	+	+	
12	SM10611	63	3	+		
13	SM9102	60	3	+		
14	SM9132	60	3	+		
15	SM8823	60	3	+	+	+
16	SM9150	60	3	+		
17	SM10718	63	5	+	+	
18	SM10955	63	5	+	+	+
19	SM10602	63	5	+	+	
20	SM10899	63	5	+	+	
21	SM9130	60	5	+		
22	SM8812	60	5	+		
23	SM8819	60	5	+	+	+
24	SM9140	60	5	+	+	+
25	SM10871	63	2	+	+	+
26	SM9558	63	2	+	+	+
27	SM9164	60	1	+	+	+
28	SM9112	60	1	+	+	
29	SM10990	63	6	+	+	+
30	SM9198	60	6	+	+	
31	SM9927	63	3	+	+	
32	SM9926	63	3	+		
33	SM10006	63	3	+		
34	SM9748	63	3	+	+	
35	SM9800	63	3	+		
36	SM9105	60	3	+		
37	SM8841	60	3	+		
38	SM9104	60	3	+		
39	SM9151	60	3	+	+	
40	SM9799	63	4	+		
41	SM9797	63	4	+		
42	SM9940	63	4	+		
43	SM9939	63	4	+		
44	SM9769	63	4	+	+	
45	SM9141	60	4	+	+	
46	SM9143	60	4	+		
47	SM9103	60	4	+	+	
48	SM9139	60	4	+		
49	SM9545	63	2	+		
50	SM9462	63	2	+		
51	SM9548	63	2	+		
52	SM9543	63	2	+		
53	SM9552	63	2	+		

was performed using a Rigaku NexCG energy dispersive fluorescence spectrometer with a 50 W Pd tube and silicon drift detector (SSD) of a resolution up to 145 eV. The device's excitation of secondary targets provides better signal-to-noise ratio. The excitation time was 120 seconds for every target. The samples were analysed in the form of pressed powder pellets. Matrix-based error in element quantification was minimized by using a calibration library, which is specialized for soils and ceramics. The library employs the appropriate international standards. These are the reference materials produced by the National Institute of Standards and Technology (NIST), the China National Analysis Centre for Iron and Steel, the National Research Centre for Certified Reference Materials in China and the National Institute of Advanced Industrial Science and Technology in Japan and MINTEK. The obtained element concentrations were statistically evaluated by principal component analysis (PCA).

PCA using the FactoMiner package in R[38] was performed on the obtained chemical composition. The PCA results were further used for hierarchical clustering[39] which served to select a subset of 25 samples for petrographic analyses. Standard thin sections (30 µm) were analysed by an Olympus BX 51 polarizing optical microscope. The thin section analysis methodology used in this study followed the procedures in the works of Whitbread[40] and Quinn[41]. Inclusion abundance was estimated according to Whitbread[42] and expressed as a semiquantitative score according to Sauer and Waksman[43]. The statistical analysis of the semi-quantities of rocks and minerals was performed by the principal component analysis that helped to sort the samples into fabric groups.

During light microscopy analysis, nine samples that showed potential signs of high firing temperature were further analysed by powder X-ray diffraction (XRD). The samples were pulverized in isopropyl alcohol using a McCrone Micronising Mill. Subsequently, 20 wt. % of zincite (ZnO) as an internal standard for amorphous phase quantification was added to the samples. The analysis was conducted using an X'Pert PRO MPD diffractometer, equipped with a Co tube ($\lambda K\alpha$ = 0.17903 nm) and a 1-D RMTS detector (X'Celerator) at the conventional Bragg-Brentano geometry. Measurement specifications: step size of 0.017° 2Θ, time per step of 200 s, angular range of 4–100° 2Θ, and the total scan duration was 9,254 s. The acquired data were processed using the Panalytical HighScore 4.8 and the Bruker AXS Diffrac plus Topas 4 software. The quantitative phase analysis was done by the Rietveld method. The maximum firing temperature was estimated based on the knowledge of the thermal resistance of the minerals present, such as clay minerals and carbonates[44].

2.4 Predictive classification

The prediction model created using the sparse partial least squares – discriminant analysis (sPLS-DA) was employed for the classification of samples that did not undergo petrographic analysis. The sPLS-DA method seeks variables that discriminate between groups the most effectively[45]. The sPLS-DA method has been implemented as an-open access library MixOmics for R statistical software that was designed to deal with data coming out of sequencing methods in biology[46]. The performance superiority on small datasets was taken advantage of for classification on the chemical composition data (ED-XRF). The initial prediction model was fitted with ten components to evaluate a number of components for the final model. The final number of components was determined by four-fold, 50-times repeated cross-validation. The tune function, which performs iteratively working each component separately, was used to define the optimal variables used to construct each component. The operations resulted in the two components necessary for the dataset classification. Component 1 is represented by Al and Ti and component 2 is expressed by Fe and Ni. For the model building documentation, see Supplementary Fig. 1. The small dataset of samples forced us to use all of them for model training to achieve the highest precision.

3 Results

3.1 Macroscopic classification

Macroscopically the ceramics assemblage corresponds to the pottery generally found within the different parts of the centre Staré Město near Uherské Hradiště and its hinterland during the Great Moravian period[47]. Based on differences of the clay properties and temper, six macroscopic groups were defined (Figs. 5; 6).

Macroscopic group 1 (Fig. 5,1): finely floated sandy and clayish material without temper. Vessels of this type of fabric were well fired. The colours of fragments varied from yellow to yellowish red or beige. In the evaluated assemblage, the macroscopic group 1 was represented by 59 pieces; two characteristic fragments from the group were selected for further analyses.

Macroscopic group 2 (Fig. 5,2): finely floated material without temper, vessels of this type of fabric were well fired to shades from grey to grey-white. In the evaluated assemblage, macroscopic group 2 was represented by 184 pieces; seven characteristic fragments were selected for further analyses.

Macroscopic group 3 (Fig. 5,3): fine clayish material without any significant admixture of sand. Temper is rare and in the form of small stone chips of less than 1 mm in size. Vessels of this type of fabric were well fired to shades of grey, light brown or reddish-brown. In the evaluated assemblage, macroscopic group 3 was represented by 1,124 pieces; 17 characteristic fragments were selected for further analyses.

38 Lê/Josse/Husson 2008.
39 Husson/Josse/Pagès 2010.
40 1986; 1995; 2001; 2017.
41 2013.
42 2017.
43 2005.
44 E.g. Földvári 2011.
45 Le Cao/Boitard/Besse 2011.
46 Le Cao *et al.* 2016.
47 Cf. Valášková 2010.

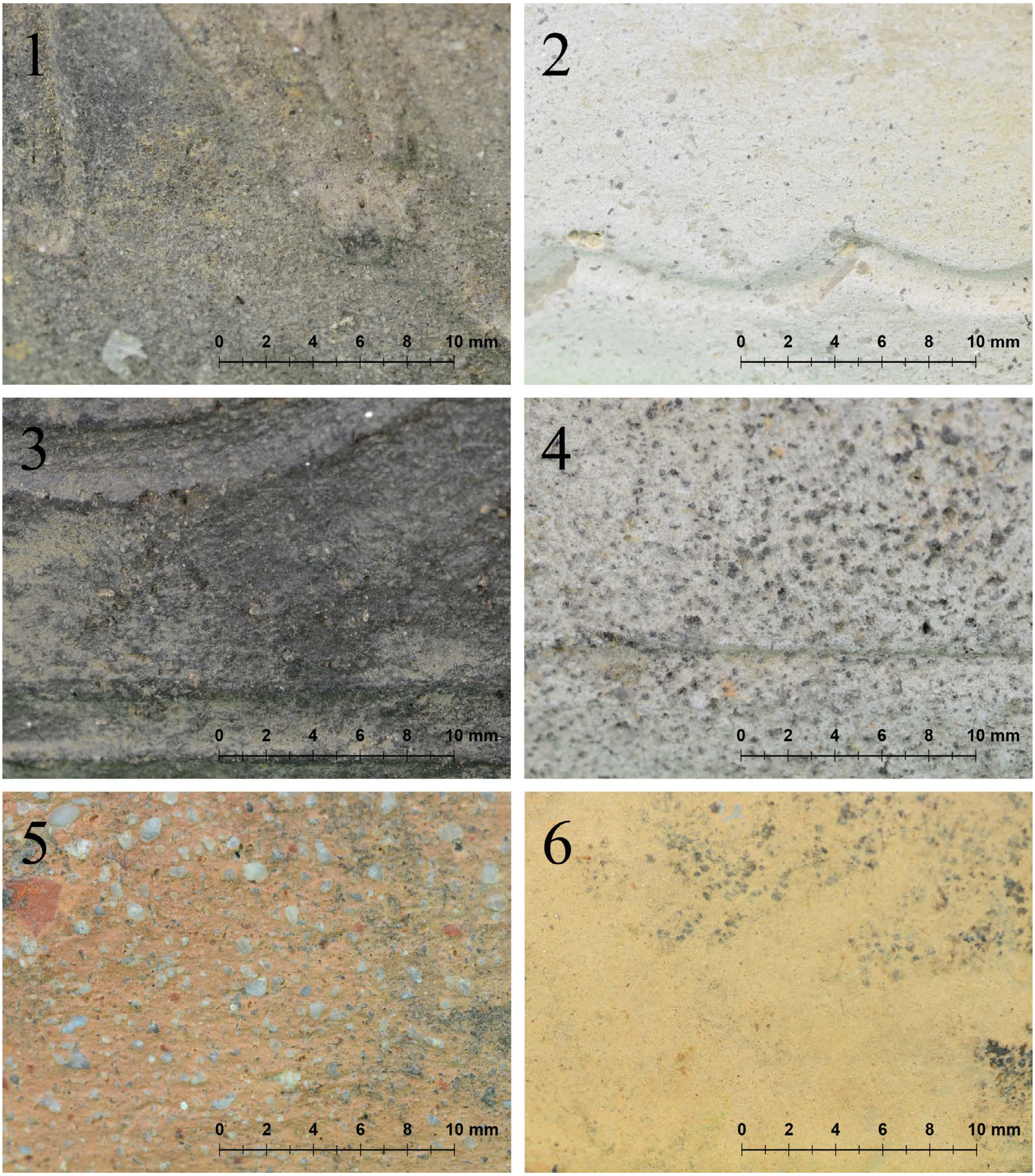

Fig. 5: Surfaces of pottery fragments classified into macroscopic groups. 1–6: Macroscopic groups 1–6.

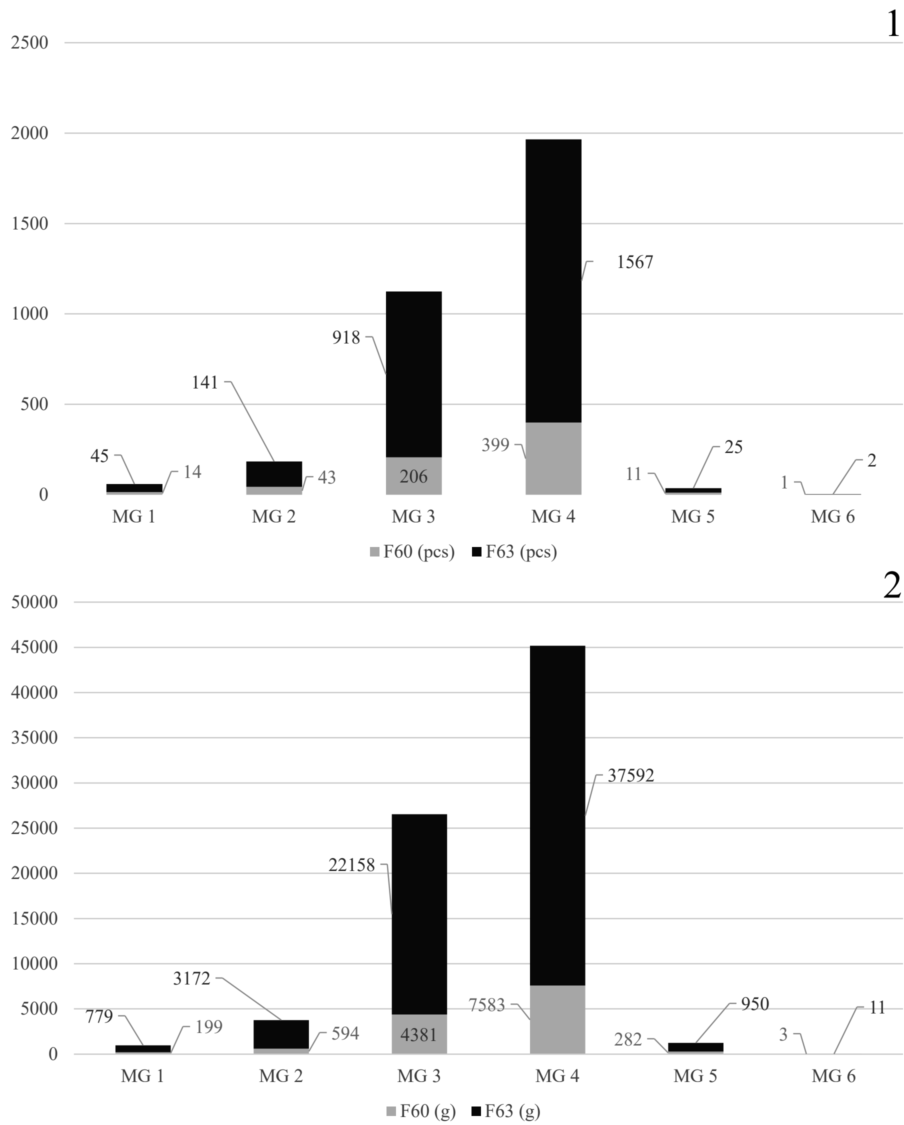

Fig. 6: Numerical (chart 1) and weight (chart 2) distribution between individual macroscopic groups from features Nos. 60 and 63.

Macroscopic group 4 (Fig. 5,4): fine clayish material tempered by graded sand, other temper is rare and has a shape of small stone chips of a size of less than 1 mm. The sand is visible especially on the surface of the fragments, which is roughened. In most cases, fragments originate from well fired vessels, which had grey or brownish red tints. In the evaluated assemblage, macroscopic group 4 was represented by 1,966 pieces; 17 characteristic fragments were selected for further analyses.

Macroscopic group 5 (Fig. 5,5): Compared to the rest of macroscopic groups, it consists of crude clayish fragments with temper in form of sand grit and stone chips of about 2 mm in size. Temper is significantly present inside the ceramic material, as well as on the surface. Vessels of this type of fabric were both well- and insufficiently-fired. The colours of fragments present in this group vary from dark grey, through greyish brown and red, to black. In the evaluated assemblage, macroscopic group 5 was represented by 36 pieces; 8 characteristic fragments were selected for further analyses.

Macroscopic group 6 (Fig. 5,6): very rarely present fragments of very finely floated clay, which is perfectly fired to brown-orange of orange-yellow shades. The surface is glimmer glazy. In the evaluated assemblage, macroscopic group 6 was represented by three pieces, and two samples were selected for further analyses.

3.2 Chemical composition analysis

Statistical analysis (PCA) on the concentration of selected elements (Tab. 2) revealed that the first component, which explains ~32 % of variance, is based on significantly high concentrations of Ca and Sr in samples 29 and 30. Compo-

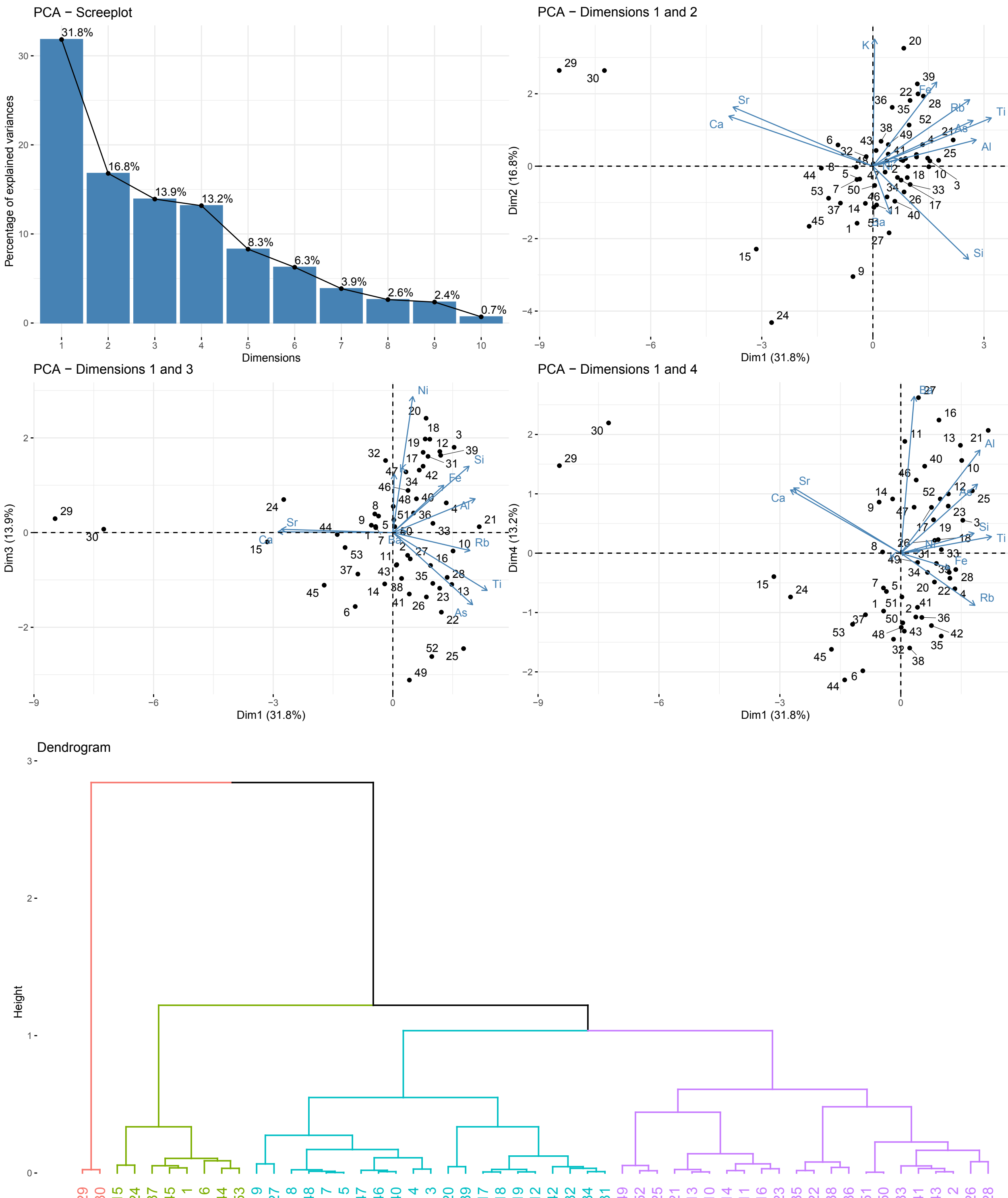

Fig. 7: PCA evaluation of chemical composition and hierarchical clustering on the first 7 components for selection of samples for petrography analysis.

Tab. 2: XRF results – bulk chemical composition of ceramics (in ppm).

Sample No.	Inv. No.	Al	Si	K	Ca	Ti	Fe	Ni	As	Rb	Sr	Ba
1	SM10910	84000	350000	15900	8860	3580	26200	48,4	6,2	117	83,6	648
2	SM10778	91700	339000	18600	8660	3730	32100	36,4	6,84	119	103	411
3	SM10319	97200	362000	20500	9830	3620	28800	76,4	7,21	146	106	760
4	SM10734	89700	346000	20100	8720	3810	28700	65,2	7,09	165	86,2	656
5	SM9168	81600	327000	19000	11800	3460	26400	59,8	6,68	141	126	797
6	SM8821	72700	291000	18800	6570	3550	34400	33,4	6,93	129	92,6	598
7	SM9172	80100	326000	19000	11100	3320	26800	59,8	7,3	127	90	735
8	SM9188	83800	321000	19200	18200	3310	28800	65,2	7,64	113	132	727
9	SM10984	84500	377000	15400	10200	3420	20200	50,5	6,94	81,3	113	914
10	SM10632	99700	339000	17300	8800	3930	32900	51,6	8,05	98,7	109	778
11	SM10595	89200	329000	15900	11600	3710	33600	44,2	7,5	82,6	185	1100
12	SM10611	95700	343000	19400	9910	4010	37800	74,7	6,89	102	145	849
13	SM9102	100000	331000	17300	8760	4030	34600	39,3	7,99	101	197	857
14	SM9132	85400	321000	15800	9260	3750	29000	46,6	7,69	80	163	864
15	SM8823	78300	316000	14400	38200	3220	19300	53,6	6,38	61,5	196	632
16	SM9150	93200	323000	18700	10700	3850	30400	51	8,01	109	196	1120
17	SM10718	88900	350000	19000	7530	3630	35300	77,3	7,35	99,7	94,3	867
18	SM10955	90100	356000	18500	6830	3700	37000	79,1	7,13	101	76	724
19	SM10602	93200	337000	18900	9920	4000	38400	80,9	6,78	90,3	122	763
20	SM10899	87600	331000	34100	7590	3720	35600	70,4	7,15	130	72,2	648
21	SM9130	99700	345000	19100	9600	4200	37800	58,3	8,05	109	203	925
22	SM8812	89300	280000	17800	4990	4150	41300	45	8,05	125	70,9	573
23	SM8819	85900	317000	16800	6660	3940	34300	53,7	8,37	117	75,4	864
24	SM9140	72800	357000	12400	8420	2880	19100	58,6	6,19	50,8	142	743
25	SM10871	87800	334000	18100	9160	4490	21400	41,8	8,41	136	97,2	851
26	SM9558	91800	354000	18500	12600	4050	19100	33,2	6,91	143	79,7	753
27	SM9164	90500	350000	17100	10600	3780	20500	51,1	7,5	103	203	1280
28	SM9112	94600	336000	25100	10600	4180	29600	33,2	7,56	133	150	474
29	SM10990	78000	249000	23400	114000	2880	24900	46,3	5,87	63,5	3060	613
30	SM9198	79700	254000	22500	101000	3090	26000	52,3	6,53	70,8	3060	757
31	SM9927	90100	346000	19800	7390	3820	35700	73,6	6,92	112	75,2	666
32	SM9926	84500	329000	19700	8200	3700	36200	71,4	6,54	97,5	70,5	439
33	SM10006	93500	364000	17600	7100	3630	33900	48,2	7,57	102	74,1	549
34	SM9748	91800	351000	18200	7710	3810	34100	67,8	6,83	99,8	87,4	559
35	SM9800	83800	300000	18900	5230	3950	39400	50,7	7,99	134	55,9	417
36	SM9105	80000	292000	19900	5910	4120	39800	76,5	7,42	113	71,8	582
37	SM8841	77400	325000	15600	8050	3520	32500	42,3	7,19	85,7	104	576

Tab. 2 (continued)

Sample No.	Inv. No.	Al	Si	K	Ca	Ti	Fe	Ni	As	Rb	Sr	Ba
38	SM9104	75800	307000	17600	4710	3820	34600	56,7	7,91	119	55,9	465
39	SM9151	88400	325000	26400	6570	3910	37400	76,8	7,61	120	68,1	600
40	SM9799	88000	351000	18200	11400	3570	26700	70,2	7,72	111	144	1020
41	SM9797	85500	318000	16500	7490	3860	36400	37,2	7,35	117	91,7	532
42	SM9940	92500	357000	20000	9990	3630	28400	69,7	6,98	129	80,3	331
43	SM9939	87300	320000	18900	7320	3720	32800	36,6	6,62	132	96,1	520
44	SM9769	75300	300000	19000	9060	3280	26100	60	6,87	119	93,4	451
45	SM9141	75400	325000	16600	8920	3500	21300	37	6,44	92,8	124	531
46	SM9143	93000	349000	19200	10500	3410	25700	64,5	7,43	109	146	906
47	SM9103	91500	346000	20100	19000	3570	29800	69,3	7,21	111	110	813
48	SM9139	82700	334000	19900	7860	3340	27500	63	7,2	140	82,4	554
49	SM9545	81100	292000	17800	10200	4350	21500	40,2	8,5	112	103	594
50	SM9462	88300	336000	17500	9980	4170	25000	59,9	6,47	97,5	86,5	383
51	SM9548	88000	349000	16800	10000	4080	24100	60,5	6,57	90,1	97,6	467
52	SM9543	90500	307000	19900	24900	4380	19900	40,4	8,45	134	110	710
53	SM9552	75000	302000	16900	9640	3860	23600	63	6,39	104	77,1	704

nents two to four explain 13–16 % of variance each, giving them all a similar weight. The second component is formed by negative correlation among K and Ba along with Si. The third component is based on concentrations of Ni and K against As and Ti. The most important for the fourth component is a ratio of Ba to Rb. It was decided to use the first seven components for hierarchical clustering (combined variance explained was 94.2 %). The resulting dendrogram (Fig. 7) was used for the selection of 25 samples for petrographic analyses in a way that all clusters were represented.

3.3 Petrographic classification

Based on mineral and rock fragment abundance and microstructure analysed using petrography, the assemblage of 25 samples was classified into five petrofabrics (A–E, Fig. 8). The classification was cross validated with use of statistical evaluation of XRF results (Fig. 9). Chemical composition for each petrofabric is summarized in Tab. 3. These petrofabrics were further used for building a prediction model to classify the rest of the samples based only on their chemical composition measured by the XRF. The dataset used for predictive model formation was composed of samples of fabrics A–D. Fabric E corresponding to the macroscopic group 6 was excluded as it was macroscopically distinctive and the possibility of erroneous classification was very limited. Two samples interpreted as outliers by petrographic analysis were also excluded.

Petrofabric A is characterized by strongly aleuritic matrix with iron-rich nodules and a lower number of psammitic grains. The matrix of the fabric is coarser than of the other groups. Psammitic clasts are formed by fragments of mostly limestones and polycrystalline quartz (Fig. 10,1). Clastic sedimentary rocks, chert and metamorphic rock fragments are minor. Quartz grains are predominant among the minerals. Alkali feldspars are more abundant than plagioclase. Mica flakes are the most abundant in comparison with other fabrics and muscovite predominates over biotite. Accessory minerals are represented by amphiboles and tourmaline. Limestone fragments determine the provenance of Fabric A in a catchment area of the River Okluka between Ostrožská Nová Ves and Hluk. The region is located approximately 10 km south of Staré Město. In some samples, the biotite flakes show a medium to high level of birefringence. The limestone fragments are sometimes reddish. The ceramic matrix shows a varying extent of optically inactive parts. The reason is dehydroxylated clay minerals. The raw material was exceedingly rich in clay minerals which is documented with high Al:Si kaolin-like ratio. It arises from the XRD analysed samples (Nos. 25–27) that the amorphous

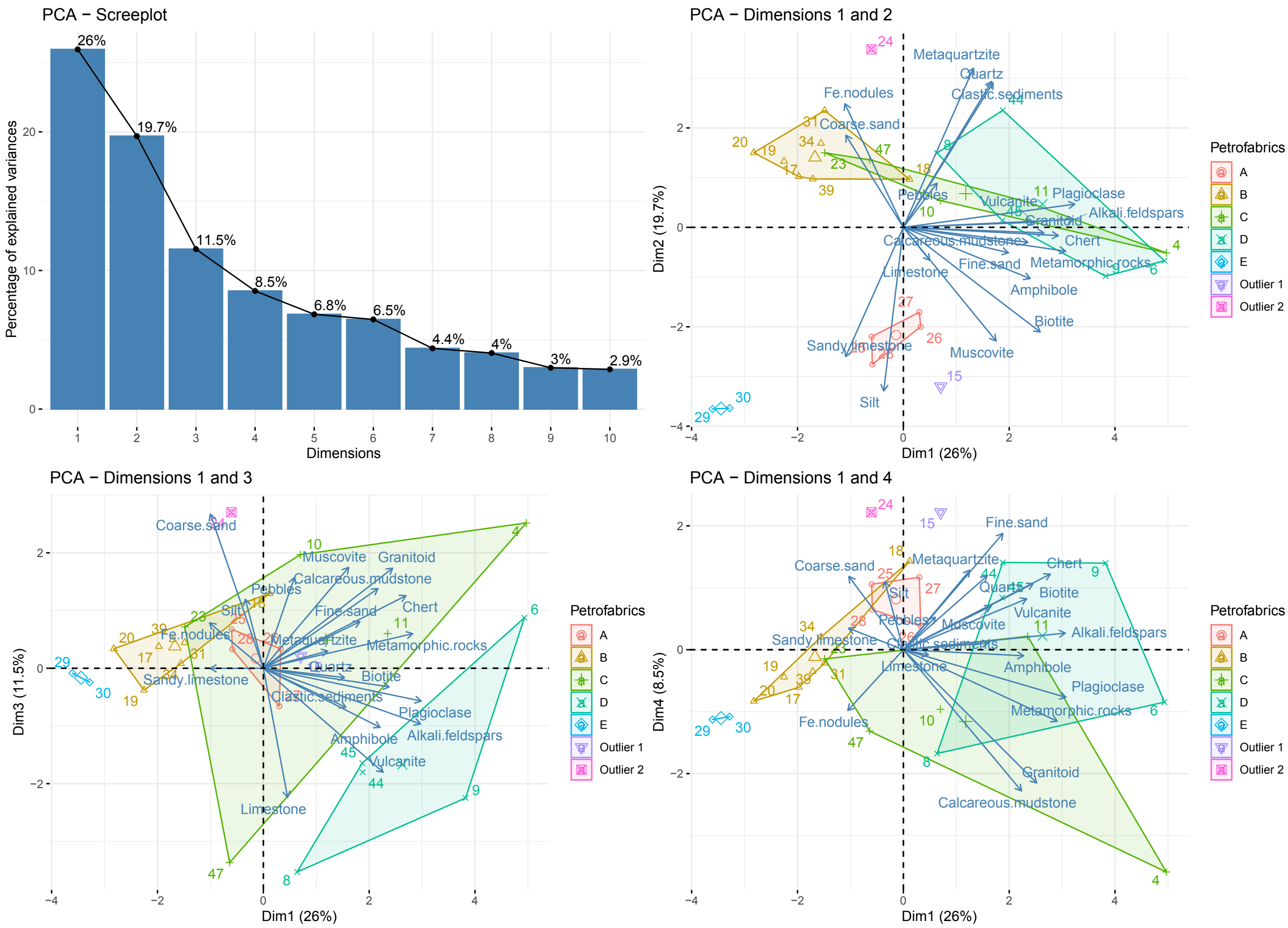

Fig. 8: PCA evaluation of petrography results with petrofabrics marked.

phase negatively correlates with the content of clay minerals (mica structure minerals and smectite). Therefore, the amorphous phase is clearly formed by dehydroxylated clay minerals with collapsed crystal structures. The maximum firing temperature ranged from 550–600 (sample No. 27) to 700–750 °C (samples Nos. 25, 26). The highest concentrations of Ca, Sr, As and Ti in the studied assemblage is chemically significant for Petrofabric A.

Petrofabric B is tempered with sand in form of rounded fragments of clastic sedimentary rocks (sandstone and other psammitic clastic sedimentary rocks, such as siltstone) and numerous rounded quartz and polycrystalline quartz grains (Fig. 10,2). Other rock types are not present. Minerals other than quartz are present in trace contents. The ceramic matrix contains relatively numerous iron-rich nodules. The temper origins in Carpathian Flysch, which has outcrops on the left bank of the River Morava and on the right bank 7 km upstream from the centre Staré Město near Uherské Hradiště. The firing temperature was lower than 650–700 °C according to the XRD of sample No. 18. Because of the temper composition, Petrofabric B is characterized by high concentrations of Si, Ni and Fe while the concentration of other elements is low.

Petrofabric C contains intentionally added grains of sand in the form of rather rounded quartz grains and fragments of sandstone. The ceramic matrix contains numerous iron-rich nodules. Less abundant rock fragments are chert, granitoid and metamorphic rocks (Fig. 10,3). Feldspars are present in a variable amount (rare to common) – they are few in number and plagioclase predominates over alkaline feldspars. Mica flakes are low in number (muscovite predominates over biotite). Accessory minerals consist of amphiboles and tourmaline. The area of raw material provenance is to be sought in the proximity of Staré Město in the River Morava's floodplain. The estimated firing temperature was 750–800 °C. The high content of non-dehydroxylated clay structure minerals in sample 23 appears optically inactive despite the matrix (Fig. 10,4). The chemical definition of Petrofabric C is based on high concentrations of Rb, K, Fe and Cr whereas Ca and Sr concentrations are low.

Petrofabric D is specified by presence of andesite fragments (Fig. 10,5). They are not very common among

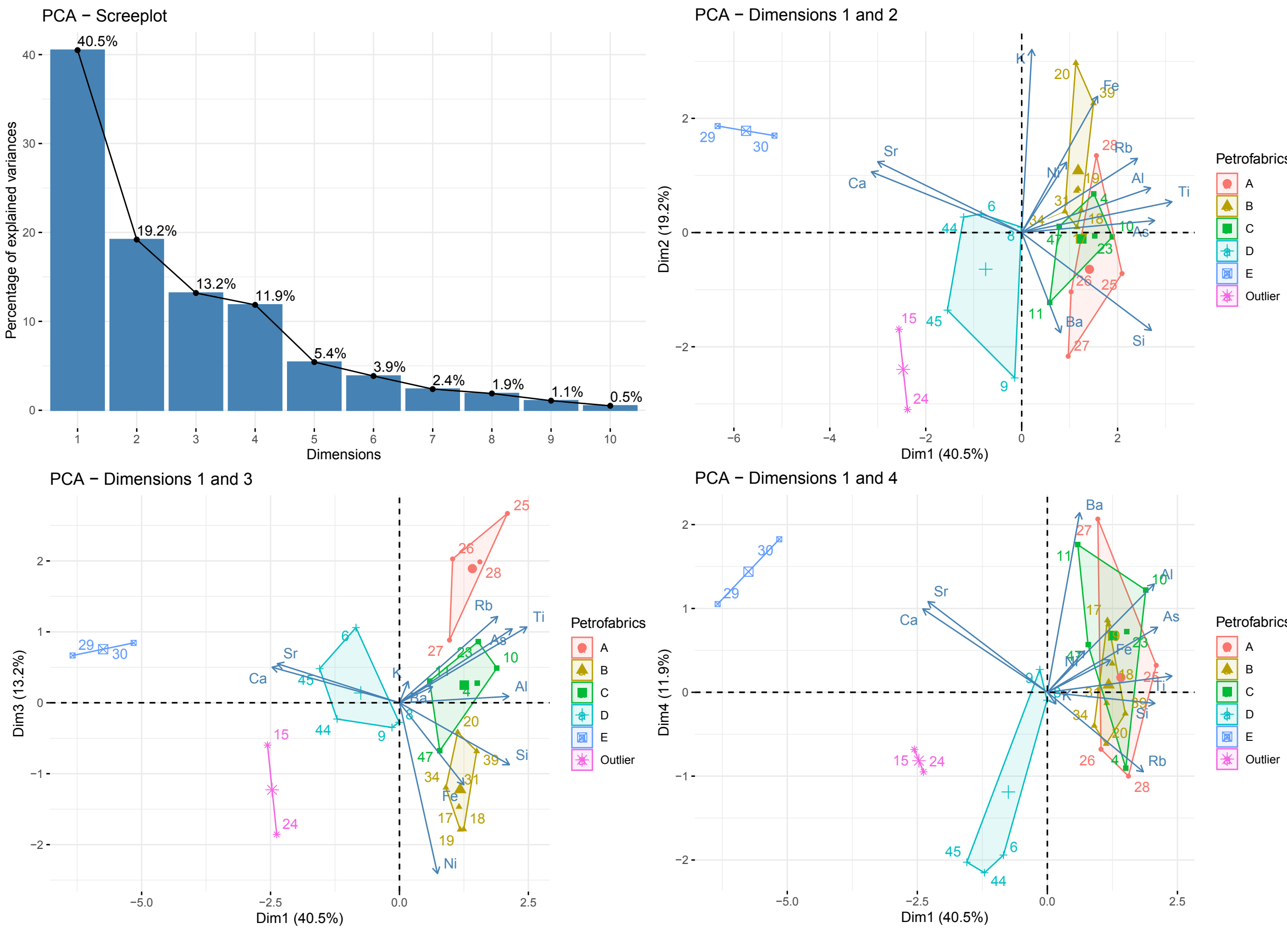

Fig. 9: Cross validation of petrofabrics by PCA on chemical composition.

other abundant rock fragments, which are represented by sedimentary clastic rocks and limestones. Other rock types included are rare granitoid and metamorphic rocks. The most abundant mineral is quartz; however, feldspars are also quite frequent. Mica flakes, amphiboles and iron-rich nodules are less abundant. The provenance interpretation is to be sought in the catchment of the River Olšava (Fig. 2). The River Olšava and its upstream influxes spring in the area of trachyandesite outcrops near Uherský Brod (Bánov specifically). The origin in this area is supported by the amount of feldspar and amphibole grains. The limestone fragments included were part of the flysch sediments. In samples which include metamorphic and granitoid rocks (Nos. 6, 8, 9) it is suggested that area of origin is the River Morava's floodplain where the River Olšava joins the larger stream. Several limestone fragments also show signs of thermal alteration. The estimated maximum firing temperature of sample No. 6 was 750–800 °C.

Petrofabric E is made of calcareous clay with very few grains of temper which consists of sandy limestone fragments (Fig. 10,6). The ceramic matrix includes foraminifera microfossils. It is impossible to determine the provenance of Fabric E due to the low level of granularity. The signs of firing show homogeneous firing conditions in oxidizing atmosphere at a temperature around 550–600 °C. The temperature estimation was based on the low volume of amorphous phase compared to the number of phyllosilicate minerals present. Biotite flakes have lost their birefringence, but the matrix is still completely optically active.

Outlier 1 (sample 15) is a pottery fragment with a very high content of fine sand grains which are subangular (Fig. 10,7). The grain shape suggests the raw material was eluvial. The specific of the sample, apart from its granularity, is its abundance of mica flakes and amphibole grains. The rock fragments include sandy limestone, polycrystalline quartz, chert, and sandstone. Thanks to the high amount of clay minerals and calcite with preserved structure, it is possible to estimate the firing temperature to the range of 550–600°C. Due to limestone fragments, the sample is strongly enriched with Ca and Sr. The concentrations of Fe and Rb are noticeably low. The provenance of the sample is most likely to be sought in the River Morava's

Tab. 3: Chemical characterization of petrofabrics – mean, standard deviation, minimum and maximum concentrations of elements (in ppm).

Element/Fabric	A				B			
	Mean	SD	Min	Max	Mean	SD	Min	Max
Al	91175	2827	87800	94600	90014	1959	87600	93200
Si	343500	9983	334000	354000	342286	11485	325000	356000
K	19700	3648	17100	25100	22129	5997	18200	34100
Ca	10740	1414	9160	12600	7649	1086	6570	9920
Ti	4125	295	3780	4490	3799	128	3630	4000
Fe	22650	4729	19100	29600	36214	1458	34100	38400
Ni	40	9	33	51	75	5	68	81
As	8	1	7	8	7	0	7	8
Rb	129	18	103	143	108	14	90	130
Sr	132	56	80	203	85	19	68	122
Ba	840	334	474	1280	690	104	559	867
	C				D			
	Mean	SD	Min	Max	Mean	SD	Min	Max
Al	91200	5164	85900	99700	78340	5419	72700	84500
Si	335400	12422	317000	346000	322800	33454	291000	377000
K	18040	1946	15900	20100	17800	1703	15400	19200
Ca	10956	4828	6660	19000	10590	4454	6570	18200
Ti	3792	156	3570	3940	3412	117	3280	3550
Fe	31860	2464	28700	34300	26160	5788	20200	34400
Ni	57	10	44	69	49	14	33	65
As	8	1	7	8	7	0	6	8
Rb	115	31	83	165	107	20	81	129
Sr	113	43	75	185	111	18	93	132
Ba	842	163	656	1100	644	182	451	914

valley downstream from the limestone outcrops close to Ostrožská Nová Ves.

Outlier 2 (sample 24) represents coarse-ware heavily tempered with rounded grains of coarse sand and pebbles. The temper consisted of quartz, polycrystalline quartz, sandstone and siltstone (Fig. 10,8). The ceramic matrix is fine grained with angular silt grains. The mica flakes and feldspars are few. The original firing temperature was low, comparable to Outlier 1, i. e., 550–600 °C. The bulk chemical composition is strongly influenced by the tempering practices. The high amount of quartz and low quantity of feldspars is projected in the Si and K concentrations. The raw material provenance is a region of Carpathian flysch outcrops, like Petrofabric B.

3.4 Predictive classification

Petrofabrics were further used for building a prediction model to classify the rest of the samples based only on their chemical composition. The dataset used for predictive model creation was composed of samples of petrofabrics A–D. Petrofabric E and two samples interpreted by petrographic analysis to be outliers were excluded. The finely floated pottery of groups MG 1 and 2 had six out of nine samples attributed to the two groups corresponding with petrofabric A, the rest (3 samples) belong to petrofabrics C and D. The samples classified as MG 3 (16 in total) were mostly distributed between petrofabric B (6 samples) and C (6 samples). The rest consists of one sample assigned

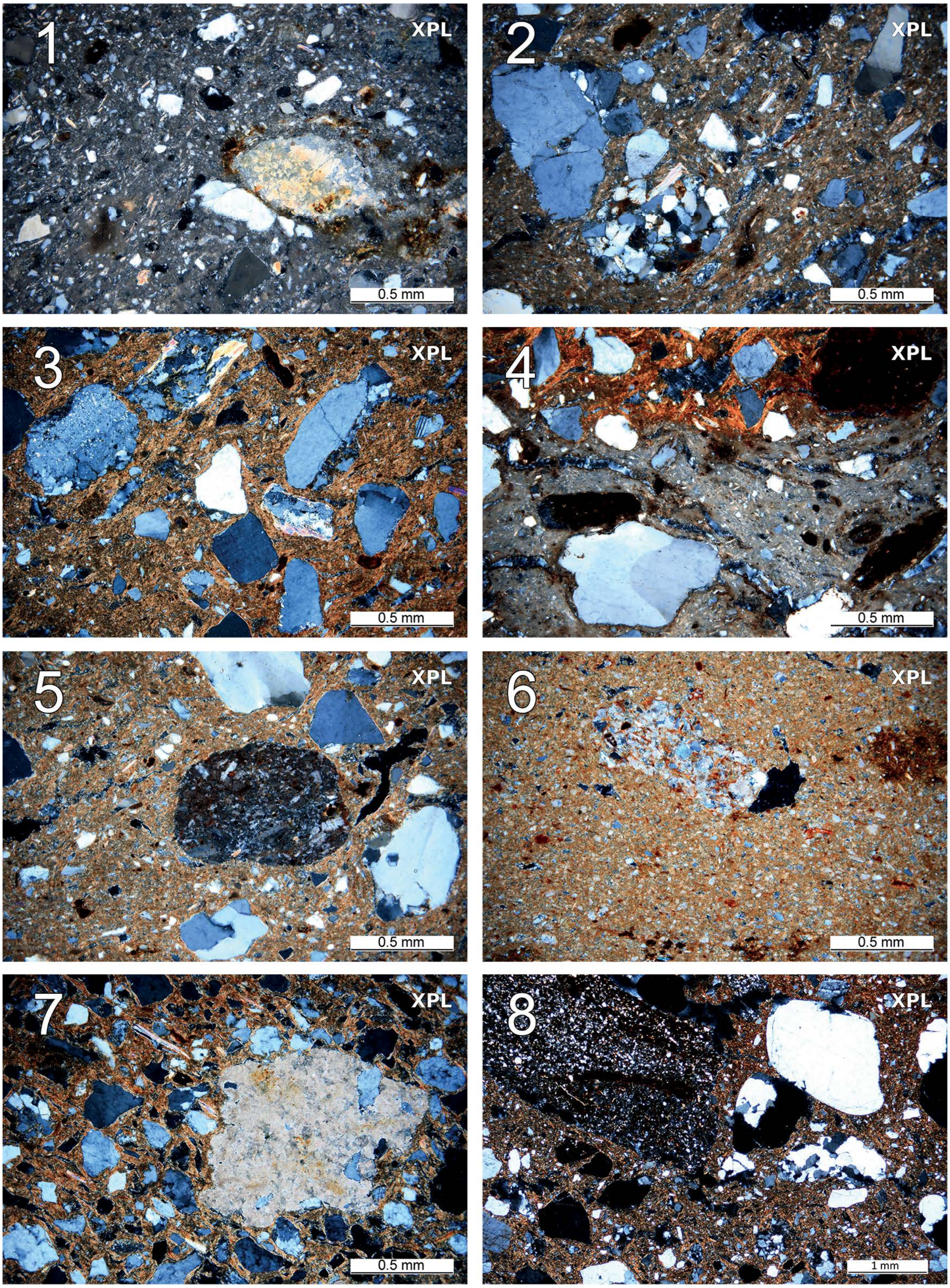

Fig. 10: Photomicrographs in cross-polarized light (XPL). 1: Fabric A (sample 26) a limestone fragment and quartz grains in an optically inactive matrix; 2: Fabric B (sample 18) – clastic sedimentary rock fragments (sandstone) and quartz sand; 3: Fabric C (sample 11) non-plastic inclusions consist of metamorphic rock fragments (phyllite), quartz, alkali feldspars and plagioclase; 4: Fabric C (sample 23) oxidizing margin and reducing core with an optically inactive matrix composed of amorphous clay minerals, the matrix commonly contains Fe-nodules; 5: Fabric D (sample 9) pottery tempered with andesite containing sand; 6: Fabric E (sample 29) the fine-ware antique type pottery with inclusions of sandy limestone fragments; 7: Outlier 1 (sample 15) the sample differs with a high amount of fine quartz sand inclusions, mica and limestone fragments; 8: Outlier 2 (sample 24) coarse-ware pottery heavily tempered with quartz, polycrystalline quartz and siltstone fragments.

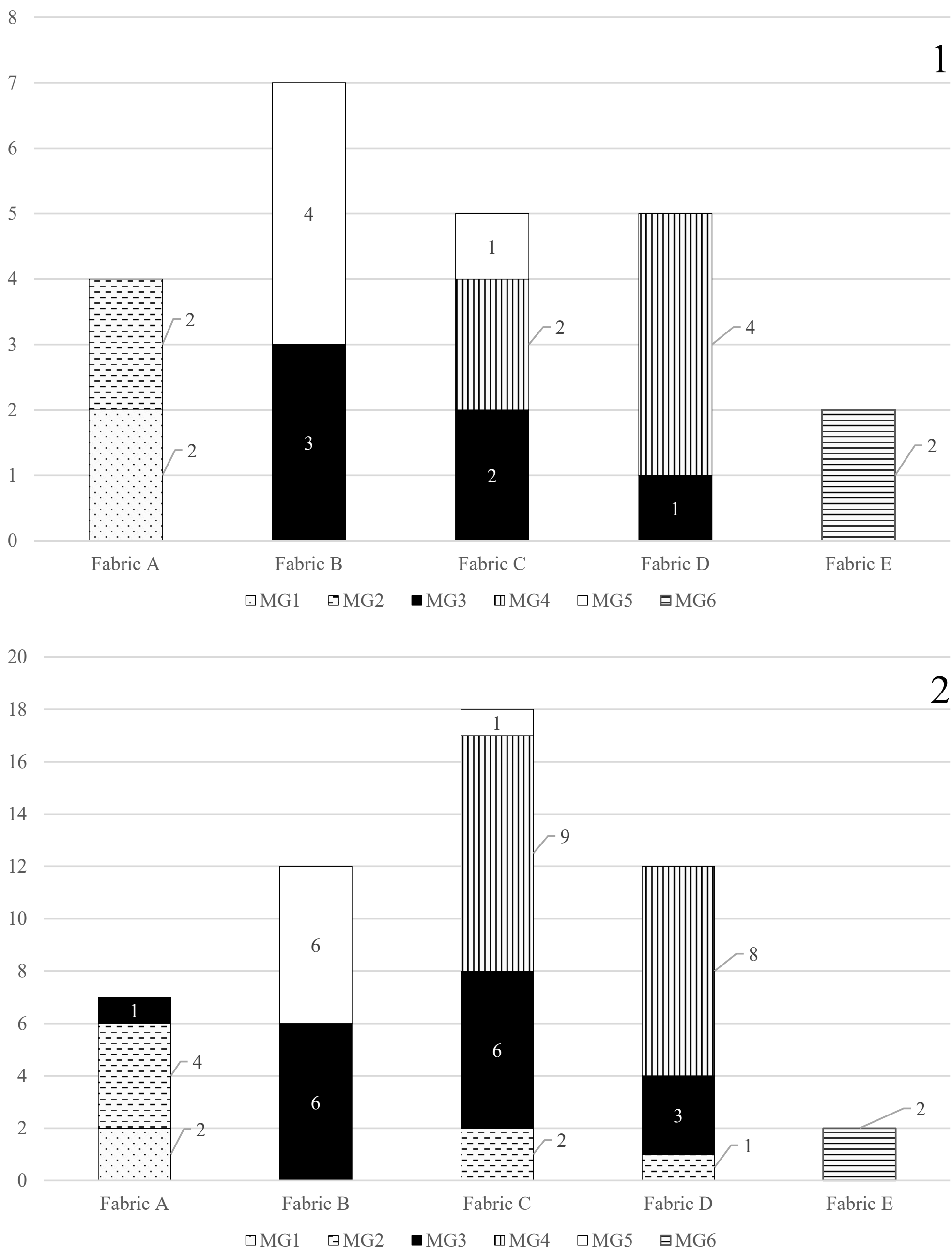

Fig. 11: Relation between macroscopically determined groups and fabrics defined by petrographic analyses (chart 1) and by petrographic analyses including the prediction based on sPLS-DA (chart 2).

to petrofabric A and three samples assigned to petrofabric D. MG 4 (16 samples) were evenly distributed among petrofabric C (9 samples) and D (7 samples). The majority of MG 5 was classified as petrofabric B (6 samples), while one sample was assigned to petrofabric C. MG 6 which is rare and was not tested by the model and it is petrofabric E (Fig. 11,2).

4 Discussion

The study of chemical and petrographic composition shows that the 9th-century artisan district 'U Víta' was supplied with pottery from multiple sources within the rural hinterland of the centre. All fabric groups, except local Fabric C (which can potentially include production of workshops within the district 'U Víta' itself), and Fabric E (which most probably represents relics of prestigious goods of the 'antique type' pottery, i. e. Moravian imitation of Byzantine ceramics[48]) were evincibly located outside the Great Moravian centre of Staré Město near Uherské Hradiště in areas inhabited by contemporary rural communities (Fig. 12). These results thus point to the production of the pottery at multiple rural workshops around the centre, which were brought to the centre and consumed within it. This also corresponds with findings of XRD analysis showing the application of production technology with lower control of firing conditions, and macroscopic heterogeneity of individual fabrics (Fig. 11,1) thus also indicating the lower specialization of production[49]. The supply network within which everyday items including pottery vessels circulated could be also partially or temporarily supplemented by local production localized in the centre (potentially represented by Fabric C).

The excavated situation at the artisan district[50] in combination of this newly acquired knowledge thus shows that the cessation of pottery production within production features Nos. 60 and 63 during the continuing of other production activities at the district (for which these features served as refuse pits), were supplemented by pottery from multiple sources within the region. The result implies that despite possible initial efforts to ensure the supply of the pottery within the district, where kilns suitable for pottery firing were present (Figs. 3; 4), the local production was most probably abandoned in favour of the supply from multiple independent workshops including those around the centre Staré Město near Uherské Hradiště. The most probable explanation of this shift from the self-supply efforts is the appearance of a distribution network that was (from the perspective of the elite patrons of potentially attached producers) measurably more effective and less costly to maintain. There was thus no reason to carry on local production within the district, which does not fulfil any elite political agenda[51]. If we also take into account that controlled (redistributive) supply of producers with everyday items including pottery from multiple areas of the hinterland would be much more costly than the redistribution of local production (which was obviously available), and that the hypothetical tributary mobilization of food production, which can be followed by some pottery, is hardly enough for continual supply of artisans with ceramics, the presence of the market at the 9th-century centre of Staré Město near Uherské Hradiště is highly probable. As Ahmad Rustah's mention indicates, this market exchange probably took the form of a periodic market event, and it was present not only at the residential centre of Svatopluk as described in the source[52], but, as results of this study shows, also at the other major 9th-century Moravian centres surrounding the market zone of the centre of Pohansko near Břeclav along with the Moymirid power centre at Mikulčice[53].

The evaluation of small ceramic assemblage from one of these centres was thus able to further refine our knowledge about economic relations within (and indirectly also between) the 9th-century Moravian central places, which during the period were able to transform into the commercial relations manifesting market exchange. The presence of multiple market centres in the power core of Great Moravia (Fig. 1) most probably also resulted in the establishment of the system of interconnected marketplaces, i. e. a Moravian market system. Its apical point was probably located at the centre of Pohansko near Břeclav close to the Moymirid power centre in Mikulčice, the commercialized economic relations had probably further expanded from these centres[54] and reached the surrounding major Great Moravian strongholds[55]. The presumed control of the interregional marketplace at Pohansko near Břeclav by the Moymirid dynasty forming a bottleneck on inflows of imports indicates the dendritic shape of this market system[56], but the level and the extent of mutual connections between individual Moravian central places needs to be further studied. This study was able to illustrate the potential of archaeological evaluation of assemblages of everyday items, and pottery especially, for determining the level of commercial relations (i. e., market exchange), not only on other 9th-century Moravian central places, but also in other similar cases outside early medieval Moravia. Such studies can thus help to gain more general knowledge about the transformation processes that affected pre-commercial economies after contact with more complex economic milieus.

5 Conclusion

In this study we introduced a small-scale test utilizing the archaeologically well visible representative of former everyday items in the form of pottery. The main purpose of the analysis was to determine the origin and context of the production of the pottery refuse discarded by artisans from

48 Hrubý 1965.
49 Cf. Thér 2014.
50 See Hlavica *et al.* 2016.
51 See also Stark/Garraty 2010.
52 Hrbek 1969.
53 Cf. Hlavica/Procházka 2020b.
54 See also Hlavica/Bárta 2021.
55 Cf. Hlavica/Kouřil/Mikulec 2022.
56 Cf. Minc 2006; Junker 1999.

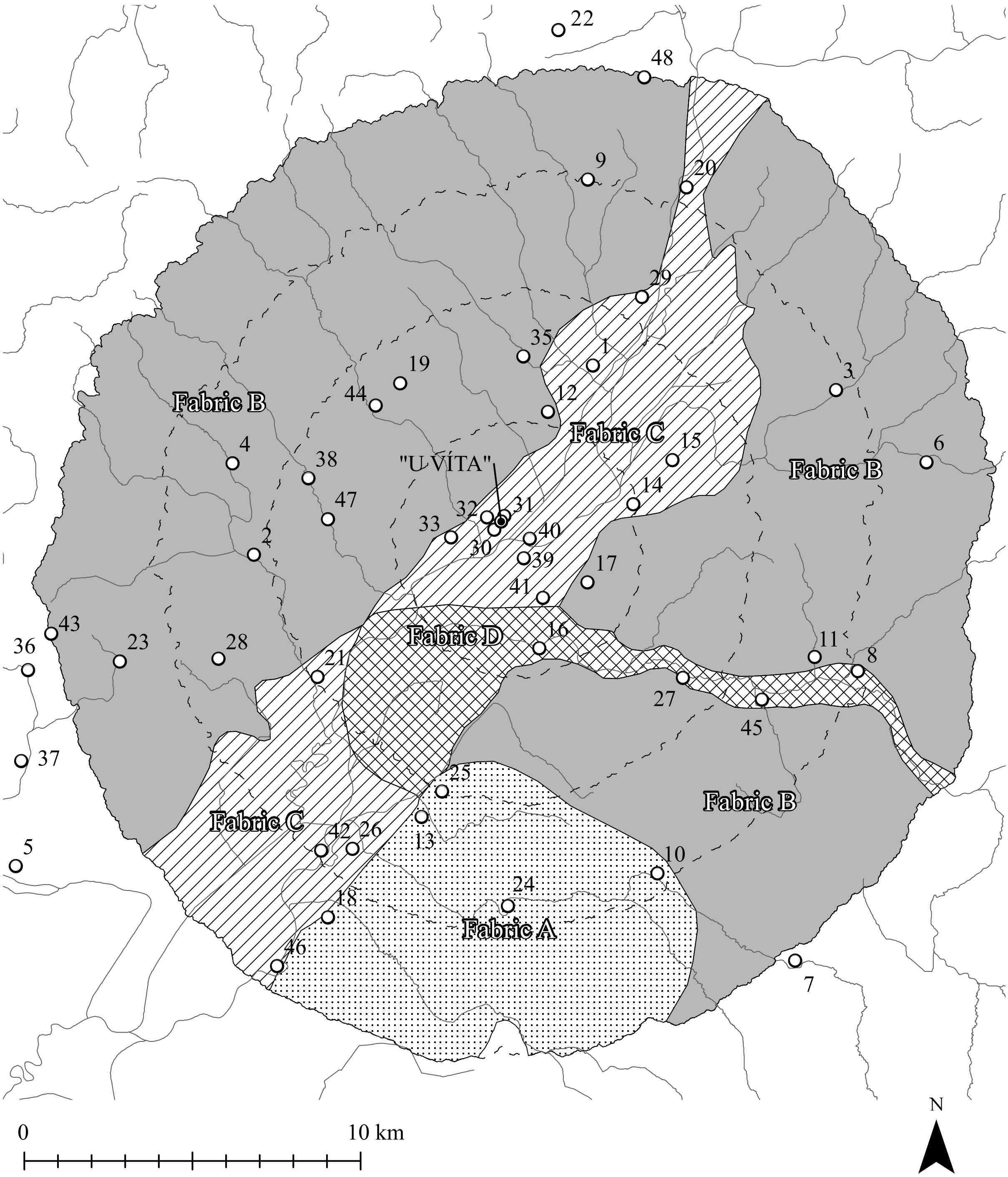

Fig. 12: Delimitation of areas corresponding to recognized fabrics A–D. The area is limited to a 4-hour walking radius from the centre of Staré Město, calculated using Tobbler equations[57]. For list of sites, see Fig. 2

57 Cf. Tobler 1993.

the district 'U Víta' of the 9th-century Moravian centre at Staré Město near Uherské Hradiště and with the main aim of acquiring new knowledge about the exchange network through which the pottery was obtained by the artisans. Utilizing multiple analytical methods including XRF, petrography, and XRD we have shown that the pottery originated in various parts of Staré Město's hinterland. The results also indicated that the pottery was produced in conditions that did not allow full control of the firing process. It indicates less developed production technology, despite the fact that the centre of Staré Město was able to use its own specialized pottery kilns.

The results of the evaluation thus allow us to deny the hypothesis of purely local pottery production as the basis for artisan supply. Instead, these results point to complex exchange relations between the centre and its hinterland that could be, as explained above, hardly maintained as a solely redistribution (tributary) network. We thus concluded that the results further support the hypothesis about the presence of a marketplace at the former centre at Staré Město, where rural communities brought pottery and other everyday items during periodic market events. In the 9th century, the centre of Staré Město near Uherské Hradiště thus most probably already experienced market exchange. On its marketplace, rural communities most probably seek locally unavailable goods in exchange for their production (e. g., imported salt, quern-stones, iron products, etc.), it thus was probably also a part of a 9th-century Moravian market system, within which these regionally produced and imported goods circulated.

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Supplementary files description

Supplementary Fig. 1: Scheme of predictive model building.
Supplementary Fig. 2–10: Diffractograms of the analysed samples with the Rietveld method results.
Supplementary Tab. 1: Petrography of ceramics expressed using the semiquantitative scale (0.1 – scarce, 0.5 – rare, 1 – occasional, 2 – common, 3 – frequent, 4 – abundant, 5 – dominant).
Supplementary Tab. 2: Results of sPLS-DA prediction – sample classification into petrofabrics.
Supplementary Tab. 3: XRD results – mineral composition of ceramics quantified by the Rietveld method (vol. %) and estimation of their max. firing temperature.

Supplemental Material: This article contains supplementary material (https://doi.org/10.1515/pz-2023-2012).