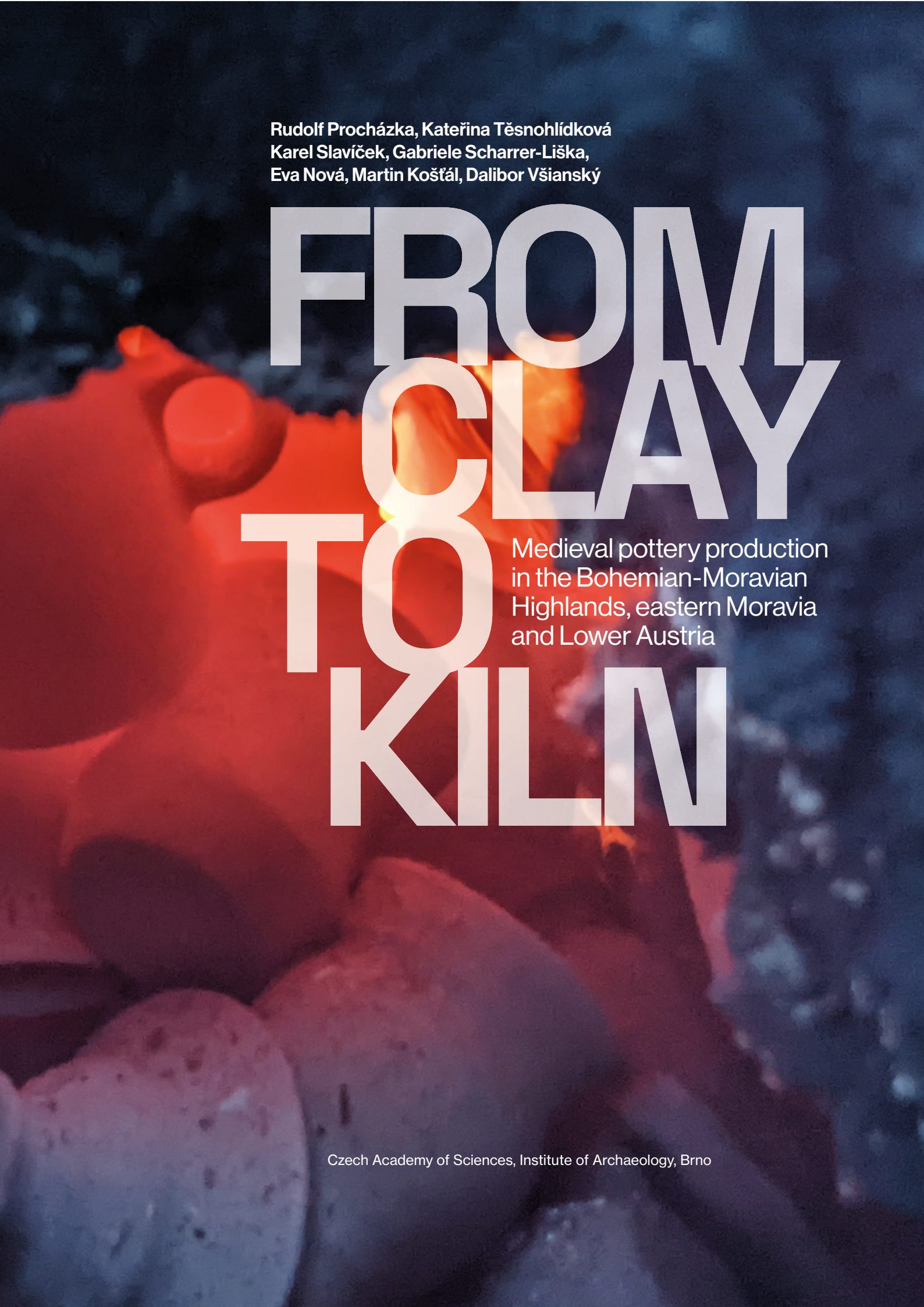


Rudolf Procházka, Kateřina Těsnohlídková
Karel Slavíček, Gabriele Scharrer-Liška,
Eva Nová, Martin Košťál, Dalibor Všianský

FROM CLAY TO KILN

Medieval pottery production in the Bohemian-Moravian Highlands, eastern Moravia and Lower Austria

Czech Academy of Sciences, Institute of Archaeology, Brno

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1
Introduction

As a primary and abundant source of material culture, medieval ceramics have been and continue to be the subject of interest to archaeologists. However, they are mainly analysed from a typological and morphological perspective, as researchers focus primarily on external features such as types of vessels and their shapes or decorations. Due to their relatively high variability over time, the possibilities of dating ceramics stand at the forefront of scholarly interest. Much less attention is paid to their technological essence and how it is reflected in the so-called production chain – i.e. the structure and preparation of raw materials, forming, and firing. This is a topic that requires an interdisciplinary approach with the extensive use of scientific methods and experimentation. By drawing on knowledge gained mainly from foreign research and to a lesser extent from domestic research (notable examples include the works of W. Hołubowicz, P. M. Rice, V. Roux, N. Cuomo di Caprio, M. Richter, M. Gregerová, and R. Thér), we have attempted in this book to take a complex approach to ceramic assemblages of a special kind, i.e. the remains of pottery kiln batches. We have based our work upon the results of previous research, in particular on experiments carried out at Masaryk University's workplace in Panská Lhota, as well as within the framework of the broadly conceived NAKI project (2017–2021). A number of findings now being further developed were collected and evaluated by K. Těsnohlídková in her doctoral thesis (2021). The research drew from the remarkable assemblages of ceramics from seven pottery kilns in the eastern part of the Bohemian-Moravian Highlands, which were in operation between approximately 1250 and 1400. An interesting comparison was provided by the pottery from two kilns and a pottery hoard on the opposite edge of Moravia – from Staré Město near Uherské Hradiště – and from two other firing facilities in the Lower Austrian town of St. Pölten. While common assemblages from settlement areas are often quite heterogeneous as they come from multiple workshops, in the case of kiln pottery, the area is confined to a single workshop, although this may involve the remains of multiple kiln batches. In addition, limited intrusions of deposited waste of uncertain origin cannot be ruled out. Notable advantage is the presence of a number of whole or reconstructable vessels, which allows for a detailed study of the entire process of production.

From a thematic perspective, we have focused on three areas: the structure of the ceramic material, the shaping of the vessels, and their firing. From a methodological point of view, a combination of traditional archaeological evaluation, scientific analytical procedures, and statistics was applied. This approach made it possible to study the ceramic raw materials, their provenance, and the changes caused by firing. All these stages of the production chain were compared with findings obtained via experimental production, including both the preparation of the material and firing in various types of pyro-technological equipment.

The introductory section of the book presents a chapter on the settlement context of pottery workshops and the socio-economic status of the individuals who operated them. It also includes a chapter dealing with written reports on the sources of pottery clay. The next and highly important part of the book presents the characteristics of the assemblage of examined kilns and their batches. It includes

both a description and classification of the kilns and a comprehensive characterisation of the pottery found in them in terms of morphology, petrography, and forming and firing technology. The extensive following chapter presents and evaluates 12 seasons of experimental pottery production, which thematically cover the entire operational chain. The results presented in the material and experimental parts of the monograph are discussed in the context of contemporary research. In the discussion, we attempt to show the advantages and pitfalls of the chosen methodological approach and, in some areas, possibilities for further research.

Our work, supported by the Czech Science Foundation through the project Emergence of the high medieval pottery – pottery kilns and their batches, would not have been possible without the gracious help of the experts at the Museum of the Vysočina Region in Jihlava, especially David Zimola; the Regional Museum in Žďár nad Sázavou – Martina Schutová and Miloš Lopaur; the Slovak Museum in Uherské Hradiště, namely Dana Menoušková and Tomáš Chrástek; the Moravian Museum – Kateřina Bergerová, Lucie Valášková and Luděk Galuška.

The Archaeological Institute of the Czech Academy of Sciences and the Department of Geological Sciences at Masaryk University also provided us with the optimal environment for work and research. We would also like to mention the support of the Institute of Archaeology and Museology at Masaryk University's Faculty of Arts, particularly in the area of 3D imaging methods. The extensive experiments that have been ongoing since 2012 would not have been possible without the involvement of a number of collaborators – archaeology students and archaeologists, professional and amateur potters, and members of the public interested in experimental archaeology. Thanks to these 'experimental' meetings, some of these individuals have become friends whose aid and support we can always rely on. Therefore, we would like to thank them all, especially Zdeňka Bočková, Martin Cvejn, Karel Pročka, Tereza Přichystalová, and the DANAR Association of Historical Crafts.

It is also our pleasant obligation to thank the reviewers – Simona Raneri (Department of Earth Sciences, University of Florence), Ladislav Čapek (Department of Archaeology, Faculty of Arts, University of West Bohemia), and Rudolf Krajíc (Institute of Archaeology, Faculty of Arts, University of South Bohemia) – for their valuable suggestions and comments.

We would like to thank Ronald Risy (Stadtarchäologie St. Pölten) for enabling us to take samples from the medieval pottery kilns in St. Pölten, as well as for providing digital images and permission to use them for Figures 125: 2 and 131: 8, 9. We owe our gratitude to Erich Draganits (University of Vienna, Faculty of Earth Sciences, Geography and Astronomy, Department of Geology) for sharing his expertise on the geological situation in Lower Austria, and to Nikolaus Hofer (Federal Monuments Office – Department of Archaeology) for providing digital images and permission to generate scans of analogue images. We also thank Nikolas Gail (Austrian Academy of Sciences, Austrian Archaeological Institute) for permission to use his images for Figures 128 and 131: 1–9, and Dimitrios Boulasikis (Archnet Bau- und Bodendenkmalpflege GmbH) for permission to use his images for Figure 125: 2. Finally, we thank Ute Scholz (ASINOE GmbH) for providing the digital image and permission to use it for Figure 127: 5.

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2

Medieval pottery workshops in the Czech lands: Spatial and social context of the high and late medieval settlement

A number of high and late medieval[1] pottery kilns, sometimes accompanied by other features, have been studied in the Czech Republic. In the vast majority of cases, these involve fragments of larger complexes originally comprising several functionally different buildings and facilities related to production, but also potter's dwellings and various equipment that was commonly used to operate a household at the time. Although we are already relatively well-informed concerning the form of the kilns themselves, knowledge of their wider context is still quite insufficient (e.g. Procházka 2015; Čapek, Preusz 2019). One of the main reasons for this is the fragmented nature of the finds, which are often investigated in rescue excavation mode and under conditions that often allow us to focus only on production equipment related to firing. Nonetheless, the topic of broader spatial relationships raises a number of questions. Were pottery kilns always located within building plots? If so, how were these plots structurally designed? Where were other production sites located, and where was waste disposed of? What can be said of production areas located outside building plots? Under what conditions were export pottery centres established, and what were their characteristics? Unfortunately, the available sources in the Czech lands and the state of their evaluation allow us to answer the questions posed only partially.

Settlement structures associated with pottery on a macro scale, i.e. the topography of pottery sites, also deserve deeper exploration. Questions arise concerning the location of workshops in the environment of early market settlements, within town walls, and in suburban areas or villages, especially in relation to potters' dwellings. We are also interested in their concentration, continuity, etc. In this context, written sources, especially those from cities, also come into play, allowing us in an optimal case to determine the frequency of potters in various town districts, to gain a better understanding of the issue of their spatial and social mobility, and obtain some information concerning their property relationships, professional organizations and social status, which is dealt with in the final part of this chapter (for a more recent review, see Čapek 2022, 355–358).

The text below does not claim to be complete; essentially, it involves a series of studies of sources concerning sites in Bohemia and Moravia from the 13th to 16th centuries where pottery kilns have been archaeologically investigated. Archaeological records have been compared with written sources, i.e. mainly with data available in municipal records (i.e. town books) of various kinds, in the Middle Age mostly memorial books, books of purchases and sales (property transaction books), tax books or registers, etc.

2.1 Pottery workshops in the structures of the Early Middle Ages (9th–12th centuries)

In the environment of Central European Slavic ethnic groups, it is generally assumed that outdoor firing in aboveground hearths, in pits or simple single chamber kilns without a separated firing area was widespread, although only a minimal number of

1 The periodization of the Middle Ages is quite different in individual European countries. In this book, we understand the term 'high medieval' to mean the period 1200–1400, and late medieval to mean 1400–1500.

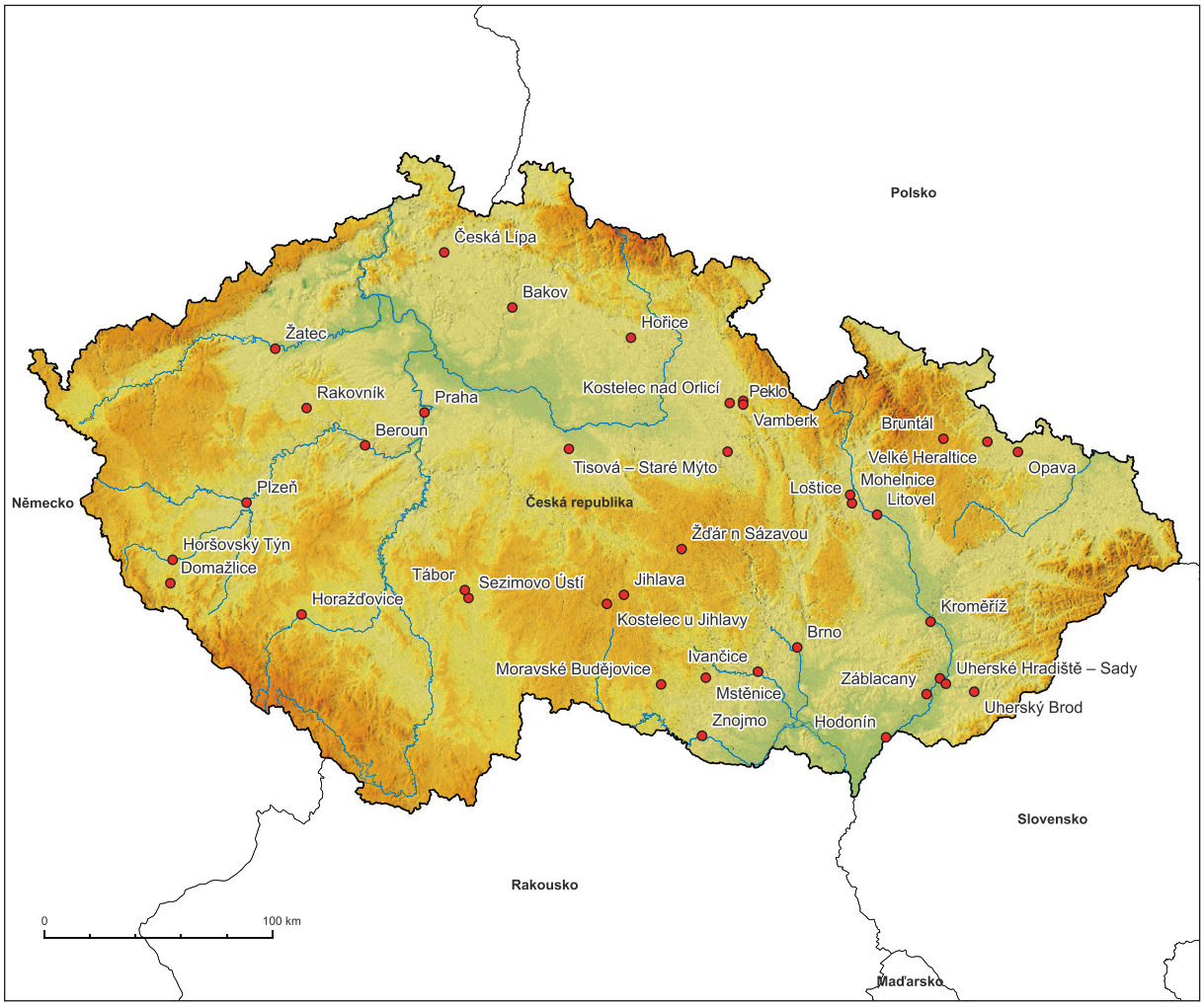


Fig. 1. Medieval sites in the Czech lands mentioned in the text. Graphics by M. Filip.

unambiguous installations have been found. Specialized kilns have been demonstrated only in rare cases, as the oft-recurring statement that we need at least some indicative finds (i.e. residues of kiln contents, tools, defect products, production waste, etc.) in order to establish the purpose of a pyro-technological device generally proves to be true (Buko 1990, 150–151; Klápště 2005, 310, 313; Varadzin 2010, 22–23, 27–31; Biermann,Pust 2008–2009).

Some of the oldest and exceptional finds (in terms of location) of actual kilns are the workshops from **Uherské Hradiště-Sady** in southeastern Moravia (Fig. 1) and **Nitra-Lupka** in western Slovakia from the peak period of the Great Moravian Empire (second half of the 9th century – early 10th century). The pottery kiln in Sady, producing specific pottery in the Roman-provincial tradition, was in the area formed by a church, burial ground and settlement interpreted as the seat of a religious community. The kiln was about 100 m west of the church, i.e. away from the centre of the built-up area where relics of a dispersed early medieval settlement were reportedly found (Hrubý 1965, 42; Hochmanová-Vávrová 1965). The context of this find remains unclear. The structure of the Lupka production area is also not entirely clear from individual publications. Two groups of pottery kilns were in close proximity to a contemporaneous burial site and one solitary kiln at its edge, all in the foreground of the wall of a prehistoric hillfort (for the Nitra complex, see Fusek 2008, especially 272–273). Any other settlement features are absent (Chropovský 1959; 1962; Vlkolinská 2002). The pottery area at Lupka is somewhat reminiscent of pottery centres in the contemporaneous Frankish Kingdom in the wider Rhineland and in areas located further west (e.g. Mayen, Grunwald 2022). Two kilns, interpreted as pottery kilns, have also been uncovered within a settlement complex with evidence of other

production activities at **Staré Město** near Uherské Hradiště, at the 'U Víta' site (Fig. 1); however, we cannot claim this with certainty (Galuška 1989; Hlavica et al. 2024, 999; 1007–1015).

In the final phase of the early Middle Ages in the Central European understanding, i.e. in the 11th and 12th centuries, we encounter for the first time in the Czech lands written reports concerning potters, mostly in forged documents regarding donations made to church institutions which were allegedly created in the sovereign's chancellery. With one exception, the potters mentioned in four documents are said to have been so-called 'donated persons (serfs)', i.e. specialists originally most likely integrated into the system of the princely demesne farms in hillforts and the deeper hinterland (Klápště 2005, 305, 307–310, 490, note 26; Petráček 2017, 261, 262, 270, 283; Čapek 2022, 355–356). To what extent these 'donated serfs' were already relieved of agricultural labour remains unclear; in this context, J. Klápště discusses serfs transferred without land, which in our case would clearly denote only potters 'bestowed' upon the convents of Hradisko near Olomouc and Kladruby (Skružný 1977; Klápště 2005, 305; Čapek 2021, 356).

Unfortunately, in the case of the pottery kilns mentioned above in the area surveyed in the **Mohelnice** settlement in northern Moravia (Fig. 1) (roughly turn of the 11th–13th centuries), we can only draw from preliminary publications. The extensive production area is said to have lacked residential sites, which were situated separately and separated by a ditch. Some of the pits are thought to have been clay pits; circular ones were used as raw material deposits, while others served to process graphite. Both the individual objects in the pits and a series of eight partly chain-arranged single-component kilns secondarily inserted into the large clay pit were identified as pottery kilns. However, the wholly inadequate state of knowledge on this issue does not allow for a concise critical assessment of the published situation, e.g. in terms of the time-space relationships of the revealed facilities (Goš 1975; 1982, 25–26; 1984, 233, 235).

The interpretation of the three kilns in the deserted village of **Záblacany** in southeastern Moravia (Fig. 1) near Polešovice (approximately turn of the 12th – mid-13th century) as pottery kilns is also highly uncertain. Pottery production here is allegedly evidenced by other features, e.g. a clay processing pit and especially defective pottery (Snášil 1970, 328–329; 1971, 102; Kováčik 1999, 85–86).

We also find ourselves on rather unstable ground in terms of the discovery of a pair of non-contemporaneous, allegedly 11th-century pottery kilns in Prague-Košíře within a partially excavated and roughly contemporaneous settlement (Fig. 1) The interpretation of these objects is not clear due to the extent of firing, which is observed only in the heating channels (Zemanová 2020).

In the period from the 9th to 12th centuries, according to more recent opinions, at least a part of pottery production was distributed by market mechanisms, which is evidenced by the results of archaeometric provenance analyses and the occurrence of identical markings in distribution areas documented both in Central Bohemia and southeastern Moravia (Varadzin 2010, 43–57; Hlavica 2023, 53–90; Hlavica et al. 2024).

2.2 Pottery workshops in the High and Late Middle Ages

2.2.1 Potters in early market settlements

In the period of societal and economic transformation, the roots of which can be traced back to the 12th century and which developed completely in the following century, production as a specialised activity primarily intended for the commercial market took shape. Producers were now predominantly artisans engaged in their economic activity on a full-time basis, although seasonal operations combined with agriculture that are known until the 20th century were probably retained in certain places (Scheufler 1972, 93). This involved so called 'individual' or more rarely 'group' workshops in D. P. S. Peacock's (1982, 9) three-tier division. In C. L. Costin's eight-level classification, these are autonomous individual household-based production units producing for the regional market (1991, especially 8).

The emphasis on individual production, run by a master craftsman with a journeymen or apprentices or family members, persisted not only in pottery production well into the modern period and was preserved by the guild system that lasted until the 19th century. Individual crafts were organised in guilds in a gradual manner according to the number of their members and socio-economic power and esteem. Various specialisations were also grouped into single guilds (in general, see e.g. Janáček 1963, 93–115, 148–159; Hoffmann 2009b, 236–256; Schulz 2010; Winter 1906; Skružný 1974). An important prerequisite for the development of craft production was

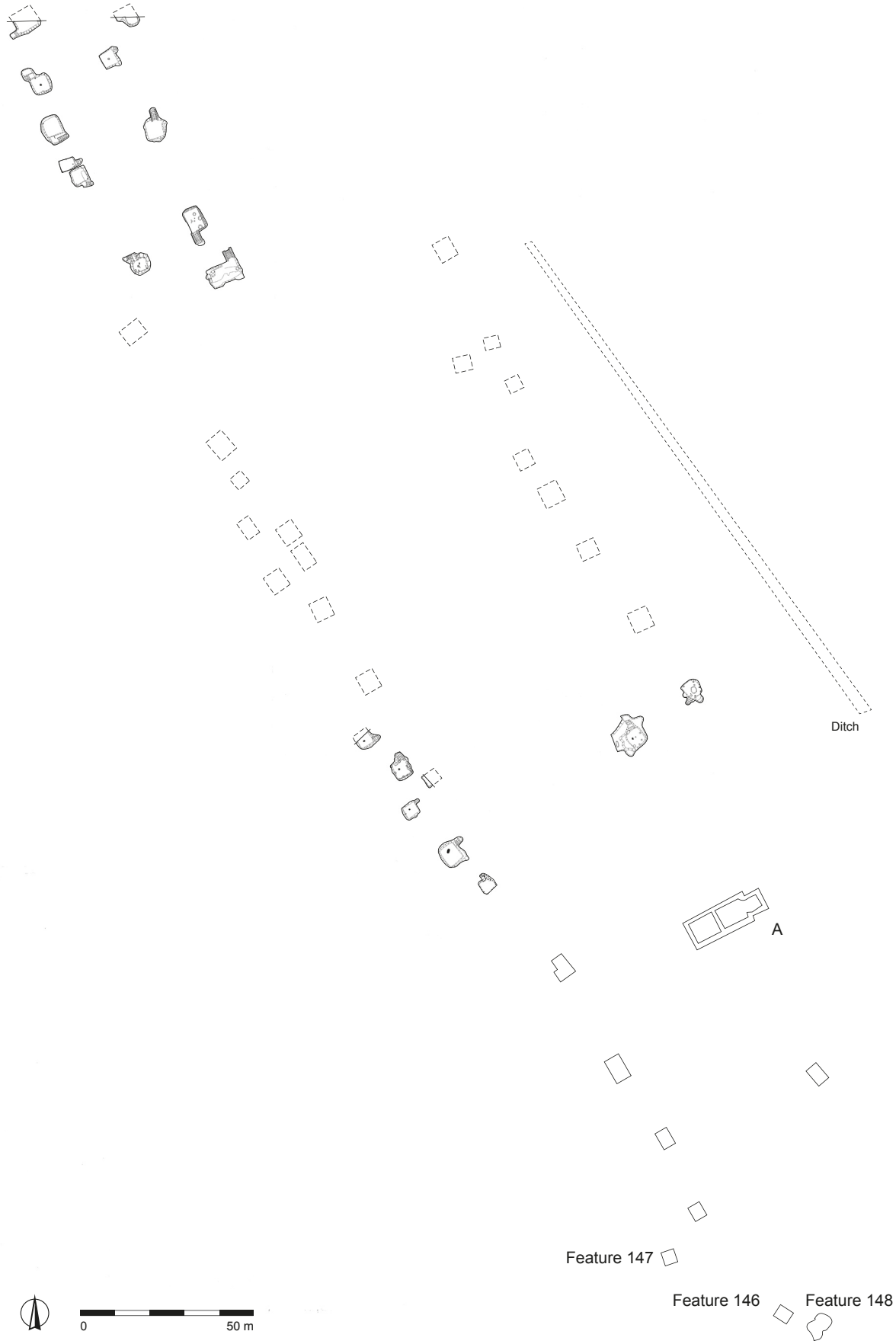


Fig. 2. Tisová – 'Staré Mýto'. Plan of the deserted market village (cellars of timber houses). A – church; 146, 147 – pottery kilns; 148 – pit, possible part of the potter's homestead. According to the plan of the site kindly provided by the Museum of East Bohemia in Hradec Králové. Graphics by M. Filip.

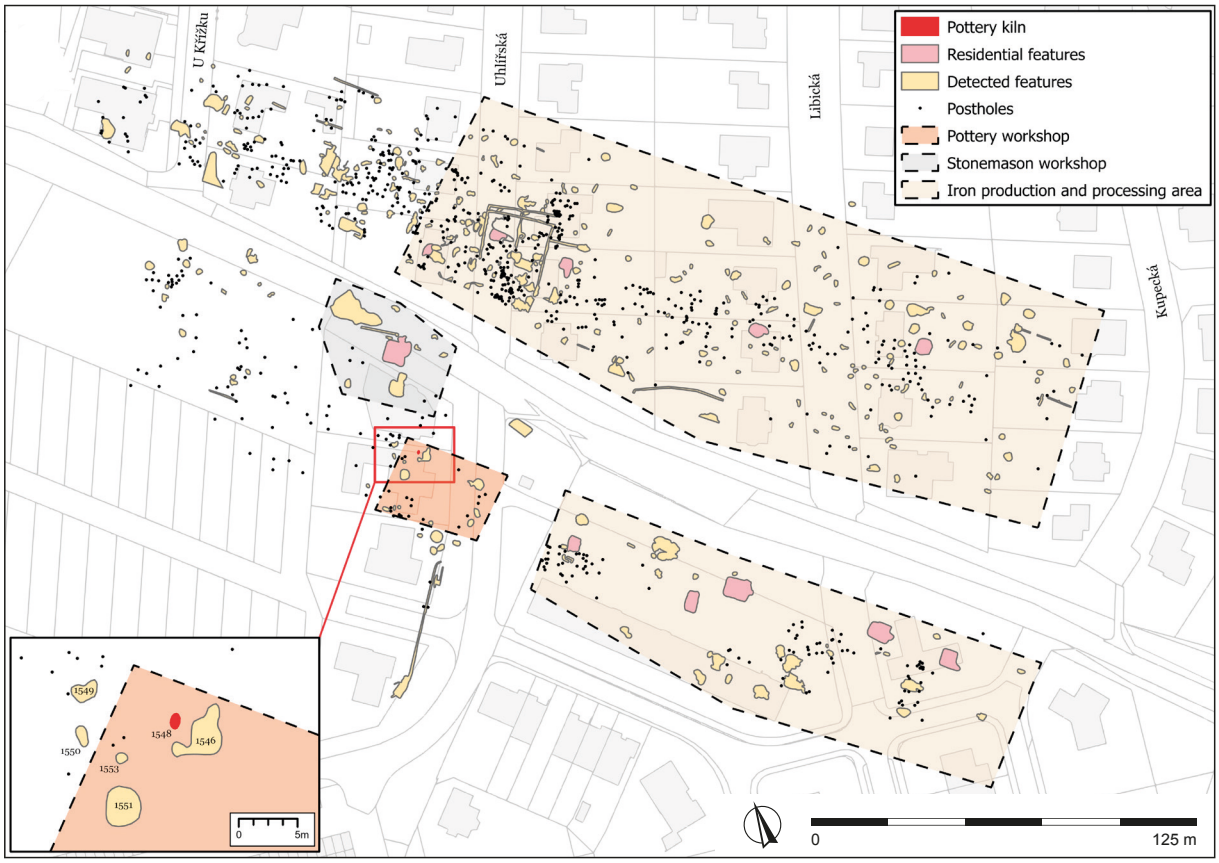


Fig. 3. Žďár nad Sázavou – 'Staré Město' (Old Town). Plan of the excavated area of the market village with marked positions of production areas and the pottery kiln. After Slavíček et al. 2023, 408, Fig. 3. Graphics by M. Košťál.

dynamic urbanisation, which included the formation of urban communes with relatively free producers and traders, although their status varied. The greatest degree of freedom was enjoyed by inhabitants of so-called 'royal towns', which enjoyed privileges granted by the sovereign. In the transitional phase of the 12th–13th centuries, the settlements beneath some important castles were transformed and the network of market villages became denser and rapidly developed into more or less full-fledged towns with town law and a characteristic spatial layout. This resulted in a regionally hierarchized urban network (for a review, see Žemlička 2014, 214–252; for Moravia, see e.g. Doležel 2000; 2025). An important factor was the transformation of the countryside, which was characterised in the social sphere by the emergence of a large class of emphyteutic peasants, whose legally established status and more advanced technologies enabled them to sell surplus products at urban markets (Žemlička 2014, 61–214).

For settlements with markets, which are frequently documented in the Czech lands as the immediate predecessors of cities and towns in the 13th century, pottery production was crucial in satisfying the demand for kitchen utensils. In contrast to the previous period, we now commonly find specialised kilns in these sites firing both traditional products (now in decline) and the emerging pottery of the Late Middle Ages with a considerably greater diversity of types of vessels, as indicated by the results of archaeological excavations at **Tisová, 'Staré Mýto'** in eastern Bohemia (ca 1230s and 1240s to 1260s; Fig. 1; 2) and **Žďár nad Sázavou, 'Staré Město'** in western Moravia (1252/1257–1262/1276; Fig. 1; 3). These proto-urban settlements were already divided up into regular ground plans, and the kilns were in the rear part of the plots. There was one kiln in Žďár and two kilns in Tisová. Kilns located on the periphery of the ground plan are only found in **Tisová**, and due to the distance between kilns – 30 m – there may have been two artisans involved. A related publication mentions the connection of the kilns to two 'sunken-floored houses', i.e. the cellars of residential buildings. But the plan of the excavation kindly provided by the staff of the archaeological department of the East Bohemian Museum in Hradec Králové shows

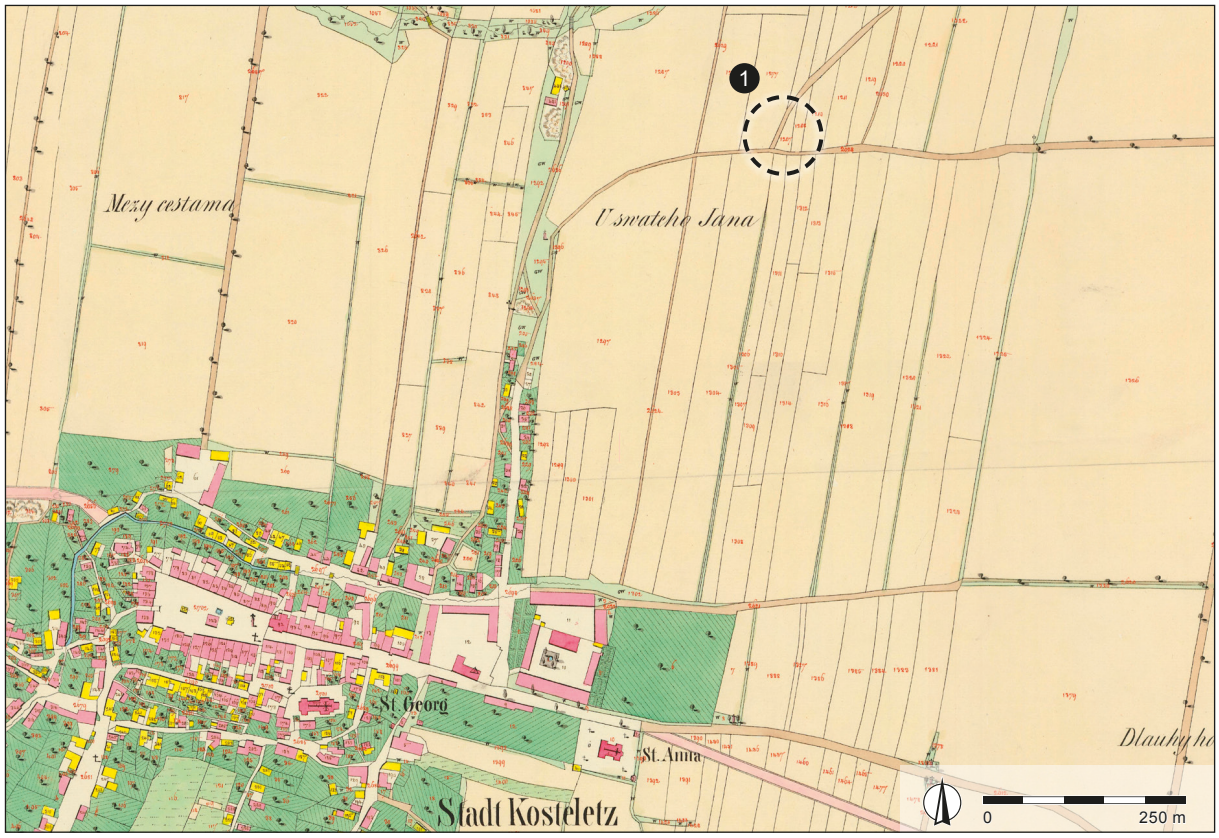


Fig. 4. Kostelec nad Orlicí. 1 – the place of the settlement from the 12th–13th centuries. Imperial Obligatory Imprints of the Stable Cadastre map from1835. State Administration of Land Surveying and Cadastre (ČÚZK). After Richter 1967. Graphics by M.Filip.

only two apparently non-synchronous pits with a still unclear function in the vicinity of the more southerly of the two pottery facilities (Sigl 1977; Richter 1994, 146, 154). In **Žďár**, the settlement context in relation to the subdivision of land is not entirely clear – there is mainly evidence of light surface shelters of a post and beam construction (Zatloukal 1999; 2000b; Slavíček et al. 2023, esp. 406–408). It is interesting to note that the near town of Žďár, which replaced the market village in the last third of the 13th century, had only one single potter according to the 1407 urbarium (Zemek, Pohanka eds. 1961, 66, 68). Pottery is absent in later urbaria from the 15th century (Marek 1958, 49–51). Despite extensive research, the spatial organisation of the situation is also unclear in **Staré Město** near Uherské Hradiště in southeastern Moravia where pottery facilities have been found both in the core of later large building plot blocks at a considerable distance from the early modern built-up area and on their periphery, as we can see on the cadastral plan from the first half of the 19th century (Fig. 1). Only a minor part of the firing facilities here can be included in the pre-urban phase of the settlement associated with the monastic market village then called **Veligrad** owned by the nearby Cistercian convent (the site 'Na Kostelíku', Michalská Street, see below Fig. 9: 1). This mostly involves production that is contemporaneous with the existence of the royal town of Uherské Hradiště (founded in 1257; Galuška 2003; Procházka et al. 2024; see below Fig. 9: 2) The earliest phase of pottery production in **Česká Lípa** in northern Bohemia, represented by a single kiln from the middle of the 13th century, is likely related to the pre-urban settlement near the Church of St Mary Magdalene (Fig. 1). Production continued here in the following centuries in the context of the suburban areas south of the chartered town (Gabriel, Panáček 2000, especially 9–10, 13–15). A regional centre also existed in the 13th century in a wider area of the town of **Kostelec nad Orlicí** in northeastern Bohemia (Fig. 1), which was formed sometime in the late 13th to early 14th centuries (Kuča 1998, 93–98). An earlier settlement, tentatively dating from the late 12th and first half of the 13th century, was located about 1.4 km northeast of the historical centre of the town (Fig. 4: 1). In this area, rescue excavations revealed a pottery workplace

made up of four at least partially non-contemporaneous kilns in a segmented pit complex. The production bore signs of the early medieval tradition (Richter 1967). However, there is no trace of a pottery workshop in Sekanka (Hradištko village near Davle), an abandoned and comprehensively investigated settlement of an evidently similar type, although suitable raw materials can be found in the vicinity of the site (Richter 1982, especially 155–156).

2.2.2 Potters in the high and late medieval villages

Evidence of pottery production in a village milieu is infrequent and for the most part belongs to the initial transformation phase, i.e. the 13th century. The insufficiently studied settlement phase of the deserted village of **Mstěnice** near Hrotovice in western Moravia (Fig. 1) from the second half of the 13th century includes a pottery workplace uncovered under the construction of a younger lord's manor house on the western edge of the settlement area. It consisted of two non-contemporaneous kilns situated near one another (Fig. 5). In the relevant publication, the head of research mentions a potter's workplace, which would have included two granaries and three slightly sunken post and beam structures. One contained a hearth and was therefore interpreted as residential (Nekuda 1963, 64–70; 1979; 2000, 110–112, 115, Fig. 173, 302–304; Nekuda, Reichertová 1968, 41–47). After reviewing the available assemblage of finds in the Moravian Museum, it can be said that only some of the finds, namely from surface buildings

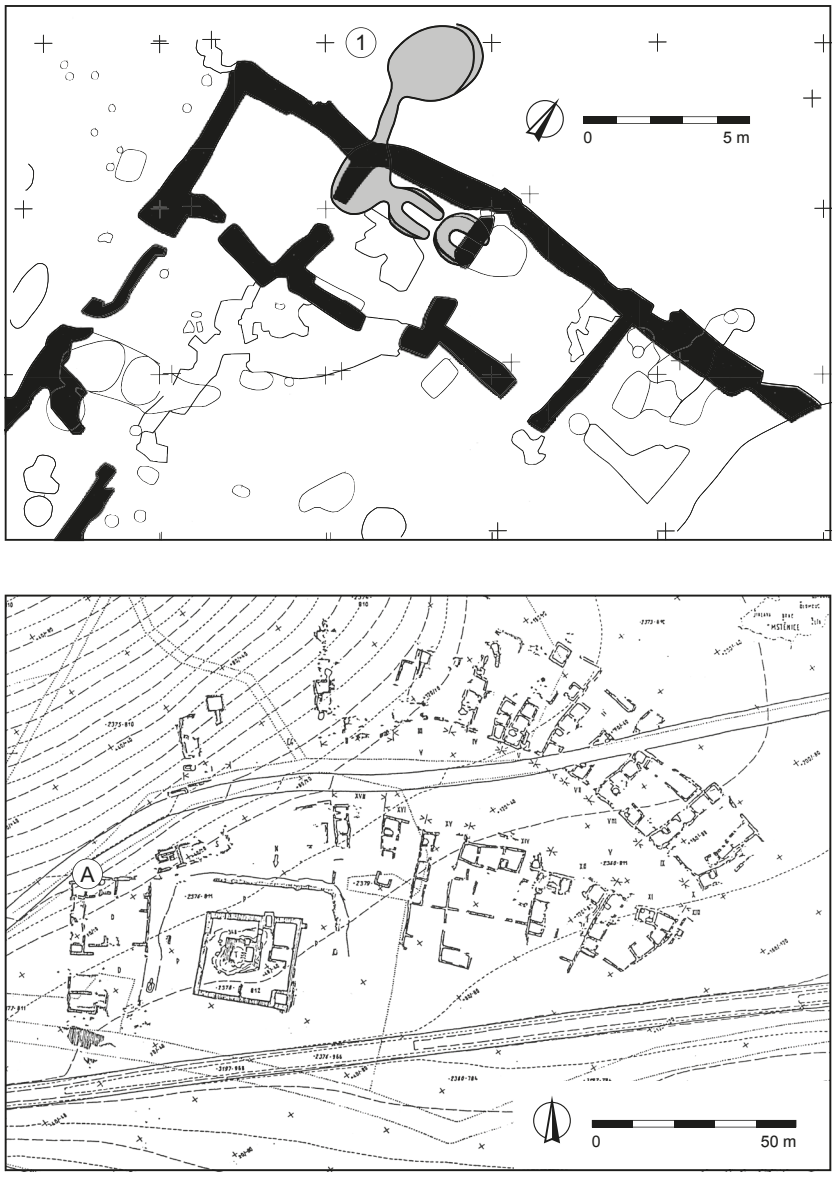


Fig. 5. Mstěnice u Hrotovic. Mstěnice. 1 – pottery kilns 1, 2 under the late medieval manor's walls; A – pottery kilns in the plan of the late medieval village. The detail above was provided by the Moravian Museum, the overall plan has been modified. After Nekuda, Nekuda 1997, obr. 124. Graphics by M. Filip.

16/62 and 46/62 could be contemporaneous with the operation of the kilns Mstěnice, however, was not an entirely ordinary village. Although it lacked a church, the small contemporaneous castle above the village, probably in the hands of the lower nobility, made it a settlement of central importance. Nonetheless, pottery production there was merely an episode in its history.

The village of **Kostelec near Jihlava** with the parish church of St Cunigunde and fortress belonged to the so-called German enclave of Jihlava (Fig. 1). From the second half of the 14th century, it was ruled by various mostly secular entities (Hosák 2004, 11). At the southern edge of the village outside the residential area from the early 19th century, east of the exit road, rescue excavation uncovered a pottery kiln from the second half of the 14th century, for which we unfortunately lack a broader context (Zimola 2021, especially 104; Fig. 6).

Another example is **Velké Heraltice** in so-called Czech Silesia (Fig. 1). The village with small castle and parish church of medieval origin was ruled by the lower nobility in the 13th–15th centuries (Hosák 2004, 782–783). A kiln dating from around the mid-13th century was uncovered in the western part of the residential area on plot No. 199 on the northwestern edge of the built-up area arranged around the village square, probably measured in the 13th century (Fig. 7: 1). The kiln was in the centre of the 19th century homestead plot; but we must consider that the village's original subdivision was altered in the modern period. The kiln included further evidence of settlement, and one sunken feature was investigated (Zezula 2013). The late medieval **Bakov nad Jizerou** in northeastern Bohemia has stood somewhere between a village and a small town (Fig. 1). The site, including a parish church from the mid-14th century, was granted market rights in 1497, which undoubtedly completed the development from village to town (Fig. 8: 1). A 15th-century pottery kiln was uncovered at the boundary of houses No. 82 and 93 on Mírové náměstí (Peace Square) at the northern edge of the unfortified historical centre located on the fluvial terrace of the River Jizera (Kuča 1996, 47–49; Hrdlička 1967).

The occasional, rather exceptional occurrence of potters in villages is also confirmed by a record from 1483 about a potter in the village of **Bítovec** on the estate of the Žďár nad Sázavou monastery. The mentioned potter also practiced agriculture on land measuring a quarter of an acre (Zemek, Pohanka eds. 1961, 139).

In the high and late Middle Ages (after 1257) and the modern period, **Staré Město** near Uherské Hradiště stood economically also on the border between a village and small town, and pottery production is documented there in the 13th to first half of the 15th centuries (Fig. 1). From an economic perspective, the settlement played the role of a suburban area of the royal town but belonged to the monastery of Velehrad. This site is problematic due to its unclear ground plan structure in the 13th and 14th centuries. In the inner areas of the historical plots of the formerly agricultural farmsteads north of the important Uherské Hradiště – Brno road, which were not built-up areas in the modern period, there is an amount of evidence of settlement primarily from the second half of the 13th and 14th centuries. It also includes the relics of heating facilities of apparently residential buildings, which are accompanied by various other relics, including assumed evidence of pottery production – the sites 'Na Kostelíku', now in Michalská Street, and 'Za Zahradou', now in Za Mlýnem Street (Fig. 9: 1, 2). Another area of pottery production on the northern edge of the historical residential area dating from the second half of the 14th to early 15th centuries in the site 'Na Dvorku' at the corner of Jezuitská and Dvorek streets has no apparent continuity (with the exception of a mill) with small-scale late 18th and 19th centuries development (Fig. 9: 3). The state of research from extensive excavations does not yet allow for a full interpretation of the obtained findings, especially because of the wider spatial relationships of the identified production relics (Procházka et al. 2024).

A pair of pottery kilns – one dating to the second half of the 14th century and the other to the interval from the second half of the 13th to the early 14th centuries – as well as three other sunken features of unclear function were revealed on plot No. 3011 in the formerly independent village of **Peklo**, today part of the town of Vamberk (Fig. 10). It is clear from the cadastral map of 1840 that the find was made at the southeast edge of the former open plot No. 184 on the western side of a local road. The assumption made by O. Bek (the author of the only evaluation of the find) that the workshop belonged to the more northerly plot with today's house No. 37 raises certain doubts, as only a barn stood on this separate plot in 1840 (Bek 2022, especially 8, 23). It is therefore possible that the kilns were located outside the built-up area similarly to the situation in Kostelec near Jihlava.

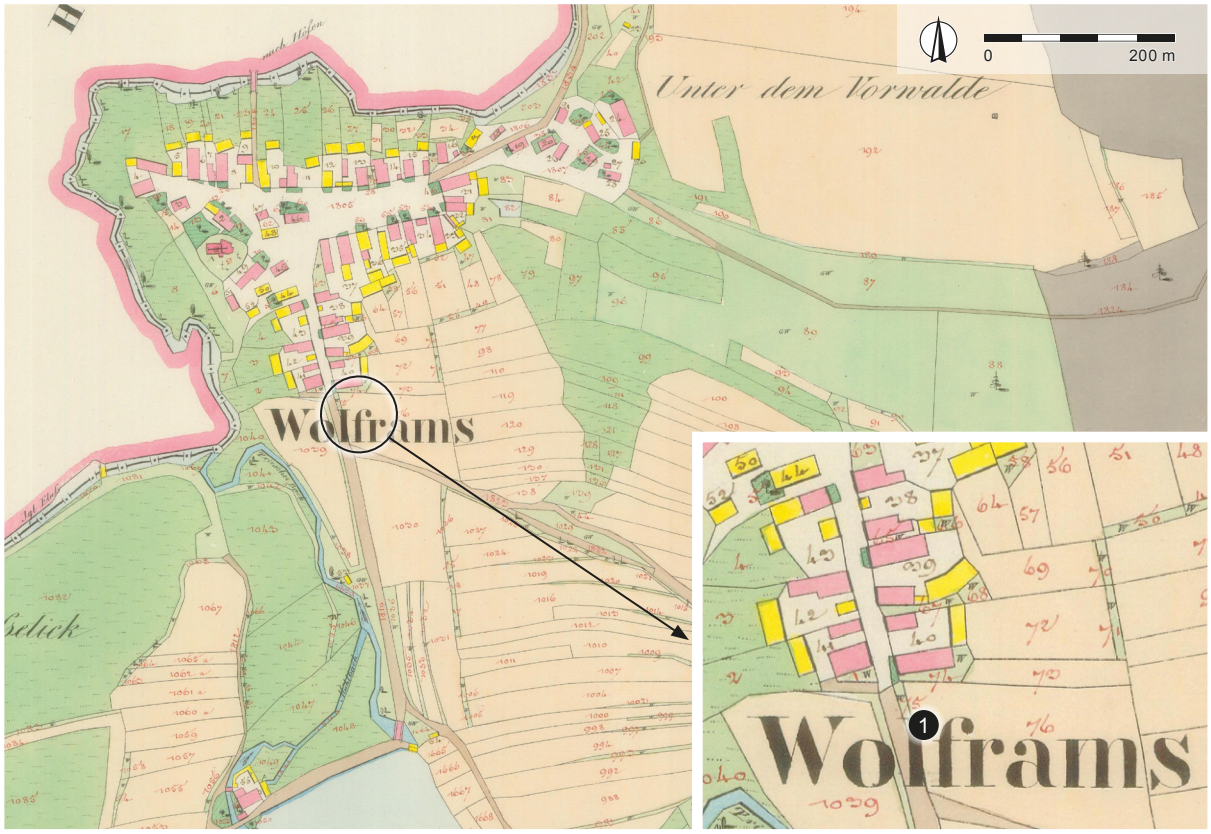


Fig. 6. Kostelec near Jihlava. 1 – the site of the pottery kiln. Imperial Obligatory Imprints of the Stable Cadastre map from 1835; ČÚZK. After Zimola 2021, obr. 6. Graphics by M. Filip.

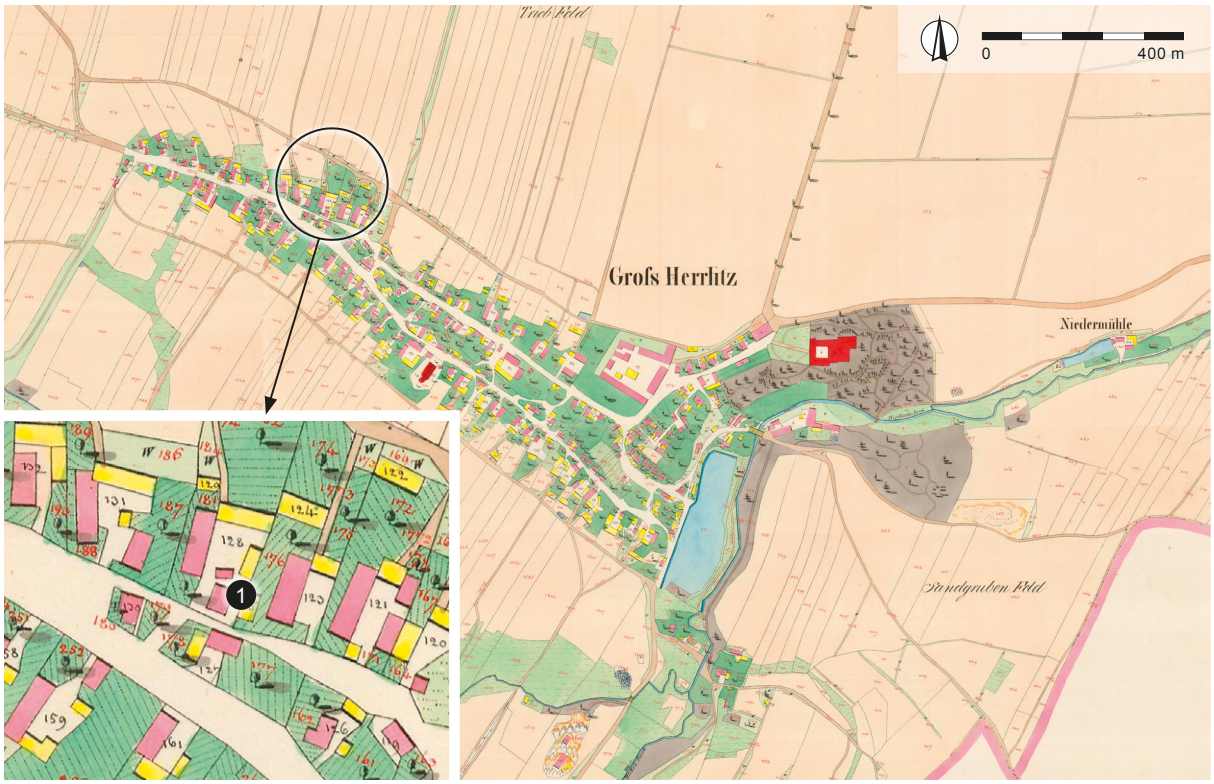


Fig. 7. Velké Heraltice. 1 – the site of the pottery kiln. Imperial Obligatory Imprints of the Stable Cadastre map from 1836; ČÚZK. After Zezula 2013, 302, obr. 1, modified. Graphics by M. Filip.

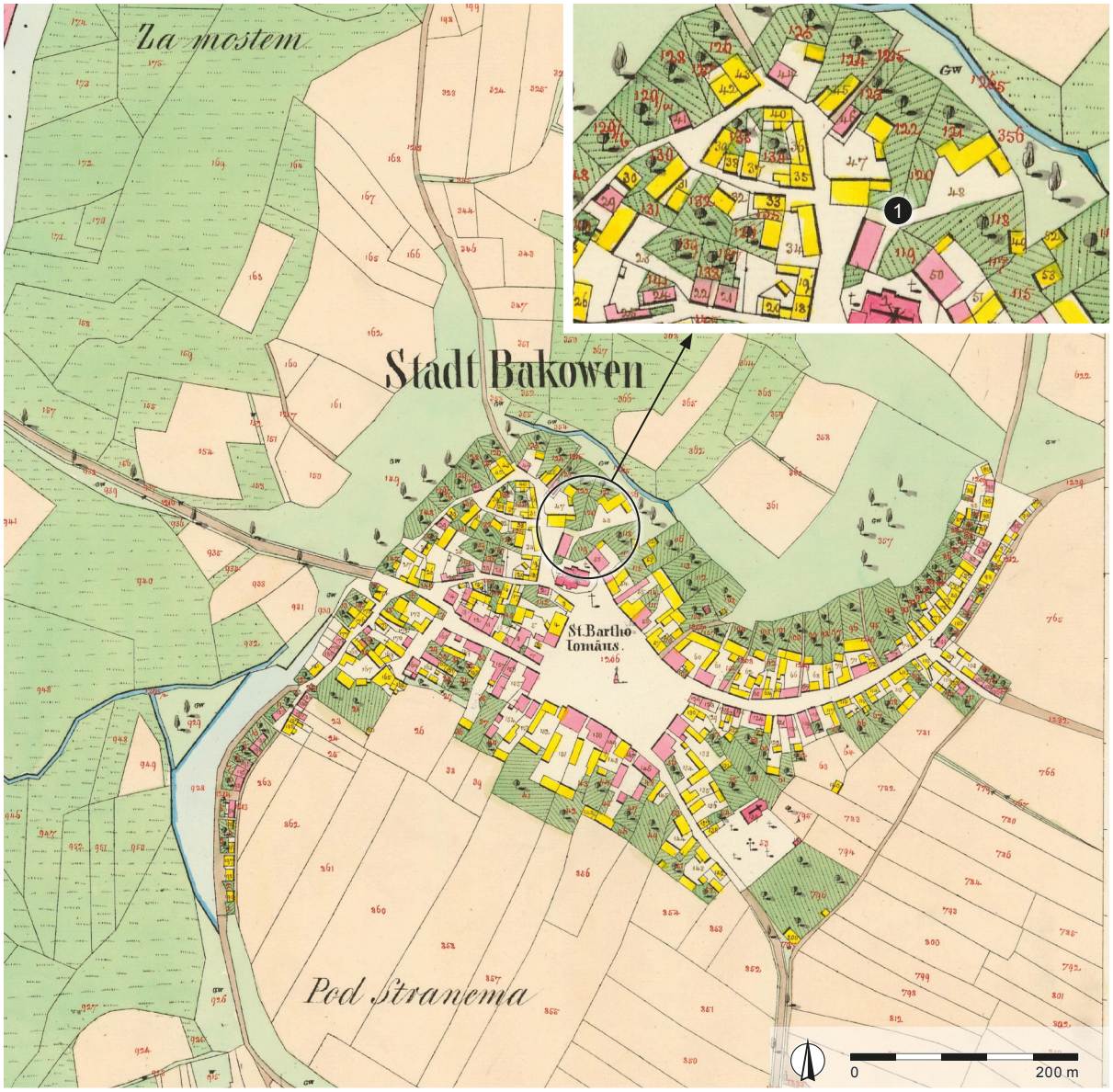


Fig. 8. Bakov nad Jizerou. 1 – Mírové náměstí (Peace Square), pottery kiln. Imperial Obligatory Imprints of the Stable Cadastre map from 1842; ČÚZK. After Hrdlička 1967. Graphics by M. Filip.

Peklo was apparently always part of the Vamberk estate, although it is at first mentioned only in 1527 in the possession of Kateřina of Chrast (Král 1927, 29). Unlike the other villages recorded so far with finds of pottery kilns, this was not a settlement of central importance. Also interesting is the location of the workshop in close proximity to the town of Vamberk, lying 1.5 km to the southeast, where pottery production is also documented in the Middle Ages.

Exclusively rural pottery production centres linked to high-quality clays, such as those documented in some regions of Western Europe, are not known from the Czech lands (e.g. Coppengrave, Stephan 1981). In the 14th and 15th centuries, the countryside procured pottery products in settlements equipped with markets, i.e. in towns and cities. The disinterest of the ruling classes in craft production in predominantly agricultural villages and the application of royal towns' 'mile law' prohibiting the practice of crafts within one mile may have played a role. It is evidently no coincidence that pottery kilns appear in rural environments mainly in the 13th and early 14th centuries, when the hierarchical market network was not yet fully developed.



Fig. 9. Staré Město near Uherské Hradiště. 1 – the site 'Na Kostelíku', now Michalská Street, two groups of pottery features; 2 – the site 'Za Zahradou', now Za Mlýnem Street; 3 – the site 'Na Dvorku', now Dvorek and Jezuitská streets. Imperial Obligatory Imprints of the Stable Cadastre map from 1827; ČÚZK. After Procházka et al. 2024, obr. 1. Graphics by M. Filip.

As there is no written evidence of the status of village potters in the Middle Ages, we also do not know the extent to which they possessed agricultural land. If they did, they are assumed to have combined their craft with agricultural activities (Čapek 2022, 356). Thus far, they seemed to have worked mostly in settlements of central importance with parishes or seats (i.e. the manors of small castles) of the lower nobility. In these locations, archaeological finds are the only evidence of pottery production, a fact which supports the theory of the temporally limited presence of this craft.

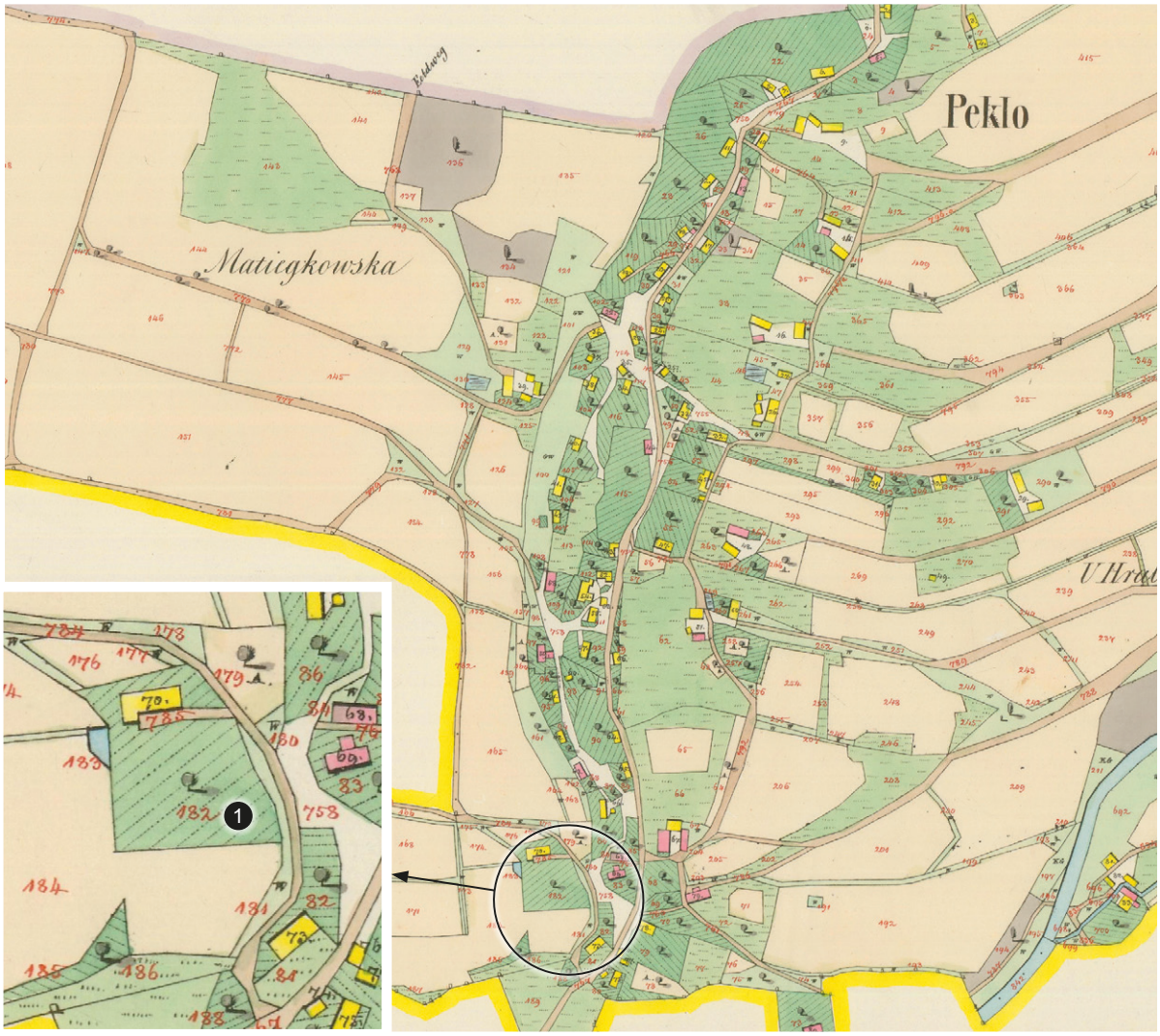


Fig. 10. Peklo (Vamberk-Peklo). Location of pottery kilns in Imperial Obligatory Imprints of the Stable Cadastre map from 1840; ČÚZK. Graphics by M. Filip.

2.2.3 Pottery production in cities

In the High and especially Late Middle Ages, archaeological evidence is supported to a greater extent by written sources. These show that a typical structure of urban craftsmanship with several branches and sub-specialisations was already being formed in the 13th century. However, we only learn of its comprehensive structure in the following century as a result of the introduction of municipal records (i.e. 'town books'), which were initially only of a memorial and tax nature. Potters, whose activity is documented from the very beginning (especially due to their kilns), are also singled out as a separate specialisation. Pottery production was now being fully applied on the market, with specialised marketplaces in some towns. Their guild organisations were established during the Late Middle Ages, most often in the Early Modern period, especially in Moravia. If we leave aside the alleged guild in Levín from as early as 1402, perhaps the oldest guilds documented with certainty were located in Cheb in 1453, Česká Lípa in 1462, followed by Ledeč in 1466, Olomouc in 1472, Lanškroun in 1487, Prague's New Town (the Old Town of Prague until 1518), Příbram, Písek, Ronov nad Doubravou (?), Hradec Králové (?) and Hlinsko (?) in 1488, České Budějovice in 1496, and Kutná Hora in 1501. In Moravia, a joint guild of potters, millers, and bakers is mentioned in Telč in 1514, and according to preserved statutes, there was an independent organisation in Jihlava in 1518 and in Znojmo in 1520 (Winter 1906, 494–495; Kühndel 1929, 60–62; Nekuda, Reichertová 1968, 22–28; Skružný 1974, 161–162; Čermák 2002, 123–124; Hoffmann 2009b, 237–246; 421–426; Smrž 2019, 66–68, 139–143).

Pottery workshops in the main royal cities

Brno in south Moravia has the richest written sources, which date back to the mid-14th century (Fig. 1; 11). Particularly significant is its series of tax books and registers, covering (albeit very sparsely) a significant part of the 14th to 16th centuries. Unique precision can be found for the 15th century thanks to the existence of three tax books in direct succession. Registers from the city's tax archives from 1343 to 1518, which have been scientifically published (with the exception of the years 1375 and 1376) until 1432, were also used (AMB, collection A1, manuscripts 8, 9, 10, 15, 22–30; Mendl ed. 1935; Urbánková, Wihodová eds. 2008; in general, see Sulitková 1998; 2004, especially 135–154; Jordánková, Sulitková 2023). Due to the highly favourable situation in terms of written and partially also archaeological records, we are able to focus most thoroughly on local pottery production here.

In terms of the pottery craft, C. Schirek (1900, 9–16) was the earliest to explore modern-age pottery producers. Studies of the vast majority of potters listed below from the 14th to the early 16th centuries were published by H. Jordánková (2021) including their locations in urban districts. Alois Gödel's topographical work makes it possible to identify the residences of craftsmen from the mid-15th century onward (Gödel undated).

The first potter known by name, Merboto, worked briefly around 1348 in the second town district, in its northwestern area (Fig. 11: 1). It is not certain whether he was a house owner or tenant (see also Vičar 1965, 281). We find other potters here listed only anonymously as *figuli* in the intermediate period of 1343 to 1350. According to records from 1348 and 1356, other potters worked in the 4th suburban district in front of Brno Gate on the southwestern side of the town wall circuit around the connecting west–east-oriented road towards Staré Brno (Old Brno) – Pekařská Street from the 15th century until today; Fig. 11: 4, 5), although only one – Štěpán – is listed by name (1356). In 1365, we register two potters in the same quarter; one a tenant living in Pekařská Street, while the other owned a small house further north in front of Veselá Gate. This was also the location of the only workshop of Hanuš of Doubravice, which is recorded in a detailed register written two years later. By the 1370s, pottery production seems to have been on a slightly upward trajectory and concentrated in Pekařská Street. In 1375 and 1376, we find four potters as house owners here, with three more active in 1387 and 1389. We also see the addition of one tenant, Kristián, if this is not the former owner of the house of the same name. Two craftsmen, Petr and Oldřich, were probably neighbours. In 1387, there was another potter working in front of Jewish Gate on the southeastern side of the town's plan. In only one case can two generations of potters be proved, and they are of the same name, Kristián.

A partial change came in the first half of the 15th century, as in the register from 1432 we find a single potter in the fourth suburban district in the Švábka Street (today's Údolní Street). Two others are documented in the first quarter, called the Brno quarter, within the walls, namely one tenant and one house owner. According to their order in the town's tax collection procedure, they were in the 'Pod Kopcem' area (i.e. on the eastern slope of Petrov Hill in the southwestern section of the street called Česká (Czech, Bohemian) in the 14th century, now part of Kapucínské náměstí (Capuchin Square); Fig. 11: 7), roughly on the site of the later Capuchin monastery (5 Kapucínské náměstí). We encounter other potters only in the records of the tax books continuously covering the period from 1442 to 1537 and in the registers of the town's tax collection records from 1471, 1479, 1487, 1499, 1504, 1510, 1514 and 1518 (AMB, collection A1, manuscripts 8–10, 22–30). These were exclusively owners of houses or small suburban houses. Identification is made difficult by the recurrence of some first names, especially Jan. We find them discontinuously in the first and second districts of the inner city, and more frequently also in the fourth suburban district, with the centre in the upper and middle part of Pekařská Street, sometimes also in Švábka and Hartlůvka streets (today's Údolní and Veveří streets). In the first quarter, potters are still overwhelmingly documented on the eastern slope of Petrov Hill. Alois Gödl correctly determined that the vast majority of the potters documented here from the second half of the 15th and first half of the 16th centuries lived at various times in some of the 10 houses removed after the foundation of the Capuchin monastery in 1634 (Gödel undated, Kapuzinerplatz; today house No. 303/5; Fig. 11: 7). In connection with this text, a revision of its data for the 15th and first quarter of the 16th centuries was carried out, which led to a number of corrections and additions. Nonetheless, some problems have yet to be resolved. The southernmost house, Kapucínské náměstí No. 304/4, was occupied by Bartholomew Reindler (ca 1471 – before 1479); Jan Kannperger (after 1442 – before



Fig. 11. Brno. 1 – náměstí Svobody (Freedom Square), approximate location of the potter Merboto; 2 – Veselá Street, house No. 235; 3 – St Anna Monastery; 4 – settlement 'opposite St Anne's' in the middle part of the Pekařská Street; 5 – upper part of the Pekařská Street 'in front of the Brněnská brána (Brno Gate)'; 6 – Starobrněnská Street, house No. 287/11; 7 – Kapucínské náměstí (Capuchin Square), house No. 304/4, 303/5. Imperial Obligatory Imprints of the Stable Cadastre map from 1825; ČÚZK. Graphics by M. Filip.

1471) operated in the northern neighbourhood (now No. 303/5). Jan of Jihlava lived two houses down in the western direction in 1514–1523, having moved there from Pekařská Street. If we continue further up the slope, the neighbouring building housed the workshop of Pavel Zachariáš (Sacharus) from 1521 to 1541. Four houses away, at the very edge of the built-up area of the later monastery, two potters, Pavel (1498–1504) and Petr Klamphel (1504–1513; Schirek 1900, 10), worked in succession on the same plot. One potter, Jakub Hewrauß, worked only periodically from 1517 to 1534 on the western edge of the first quarter in Starobrněnská Street in today's house No. 287/11, which consists of two historical plots now (Schirek 1900, 10; Fig. 11: 6). In the second quarter, we record a succession of two craftsmen, Hans

Schwab (and later his widow) and Hans Neuholth (before 1471–1495) in the same house No. 235/15 in the Veselá Street (demolished in the last years; Gödel undated, s, Fröhlichergasse; Fig. 11: 2).

Manufacturing also continues in the fourth suburban district northwest to southwest of the historical core. There were two craftsmen in Švábka Street around 1442 and one in Hartlůvka Street (in front of Veselá Gate, today's Veveří Street) around 1477. We find potters more sequentially around Pekařská Street in front of Brno Gate, in one case in Pod Puhlíkem Street running down the southern slope from the upper part of the street. The structure of records and probable changes in the subdivision of suburbs after the Thirty Years' War does not allow us to identify the houses of inhabitants in this context with such precision as with the inner city. This is similar to V. Vičar's (1966, 226, 228) claims for the 14th century. In addition, the Pekařská Street, or the part of it subordinate to the town, is divided into two parts with an unclear boundary. Roughly from the mid-15th century to 1518, a total of 10–11 potters lived here, but only usually for a short period of time, while in the early 16th century up to four craftsmen were working here simultaneously. Only in very rare cases can one potter be documented as having lived here for more than 10 years. Occasionally, there were two in one house subsequently, but never two in close succession. A move from one part of the town to another can be documented in exceptional cases. Hans of Jihlava lived from 1504 to 1514 in Pekařská Street, then in Kapucínské náměstí in the first town district until 1521. The potter Wolfgang apparently sold his house on Pekařská Street and bought another one there in 1518. The widow of another potter of the same name sold her house on the same street in 1507 and moved to the first quarter of the inner city, where she lived in the now non-existent house No. 265 near Brno Gate.

At best, we can document a succession of two producers in Brno; the longest clearly established period of time for one craftsman's stay exceeds 20 years if it is indeed one and the same person (Hans of Jihlava, 1499 – after 1521, but in two different houses). Subsequent intervals are less than 15 years. The number of master craftsmen working simultaneously within the period under review was four or less (see below Tab. 1).

Pottery production continued in Brno even in the Modern period. A potters' guild is documented there in 1601, and potters are found in various parts of the inner city (Kobližná Street). Even then, however, Brno was still not an important pottery centre. As of 1655, for example, only four craftsmen are listed in the suburbs belonging to the town as was the case in the Middle Ages (Schirek 1900, 10–15; Jordánková 2021, 407).

So far, direct evidence of pottery production from the medieval period is limited to finds from the inner city dating back to the late 15th and early 16th centuries. The find of a pottery workshop in front of Ferdinand Gate (or Jewish Gate in the Middle Ages), i.e. in the first suburb, is mentioned as being the first (Nekuda 1963, 70; Sedláčková, Zůbek 2021, 393). In the courtyard of the Capuchin monastery (5 Kapucínské náměstí), four kilns were recorded in 1962, two of which have been professionally researched but unfortunately not accurately measured. Vladimír Nekuda correctly linked them to the potter Pavel in the town's tax collection records from 1499. It is therefore the workplace of the potters Petr and Pavel from 1498–1513 (Nekuda 1963, 70–72; Nekuda, Reichertová 1968, 24, 278). In the second half of the 1970s, according to information from L. Belcredi, an employee of the Moravian Museum at the time, another pottery kiln was destroyed. If they all belonged to the aforementioned craftsmen and worked in succession, they had an average lifespan of three years.

Most recently, two pottery kilns with pottery similar to that of the Capuchin monastery were found in the core of the plot of former house No. 235/33 in Veselá Street. The kilns were in the courtyard of the approximately contemporaneous late-medieval house roughly 33 m from the street line (Sedláčková, Zůbek 2021, 393–402; Zůbek et al. 2021, especially 73–75). They can be linked to the workshops of Hans Schwab and Hans Neuholth.

Ceramics were also imported to Brno; there was a pottery market documented in 1377 in the western area of Horní trh (Upper Market; Procházka 2013a, 546–547; Jordánková 2021, 405). Brno was never a significant pottery production centre. The demand for pottery from a relatively large number of burghers attracted potters to settle, but with no more than five masters working simultaneously, it is unlikely to expect significant exports.

Jihlava in western Moravia was a prominent royal town associated with silver mining (Měřínský, Charouz 2009; Měřínský, Hrubý, Zimola 2009; Měřínský, Vosáhlo, Hrubý 2009; Hoffmann 2009a; Fig. 1; 12). Records of potters have been preserved only in the registers of the town tax collection archives from the first half of the 15th century (1425–1431,

1438, 1442) in the southeastern part of the city in the second town quarter. They were mainly concentrated on the northern side of Česká Street (today Brněnská Street), and to a lesser extent on the southern side of Hrnčířská Street (today Čajkovského Street). All of them were house owners. Most of them lived here in 1425, when we find three in Česká Street and two in Hrnčířská Street (Fig. 12: 4, 5). Between 1426 and 1428, two lived in each of the two streets in question. From 1429 to 1431, there was one less on Hrnčířská Street. Only one potter – Kunc from Hrnčířská Street – is documented throughout the entire period under study (1425–1442). In 1432, he was accompanied by another potter, Wallusch, and from 1438 to 1442 by a certain Jiří, both in Česká Street. Thus, a slight decline in the number of representatives of this craft can be noted during the second quarter of the 15th century (Hoffmann 1961, 89, 192; 2004a, 66–67, 69–76; 2004b).

Archaeologically speaking, Jihlava potters in the Middle Ages have so far been documented both in the inner town and in Old Jihlava (Stará Jihlava). In the second half of the 13th and first half of the 14th centuries, workshops were operating at the northeast edge of the town in the first urban quarter. Two pottery kilns have been found along Křížová Street facing the gate, 5 m and 11 m from the street line (Fig. 12: 3). It is possible that they were located on the same plot with their residential part facing Křížová Street, as the cellar of a wooden house from the second half of the 13th century represented the first phase of settlement along the plot's building line. Other buildings that could have been related to pottery activity are not mentioned in partial publications (Zatloukal 1998, 28–30; 2000a, 63–64).

One kiln from approximately the second half of the 13th century was examined via rescue excavation in the area of **Old Jihlava** north of the town in U Skály Street, house No. 321/11, about 320 m northeast of the Church of St John the Baptist (Fig. 12: 1, 2). This site is a predecessor of the town, and at the latest in 1304 it became part of Jihlava as a settlement with a filial church (Hosák 2004, 3–4; Měřínský, Charouz 2009). It is separated from the town proper by the so-called Špitálské Suburb. According to a preliminary research report, the remains of a sunken building, several pits and a cultural layer with high medieval pottery were recorded in the profile of the building pit in the immediate vicinity (Kochan et al. 2021, 118–125). From the map of the stable cadastre (1835), it is clear that the site lies completely outside the historical built-up area concentrated mainly to the south and southeast of the church by the River Jihlava. The actual extent and distribution of the settlement of Old Jihlava in the Middle Ages is unfortunately unknown. The only clue is the discovery of the remains of a brick house, allegedly dating from the late 13th to early 14th centuries on the eastern side of Havlíčkova Street in the house No. 238/80, about two-thirds of the distance between the church and the site with the kiln (Kochan et al. 2021, 120). Both finds are located close to the old road towards Měšín and Heroltice, along which the medieval built-up area may have developed.

In the southwestern Moravian town of **Znojmo** (Fig. 1; 13), potters are first mentioned in 1363 almost exclusively from the suburban area called Pukenthal in the valley on the left bank of the River Thaya (Fig. 13: 5). Of the four craftsmen/house owners, two – Walter and Wolulin – lived in close proximity. Only one, Hartlín, worked in the Lower Suburb (today Kollárova and Vídeňská streets; Fig. 13: 4). The register from 1397 provides only a partially similar picture. Once again, we find four potters in 'Pukenthal', and one either before Middle or Lower Gate. It was more likely Middle Gate at the eastern side of the city wall circuit judging by the order in the register (Fig. 13: 3). There was also a brickworks, *czighlhuten*, here. However, we register a new grouping of potters in the suburb in front of Upper Gate (Fig. 13: 2). There were probably three potters there that year – Henslín, Michael and Fridlín. In addition to these house owners, potters are also found among tenants (*inquilini*). This includes one Michael Haffner (probably a tile maker), mentioned without a residence. Anna, the widow of Kunczlín of Pukenthal, apparently became a tenant, and the son-in-law of the potter Perchtold also lived here (Polesný ed. 1928, 7, 18, 29, 37, 44, 51–54, 63, 66–68, 108–109, 117, 122, 123, 128, 144).

In addition, the register of fees paid to the St Elizabeth hospital in 1442 shows the most potters (3) in the suburb of Pukenthal. The widow (?) of a potter or stove builder Michel is recorded. One potter – a tax payer – probably resided in front of the Middle Gate (Fig. 13: 3; Polesný ed. 1932, 10, 26–29, 32, 37, 53, 55, 57). It is no coincidence that a pottery kiln from the late 15th or early 16th centuries was found here, demonstrating the probable continuity of pottery activity (Zatloukal 2000a, 68; Procházka 2015, 222, 223). However, the find in Sokolská Street is located outside the built-up area depicted on historical maps from the 19th century (Peškař 1958; Fig. 13: 1).

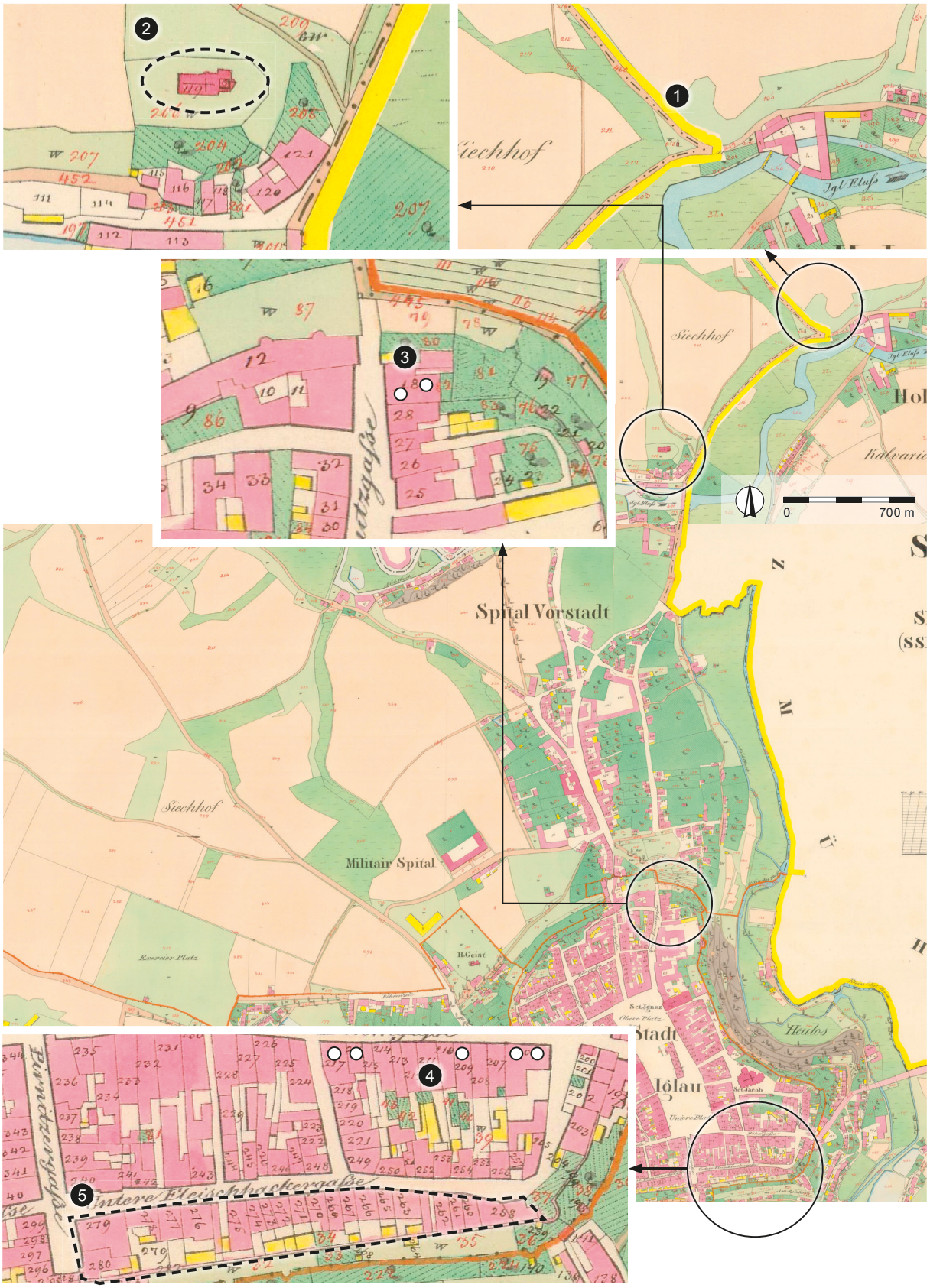


Fig. 12. Jihlava. 1, 2 – Stará Jihlava (Old Jihlava), 1 – U Skály Street; after Kochan et al. 2021, obr. 1; 3 – Křížová Street, after Zatloukal 1998, obr. 1, 2; 4, 5 – localised potter's houses in Česká (now Brněnská) and Hrnčířská (now Čajkovského) streets. Imperial Obligatory Imprints of the Stable Cadastre map from 1835; ČÚZK. Graphics by M. Filip.



Fig. 13. Znojmo. 1 – Sokolská Street, after Peškař 1958; 2 – suburb in front of the Horní brána (Upper Gate, now Pražská Street); 3 – suburb in front of the Střední brána (Middle Gate); 4 – suburb in front of the Dolní brána (Lower Gate, now Kollárova and Vídeňská streets); 5 – the former suburb Pukenthal (now Koželužská Street). Imperial Obligatory Imprints of the Stable Cadastre map from 1824; ČÚZK. Graphics by M. Filip.

The significant royal (and later ducal) town of **Opava** in Czech Silesia is unfortunately characterised by the absence of written sources relating to the pottery craft in the medieval period (Fig. 1; 14). According to a report from 1608, six guild masters are listed among the potters. The centre of production in the 16th century was in the northwestern Jaktařské Suburb near the route leading to Krnov, where it was evidenced by waste pits on the plots of house No. 2035/4 and 2968/17 in Krnovská Street (Fig. 14: 1, 2). A potters' market was located on Dolní náměstí (Lower Square; Fig. 14: 3), and later potters were alleged to have sold their products in front of the Church of the Holy Spirit at the Minorite Monastery at Dobytčí trh (Livestock Market, today's Masarykova Street; Čapský 2006, 126; Žáček 2006, 145; Korbelářová 2009, 185; Tymonová 2014, 161–162; Fig. 14: 4) during annual fairs.

A fragment of the workshop area was found within the historical Hradecké Suburb to the southwest of the town centre in today's Hradecká Street, originally probably the by-road of the two forked outbound roads (Fig. 14: 5). We do not know the medieval structure of the built-up area, and we can only assume that in the 14th century there were houses placed along both streets. An early 14th-century kiln was excavated in front of house No. 668/1 and in its garden, while several pits with production waste dating from the entire 14th century were found deeper in the plot (Šikulová 1972; 1973; 1975, 274).

Uherský Brod in southeastern Moravia (Fig. 1; 15), founded as a royal town in the second half of the 13th century, is also problematic due to the absence of relevant sources (Procházka 2008, 223–225). A single potter is mentioned in the urbarium

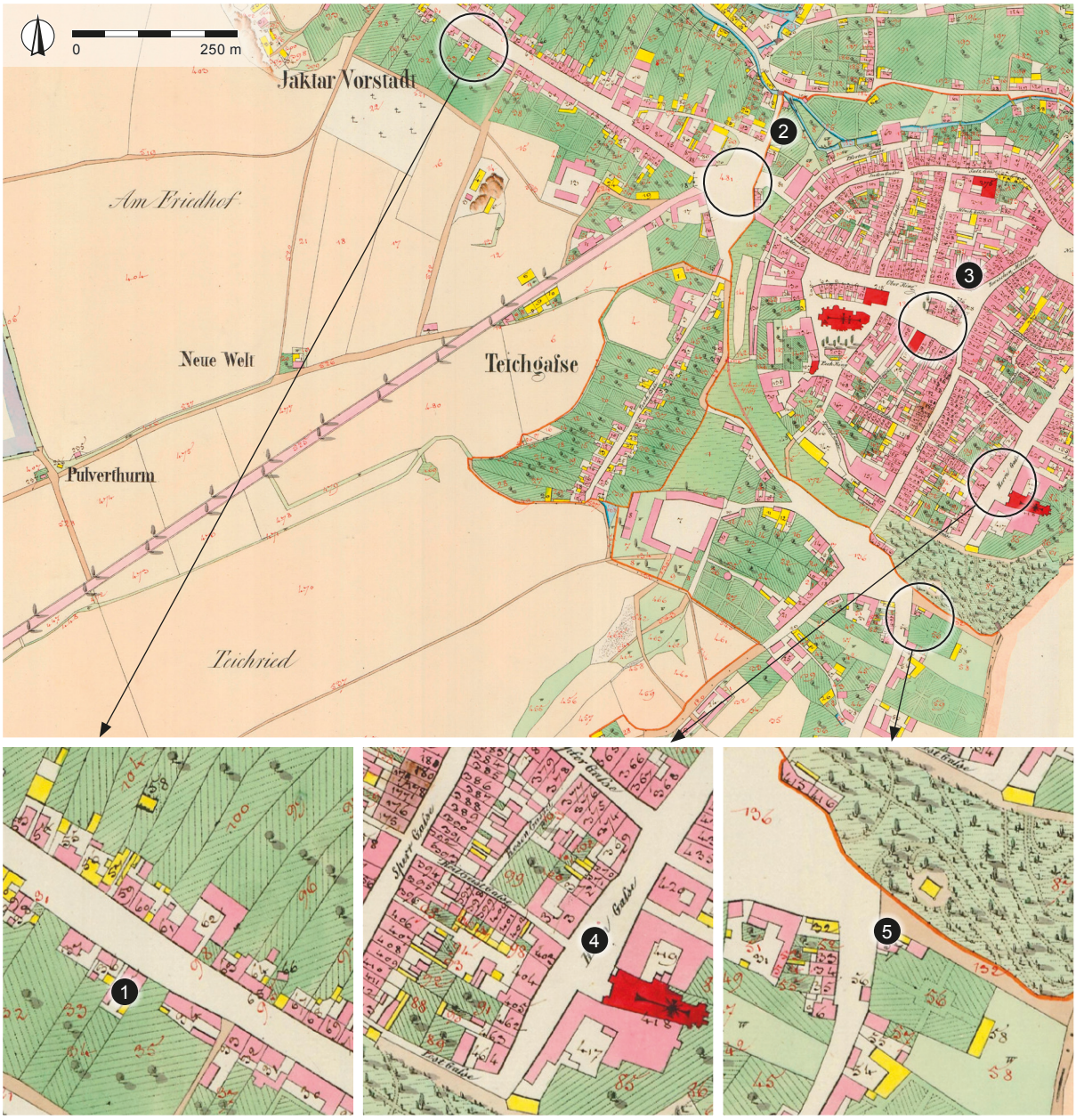


Fig. 14. Opava. 1 – Krnovská Street, house No. 2968/ 17; 2 – Krnovská Street, house No. 2035/4; 3 – Dolní náměstí (Lower Square); 4 – Masarykova Street, earlier Dobytčí trh (Livestock Market); 5 – Hradecká Street, house No. 668/1. Imperial Obligatory Imprints of the Stable Cadastre map from 1836; ČÚZK. 1, 2 and 5 after Tymonová 2014, obr. 2. Graphics by M. Filip.

from 1671, and another among the burghers admitted among Brno's citizens from 1708 to 1758 (Kučera 1903, 381; Zemek ed. 1972, 381). A single pottery kiln was found on the corner plot of the present house No. 170 at the intersection of Komenského and U Sboru streets in the southwestern corner of the historic town centre near the walls (Bartík, Chrástek, Novotný 2016; Bartíková, Bartík 2019). On the cadastral map from 1827, the plot faces towards U Sboru Street (Fig. 15: 1). The pottery kiln from the second half of the 14th or early 15th centuries stood about three metres from the street line of Komenský Street and 5 m from the northern boundary of the plot at U Sboru Street. It was sunken into the fill of an only slightly older cellar No. 505 farther back in the plot. Parts of three other cellars in various superpositions were uncovered at the eastern side of the plot; some were also built in the 14th century at the earliest. The residential buildings appear to have been oriented

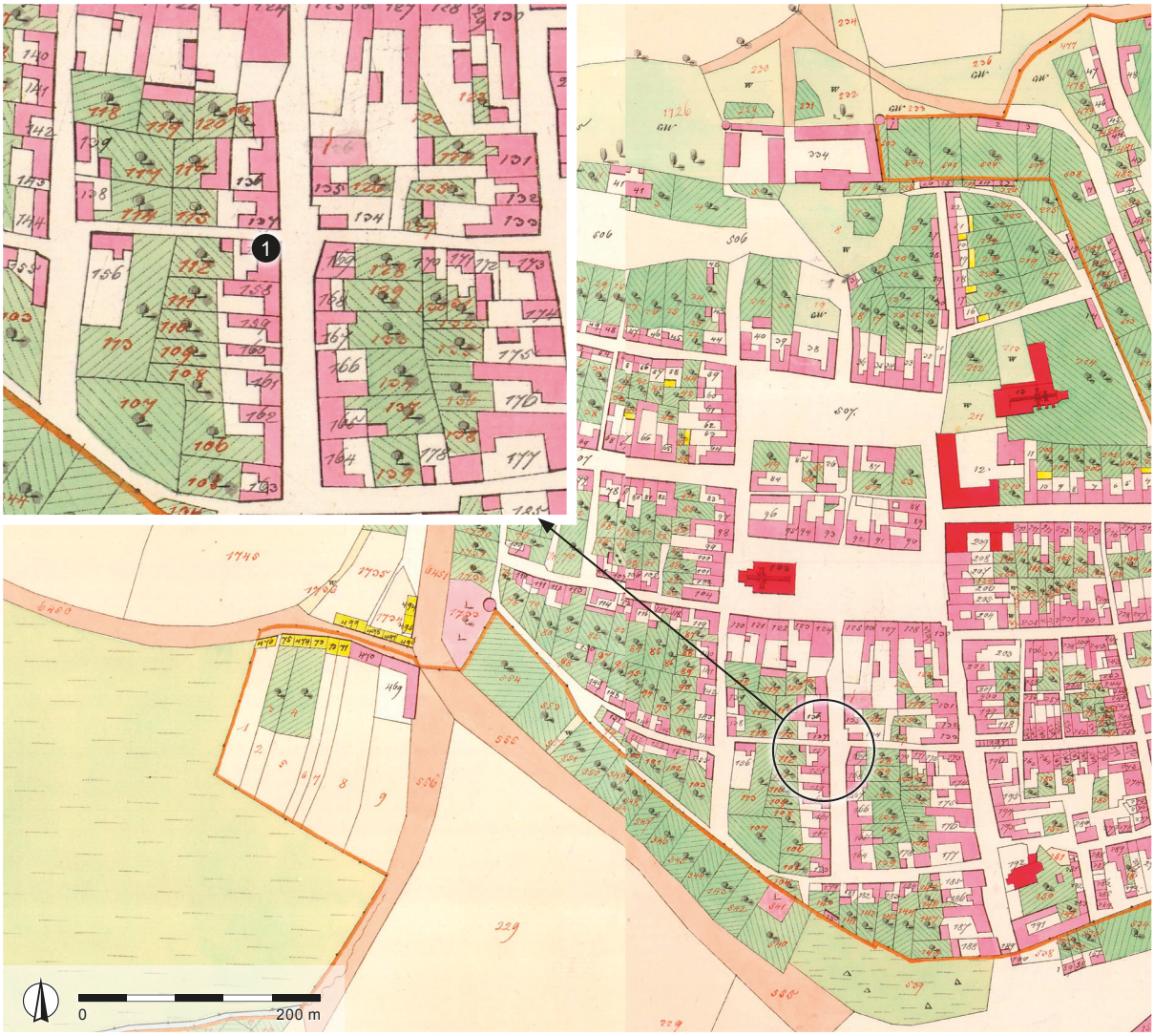


Fig. 15. Uherský Brod. 1 – Komenského Street, house No. 170. Imperial Obligatory Imprints of the Stable Cadastre map from 1827; ČÚZK. After Bartíková, Bartík 2019, obr. 1. Graphics by M. Filip.

towards Komenského Street running north–south. It is interesting to note that the kiln was built in their immediate vicinity and not closer to the wall. Pottery production here was probably only short-term and episodic in character.

Uherské Hradiště in southeastern Moravia (Fig. 1), which we mention mainly because of its relation to the Staré Město, is equipped with modest sources concerning pottery. The town was founded on an island in 1257 and did not have suburbs to the same extent as other royal towns (Fišer 1921, 179; Procházka, Sulitková 1984, 54, 65–67). We assume that the inhabitants were largely saturated with pottery production in Staré Město. It is only in the early second half of the 15th century that the potter Šimek is documented as a house owner in the town (Čoupková ed. 2001, 78). Sherd layers in the rear parts of the plots by the wall in Otakarova (formerly Hrnčířská) Street on the northwestern edge of the town date only from the late 16th–17th centuries, as does the earlier name (Procházka, Sulitková 1984, 28; Fišer 1921, 88).

Praha (**Prague**) in central Bohemia (Fig. 1; 16), the metropolis of the Bohemian kingdom, was an above-average urban formation in Central Europe and consisted of several self-governing towns in the Middle Ages and the Modern period. On the other hand, it long lacked suburban areas of a character similar to other cities of the time.

Based on works by V. V. Tomek, M. Musílek identified the aforementioned Hrnčířská Street, mentioned in the 14th century, with Dušní Street

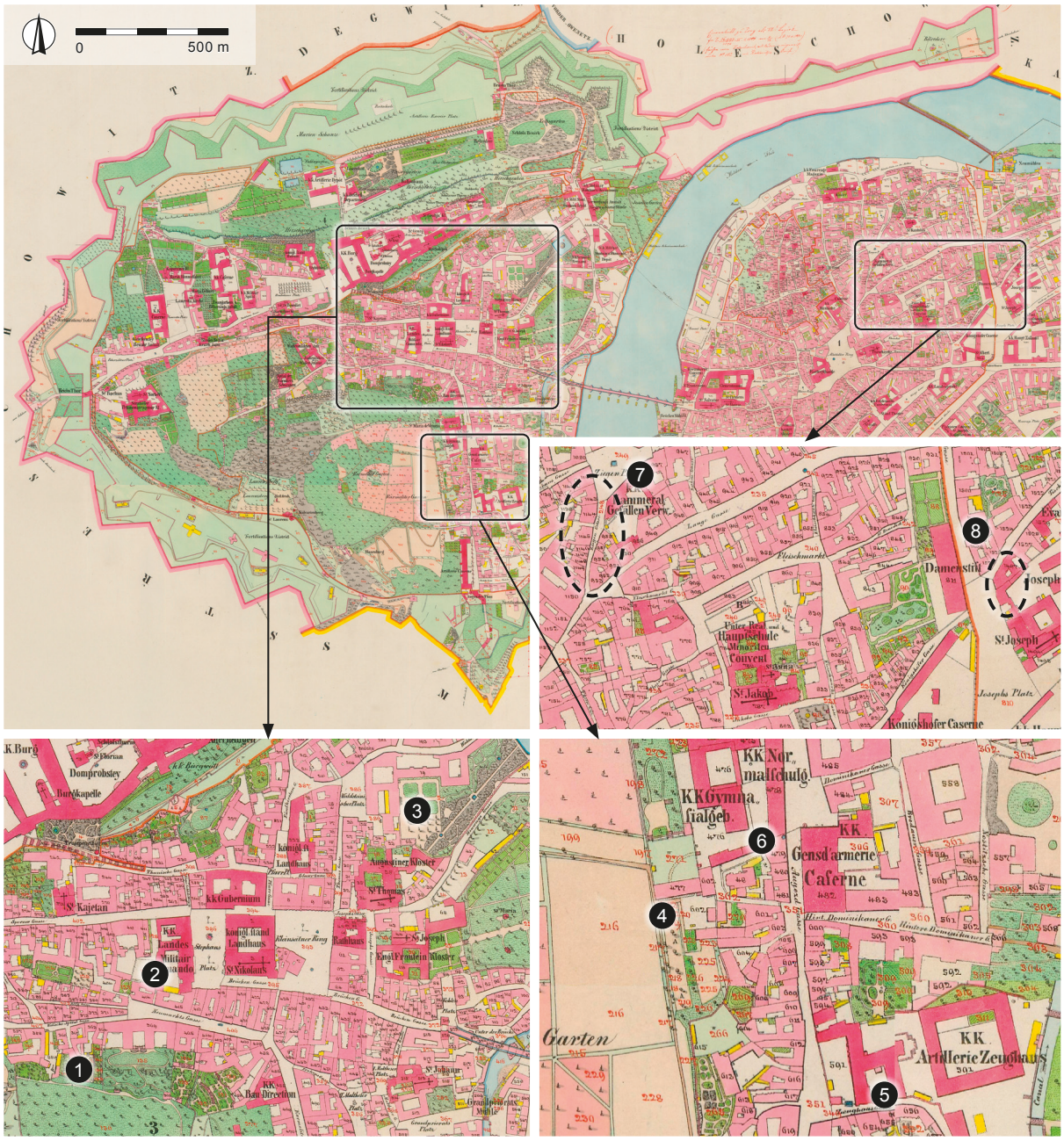


Fig. 16. Praha. 1 – Vlašská Street, house No. 355/9; 2 – Malostranské náměstí (Lesser Town Square), house No. 258/III; 3 – Valdštejnské náměstí (Valdštejn Square), house No. 162/III; 4 – Hellichova Street; 5 – Karmelitská Street, house No. 529/III, 6 – Újezd Street, house No. 450/III; 7 – Kozí Street (the medieval Hrnčířská Street); 8 – Truhlářská Street and náměstí Republiky (Republic Square), site of the former six medieval houses partially with evidenced pottery production, now the department store Paladium, Republic Square, house No. 1079/1. Imperial Obligatory Imprints of the Stable Cadastre map from 1842; ČÚZK. Partially after Havrda, Matějková 2014, obr. 41. Graphics by M. Filip.

in the northern part of Prague's Old Town (Staré Město), although the name Hrnčířská (i.e. Potter's) no longer reflected the actual structure of the inhabitants (Musílek 2015, 132–133, 136). In fact, it is a neighbouring street to the northeast, on the well-known Jüttner's plan from 1811 and still called Kozí today (Fig. 16: 7) In 1364, the potter Zreach (Strach?) bought a house there, and two years later, the potter Rzeakon is mentioned. However, other craftsmen mentioned here in the 1460s have different occupations (these are some of the houses No. 914–920). The house No. 923/5 in the Dlouhá Street was owned by the potter Wyczen in 1364. At the beginning of the 15th century, the name Hrnčířská (Potter's) was no longer used, and the built-up area consisted mostly of small houses (Tomek 1866, 181, 186; 1871,

205–206). In this case, it was definitely not a peripheral location, as the street was located near Old Town Square. In the period from 1324 to 1393, there is only one potter among those who migrated to Old Town. In the Old Town tax book (1427–1434), only two potters, Matyáš and Filip, were recorded among taxpayers in 1427 and 1429 without further localisation. Filip seems primarily to have been a stove builder and probably also made tiles; in those years, he equipped the town hall with stoves (Pátková ed. 1996, 5, 19, 88, 92, 169).

The centre of high and late medieval pottery was in New Town (Nové Město). As early as 1488, King Vladislaus II Jagiellon confirmed the guild statutes, and in 1518 the New Town guild was also extended to Old Town (Winter 1906, 494, 533; Smrž 2019, 66, 69, 93).

For the late 12th and 13th centuries, as is the case elsewhere, we must rely on the archaeological sources that are concentrated in the area of Lesser Town (Malá Strana). Pottery kilns have been found in one or at most two cases in different places. Most were located inside, closer to the walls (house No.355/9 Vlašská Street– late 13th and early 14th centuries, (Fig. 16: 1, Malostranské náměstí [Malostranské Square], house No. 258/III – second half of the 13th century, Fig. 16: 2, and with less certainty in the garden of the house No. 162/III on Valdštejnské náměstí [Valdštejn Square] – late 12th–13th centuries, Fig. 16: 3). The excavation with production waste from the 15th century in Karmelitská Street in the yard of the house No. 529/III is also part of this group (Fig. 16: 5). Other sites belonged to the suburban village of Nebovidy to the south of the walled perimeter. This includes a 13th-century kiln at the western end of Hellichova Street (Fig. 16: 4) and a clay deposit pit in Újezd Street, house No. 450/III, dated tentatively to the Middle Ages (Fig. 16: 6). Production was probably stimulated by the sources of clay on the slopes of Petřín and Strahov. A comprehensive study considers the Lesser Town as having been a centre of pottery production from the late 12th century to the first decades of the 14th century (Havrda, Matějková 2014, 46–47; Zavřel 2024, 755–756). However, we believe that this was more probably a local, quite largely dispersed and time-limited production caused by the demand of a relatively high number of inhabitants of the Prague agglomeration. In this context, it would be useful to focus on evidence of the possible export of products at least in the immediate hinterland using natural science methods.

Further evidence of production comes from Prague's New Town (Fig. 16: 8). Excavations in the rear areas of plots on the southwest side of Truhlářská (formerly Hrnčířská) Street and the adjacent section of Republic Square (now the Palladium Shopping Mall, house No. 1079/1) near the Old Town wall has yielded numerous evidence of pottery production from the 15th century (Tomek 1871, 253; Kašpar, Žegklitz 2009).

Archaeological findings can be compared here with the language of written sources. In some houses, a limited succession of potters is documented. Six historic buildings here were removed by the construction of barracks in 1841 (houses No.1077, 1078a–d, 1079). The house No. 1078 was marked by the author of the detailed topography, V. V. Tomek, from the south 1078a–d. An almost continuous succession of potters is documented in house No. 1078b on Republic Square. From 1407 to 1411, the potter Petr lived here. In 1419, the potter Matyáš also bought the house from Petr's widow, and in 1430–1436 we find the potter Blažej here, followed by burghers with other occupations. The archaeologically uncovered kilns, of which there were seven, are clustered into two groups (two and five sites). The kilns PI and PII are associated with the craftsman Petr; this potter abolished the older steeping vats of the malt house and a sherd deposit area was subsequently created in its place. Other potters, Blažej Kudlata (1417) followed by Matyáš, lived in the more northerly house No. 1079a (now 1110 Truhlářská Street). The remaining kilns PIII–PVII that were operated between 1417 and 1430 can be linked to them. In 1419, they bought the potter Petr's house from his widow Kateřina and moved at least part of the production in kilns PIII–PVI there from house No. 1110. They turned the plot with the former malt house and ruins of the late potter Petr's kilns (PI, PII) into a waste disposal area (Volf 2014, 31–40). This involves another generally rare combination of written sources with archaeological finds to explain the local mobility of craftsmen using a specific example. In the southern street front of Truhlářská Street in houses No. 1115 and 1116, as in Revoluční Street, into which Truhlářská Street opens, we find potters as early as the end of the 14th century (e.g. Kašpar, Žegklitz 2009, 90, obr. 9). The concentration of craftsmen in a particular street in a limited time period corresponds to the situation in Brno and is related to its relatively high population density.

A detailed assessment of the distribution of Prague potters in the 16th century displays considerable variability and dispersion, although apparently

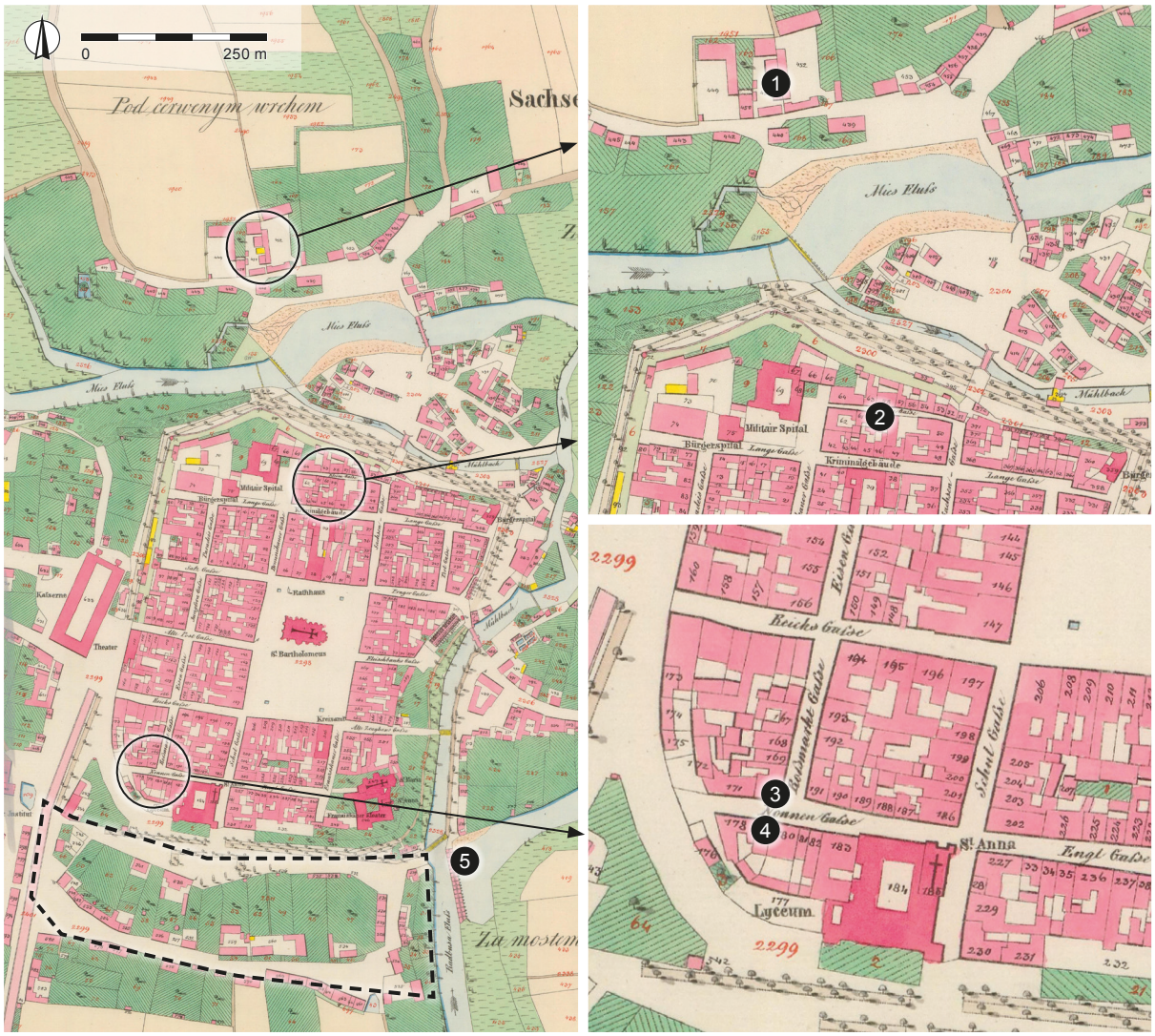


Fig. 17. Plzeň. 1 – Lochotínská Street; 2 – Malá Street, house No. 37; 3 – Sedláčkova Street, plot No. 200; 4 – Bezručova Street, house No. 184; 5 – former Litické suburb. Imperial Obligatory Imprints of the Stable Cadastre map from 1839; ČÚZK. 1–4 after Nováček, Široký 2004, 29; Nováček et al. 2014. Graphics by M. Filip.

intermittent local residence is documented, for example, in the northeast part of the Old Town. Two local concentrations, albeit over fairly large areas, have also been found in New Town, but no longer at Republic Square and Truhlářská Street except for one stove maker (Žegklitz 1990b; Žegklitz, Vitanovský, Zavřel 2009).

In the context of medieval Bohemia, the city of **Plzeň** (**Pilsen**) in western Bohemia was one of the larger royal towns (Bělohlávek 1950, 48; Fig. 1). In the inner city, sherd layers are mentioned on house No. 37 in Malá Street, plot No. 200 in Sedláčkova Street and on house No. 184 in Bezručova Street on the outskirts of the urban core (Nováček, Široký 2004, 29; Nováček, et al. 2014, 158, 164; Orna 2011, 6; (Fig. 17: 2–4). Four potters are documented in 1407 in the suburb of Litice south of the walls past the River Radbuza (Fig. 17: 5). From 1400 to 1420, 13 potters were recorded there (Strnad 1909, 82; Bělohlávek 1965, 42). In 1470, we register two potters in the inner town and the suburbs (Bělohlávek 1965, 126). A pottery workshop from the late 15th century was uncovered in the so-called Malické or Saské suburbs north of the city on the left bank of the River Mže within F. Kasl's manor courtyard, which is a fragment of the former suburban built-up area along the north side of Lochotínská Street running in a west–east direction in this area (Doubová, Nechvátal 1996; (Fig. 17: 1). Several farmyards were located here since the Middle Ages (Strnad 1909, 83–84). The historical subdivision of land as depicted on the stable cadastre map of 1839 hardly corresponds to

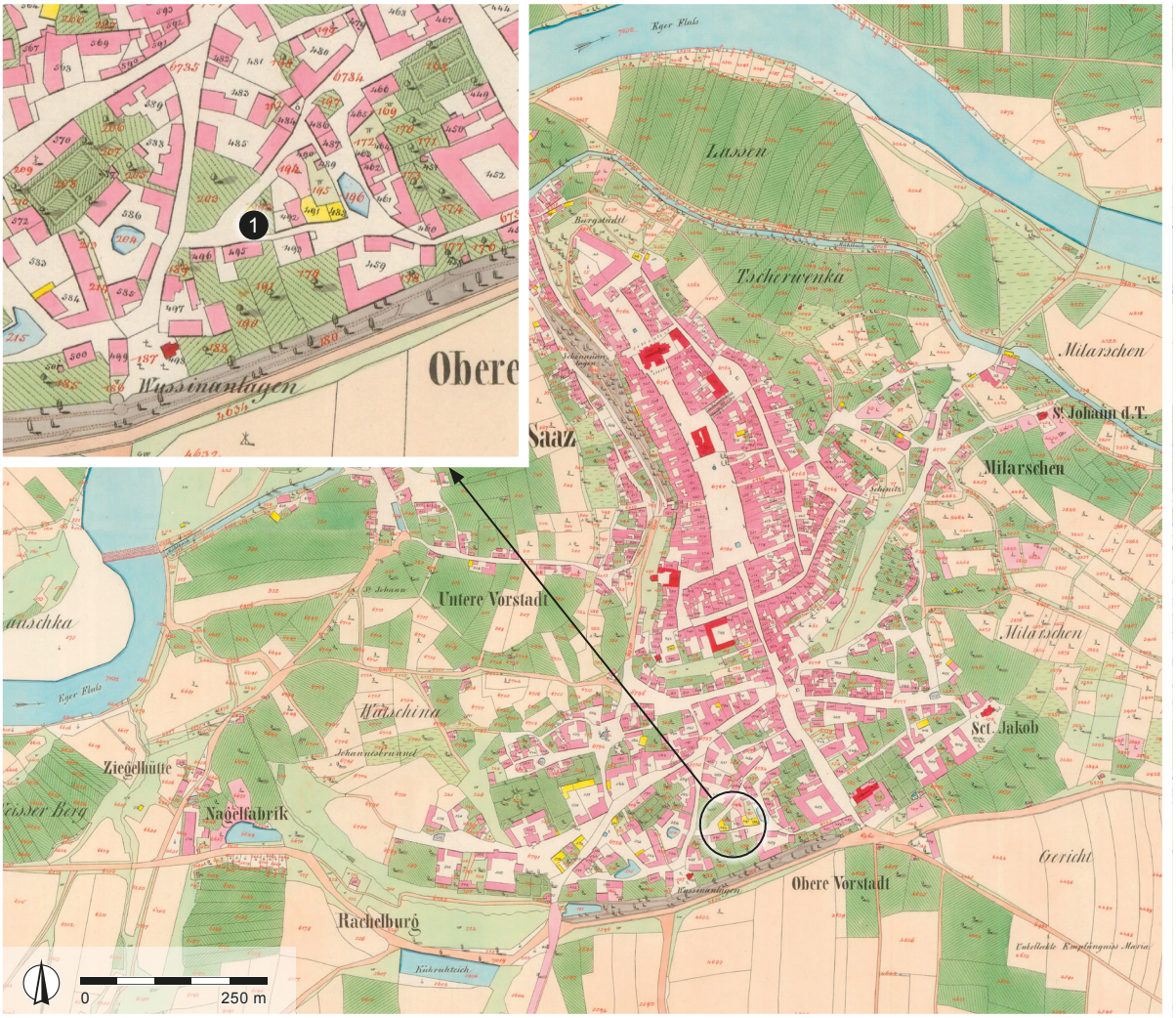


Fig. 18. Žatec. 1 – náměstí Prokopa Velkého (Prokop the Great Square), house No. 1952. Imperial Obligatory Imprints of the Stable Cadastre map from 1843; ČÚZK. After Káčerik 2010. Graphics by M. Filip.

the medieval situation. The original, evidently denser settlement was reduced during the period of the Hussite and subsequent wars. The emergence of the pottery kiln in question may belong to an initial phase of re-establishment (Kuča 2002, 189, 239; Malivánková-Wasková 2014, 418).

Although the former royal town of **Žatec** in northwestern Bohemia housed only a small area within its walls (Fig. 1), it had already well-developed suburbs in the pre-industrial era. Hrnčířská (today Nákladní) Street is documented in its largest suburb, the Horní (Upper) Suburb, to the south of the historic core. On the map of the stable cadastre, it is formed on the northern side by an arc of small houses copying the placement of the town walls. This is probably the same street that is called *prope figulos* in the 1407 deed of testamentary church donations. One of these donations apparently went to masses served at the altar of the potter Václav Nifergalt (Schlesinger ed. 1892, 137–138).

Archaeological excavations nonetheless uncovered a pottery kiln from the second half of the 14th century somewhat further south on today's house No. 1952 on náměstí Prokopa Velkého (Prokop the Great Square; Fig. 18: 1 On the map of the stable cadastre, the block, surrounded by three streets, was made up of several plots with small houses. The kiln was located at its western end at today's náměstí Prokopa Malého (Prokop the Bald Square) (Káčerik 2010, 453).

Pottery workshops in smaller towns

In **Rakovník** in Central Bohemia, potters appear only in the existent registers of taxes from 1436–1449/1450. Hrnčířská Street is mentioned, which probably consisted of U Hluboké studny Street as well as today's Martinovský Street (Fig, 1; 19). Here, only two potters, Vaněk Uhřivý and Ondráček, can be identified with certainty in the period in question. The residences of the others cannot be determined (Zenklová ed. 2022, especially 35, 92, 105). Rakovník seems already to have been a regional centre of pottery production in the late 14th and early 15th centuries. Supposedly, up to 11 master craftsmen worked here simultaneously in the Late Middle Ages. A guild is known from the mid-16th century (Winter 1909, 495, 531).

On the northern edge of the historic core, near the line of town walls on the plot of the house No. 133 in U Hluboké studny Street at the intersection with Masná Street towards the Vysoká brána (High Gate), an isolated pottery kiln with pottery from the late 15th and early 16th centuries was uncovered (Blažková, Lomecká 2006; Fig. 19: 1). The stable cadastre map from 1841 shows that this was a periphery with an irregular built-up area of small houses. The site's subdivision of land at the time was partially different from the present situation – the plot with the kiln was oriented perpendicular to Masná Street and faced the gate from the square. It is very likely that this find still belongs to the settlement in Hrnčířská Street.



Fig. 19. Rakovník. 1 – U Hluboké studny Street, house No. 133; 2 – Hrnčířská ulice (now Martinovského Street). Imperial Obligatory Imprints of the Stable Cadastre map from 1841; ČÚZK ČÚZK. After Blažková, Lomecká 2006, obr. 1. Graphics M. Filip.

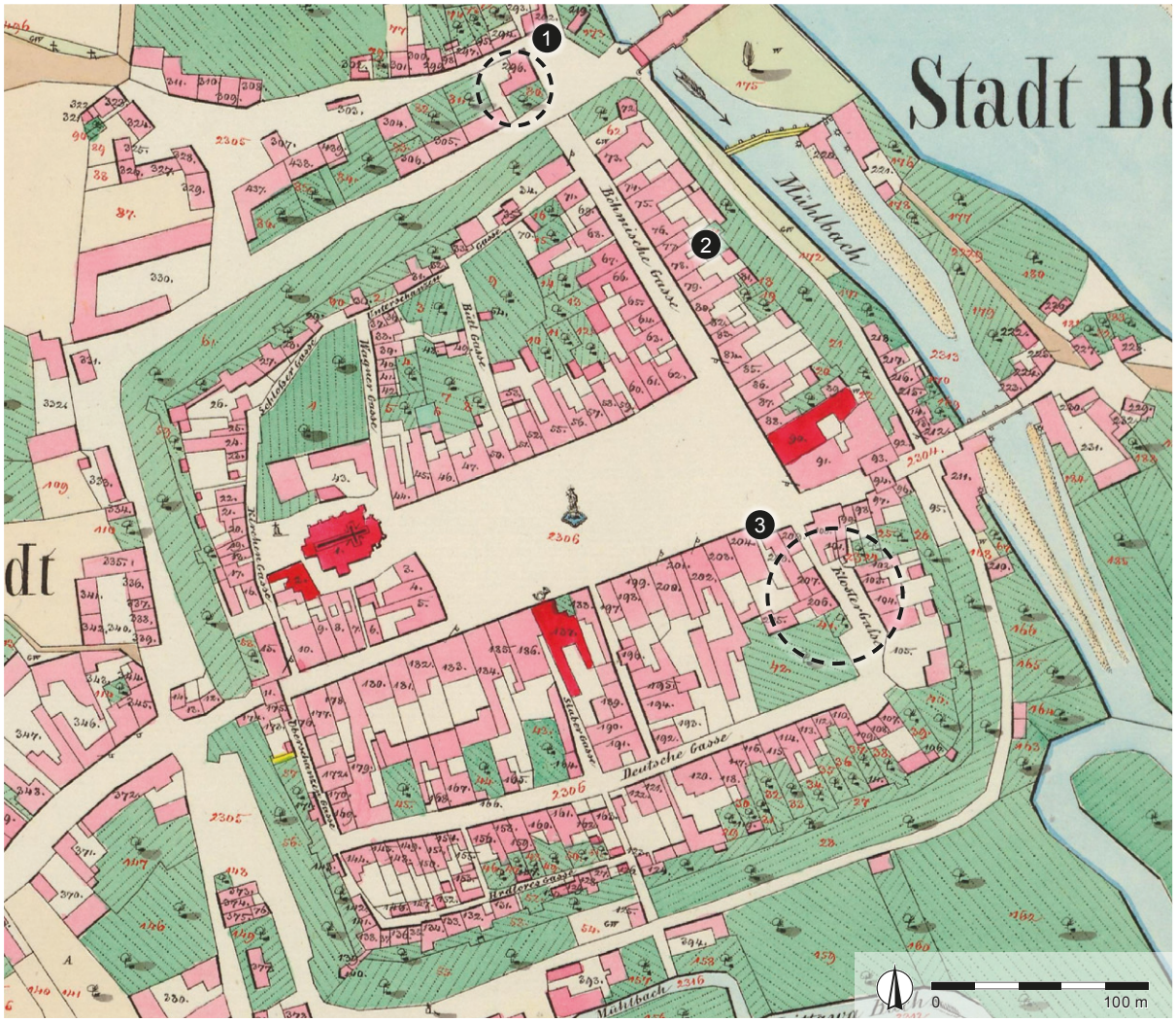


Fig. 20. Beroun. 1 – excavation area in the plot No. 296 between the Hrnčířská and Politických vězňů streets; 2 – Česká Street, house No. 56; 3 – Na Kláštěře Street. 1 – after Vyšohlíd 2015b, obr. 5; 2 – after Vařeka 2004, obr. 1. Imperial Obligatory Imprints of the Stable Cadastre map from 1840; ČÚZK. Graphics by M. Filip.

Beroun in central Bohemia was also an important centre of pottery production in the Modern period with beginnings that can be traced back to the Middle Ages (Fig. 1; 20). Craftsmen worked mainly in the Hrnčířské (Potters') Suburb north of the town wall. Individually, however, they are also documented in the inner town from the Jagiellonian period onwards in Česká Street leading to the gate of the same name. In the late 15th and early 16th centuries, J. Vávra documented 17 potters. From that time on, some prominent families managed to maintain multi-generational continuity, e.g. the descendants of Jiří Vraštil. Beroun's potters penetrated Prague's markets, which led to numerous disputes with local producers. Already at the end of the 15th century, stable market stalls near the square are documented. A guild is not mentioned until 1560. Although the pottery craft stagnated after the Thirty Years' War, 12 active master craftsmen are still mentioned in 1740 (Garkisch 2008, 59; Tošnerová 2008a, 87, 93; Tošnerová 2008b, 137–138; Vávra 1899, 64, 135; Winter 1906, 495, 432, 534; Vyšohlíd 2015b, 411–412).

Rescue excavation of plot No. 296 in the former Hrnčířské Suburb between Hrnčířská and Politických vězňů streets yielded direct evidence of medieval production (Fig. 20: 1; 21). The plot was part of a block that was built up intermittently along both its longer sides and bordered by two roads, the southern one of which ran along the former moat (Vyšohlíd 2015a; 2015b). Preliminary research was first conducted on the plot with a series of test pits.

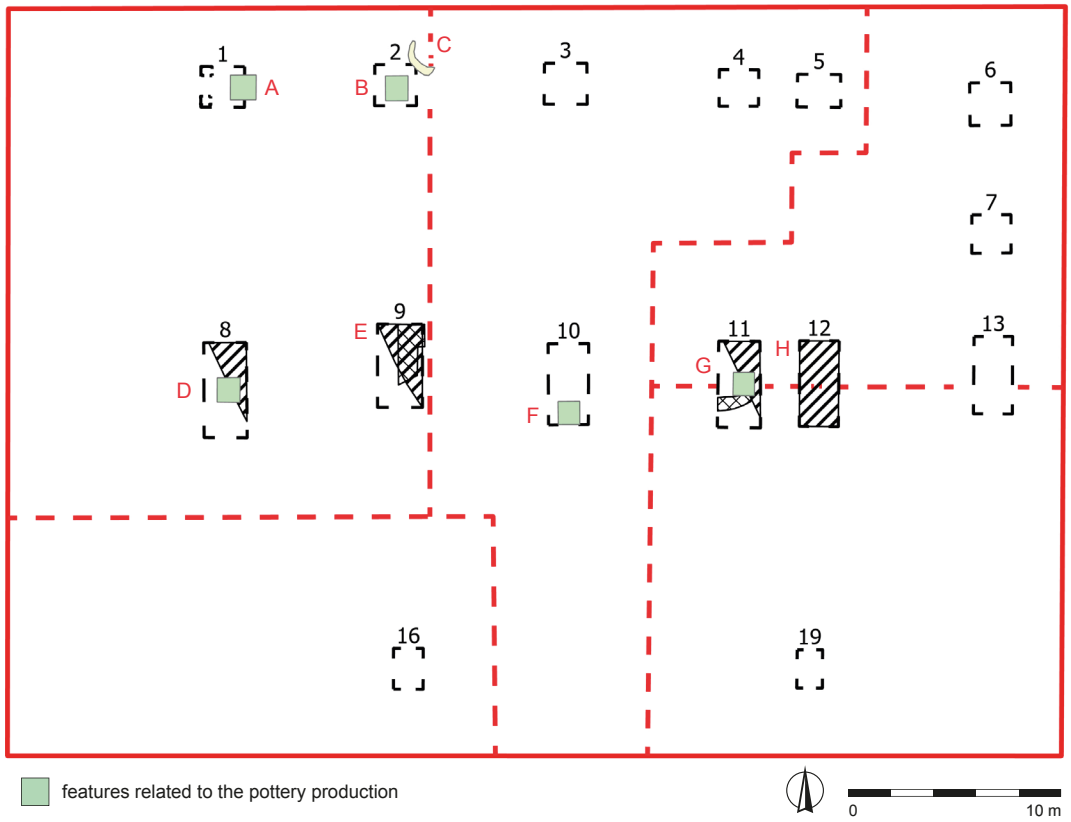


Fig. 21. Beroun. Features mostly related to pottery production in the plot No. 296. 1–13, 16–19 test trenches; green squares – features related to the pottery production; A – pit in front of the mouth of the furnace, second half of the 16th century; B – potter's clay pit; C – well, 14th century; D – potter's kiln, second half of the 15th century; E – cellar, second half of the 16th century; F – kiln, second half of the 16th century; G – potter's kiln, 15th century; H – cellar, 16th century. After Vyšohlíd 2015b, obr. 5, 7. Graphics by M. Civáň.

The earliest direct evidence of pottery production dates to the 15th century. A pair of kilns were in the central part of the plot (near the western edge in trench 8 and in the eastern half in trench 11).

The kiln in trench 11 disturbed an earlier 15th-century stone ring and that had been breached by the entrance passage of a cellar backfilled in the 17th century. Another kiln from the second half of the 16th century the brick-walled pit containing contemporary pottery waste was uncovered in the northwestern part of the area. Finally, the last and not entirely clearly interpreted firing device from the same period was found in test pit 10, roughly in the middle of the plot. The position of a well in the northeast part of the plot next to the street line is also interesting. It was located in the area of a more recent house shown on the stable cadastral map.

Subsequent total excavation conducted by another organisation yielded a large number of additional findings but was unfortunately published in only very brief form (Benková 2014). Mainly, an entire renaissance kiln, previously recorded in test pit 1, was discovered. This disrupted the westernmost of the two adjacent buildings along the northern street line, which, given the presence of clay maturing pits, were considered to have been a potter's workshop. Three early modern kilns were recently uncovered in the centre of the western part of the plot. The publication does not mention medieval kilns. The remains of the basement parts of medieval buildings, previously recorded mainly in test pits 9 and 10, were also uncovered. Given their position almost in the centre of the plot, the question arises as to whether they were part of a larger floor plan including rooms without cellars further to the southeast. The situation cannot be interpreted objectively until a detailed evaluation of stratigraphic relationships has been carried out.

Archaeological evidence of pottery production has also been found in Česká Street, which is separated from the Hrnčířské Suburb by a wall. In addition to waste layers in various plots (Sommer 1979, 44; Benková 2014), the relics of a kiln were also uncovered in the house No. 56 (Fig. 20: 2). The kiln was in the core of the plot extending up to the



Fig. 22. Domažlice. 1 – the excavated area in the Msgre B. Staška (earlier Palackého) and Elišky Krásnohorské streets. After Procházka 2016, obr. 11. Imperial Obligatory Imprints of the Stable Cadastre map from 1838; ČÚZK. Graphics by M. Filip.

wall, but due to the small scale of research, it was not possible to sufficiently clarify its relationship to the built-up area. In regard to the exposed walls, it can be assumed to have been an annex attached to the inner enclosure wall of the residential house (Vařeka 2004). Strong layers and pits with ceramics were removed without research from this street and Na Kláštеře Street as well as from the so-called Horní (Upper) Suburb (Sommer 1979, 44; Fig. 21: 3).

Domažlice was also a regional centre of pottery production from the late Middle Ages. A potters' guild there is evidenced by a seal from the mid-16th century. In 1654, six potters worked there both in the Upper (western) Suburb and within the perimeter of the walls (Procházka 1983, 2–4).

According to the stable cadastre map from 1838, the Upper Suburb consisted of a dense built-up area primarily concentrated around Msgre B. Stašek Street (earlier Palackého Street) leading from the town gate. At the western edge of the suburb before the cross-street running north–south, a rear row of houses began to form behind the gardens of the southern row of houses along the main street. The southwestern part of the Upper Suburb was affected by extensive demolition in the second half of the 20th century, when some 26 historic structures were removed and the plan of the built-up area was subsequently completely changed. During an apparently in emergency conditions conducted rescue excavation, only features related to pottery production (with some exceptions) were documented (Fig. 1; 22, 23). The sherd layers behind house No. 25 nearer to the eastern edge of the studied area are thought to be the earliest (14th century), with other activity likely dating to the late 15th century. A total of eight kilns were uncovered. The majority were concentrated in

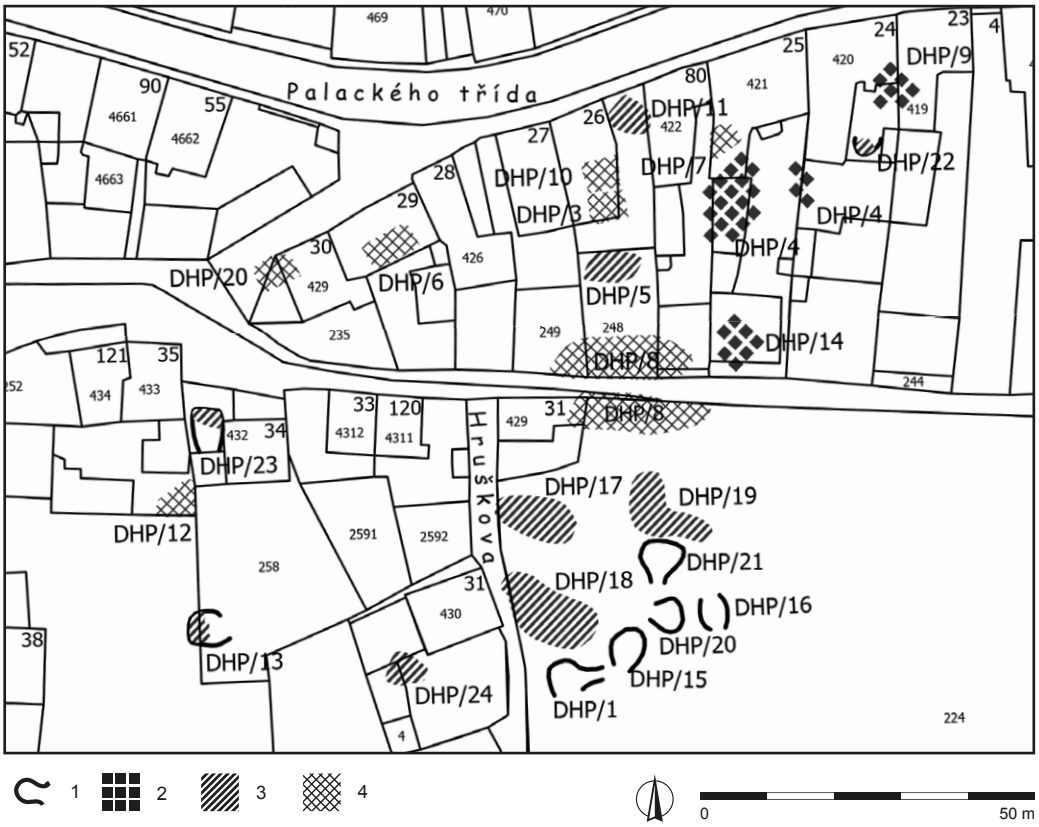


Fig. 23. Domažlice. The 1980 excavated area. 1 – kilns, 2–4 waste concentrations: 2 – 14th century, 3 – 15th century, 4 – 17th century. After Procházka 2016, Fig. 11. Graphics by M. Civáň.

the settlement core of houses No. 31(3), 34 and 35(3), with kiln DHP 23 located in front of the settlement core of house No. 34. A single kiln (behind house No. 24) was investigated at the eastern edge of the area in question. Other sherd layers were located on the plots of houses No. 25 and 26, mostly in the central and rear areas, but occasionally in front, possibly in the open area next to the residential building (No. 26). The positions of sherd layer DHP 8, 15, 19, as well as kilns DHP 20 and 21, suggest that the plot of house No. 26 continued into the street area at the rear of the built-up area along the main road and beyond it into the settlement area of house No. 31, the dating of which is unclear (for a summary, see Procházka 1983; 2016). There is a lack of evidence to draw deeper conclusions regarding spatial relationships; however, if we were to assume that a part of the kilns has not yet been registered and that other relics are located on the unexamined, opposite side of the main road, there can be no doubt about the high concentration of ceramic production in the suburb in question.

One of the most important medieval manorial towns in Bohemia, **Česká Lípa** in northern Bohemia (referred to only as Lípa in the Middle Ages; Fig. 1; 24), was formed before 1337 (Kuča 1996, 509–518; Gabriel, Smetana 1983, especially 137–139). From its initial roots, pottery production fully developed here to become an important regional centre with a guild documented in 1461. More abundant written records of individual craftsmen begin as early as the 1460s. Some were esteemed residents of the southern suburb, which is indicated by reports of their activities in relation to the local church of St Mary Magdalene (Ebelová et al. 2005, 101, 108; for a summary, see Vojtíšek 1983; Gabriel 1979; Panáček, Gabriel 1995, 25, 34, note 2; Gabriel, Panáček 2000, 15–23).

Workshops were concentrated mainly in the northern part of the southern suburb on the right bank of the River Ploučnice, south of the intersection of today's Hrnčířská Street (the traditional name was restored) and Bedřich Smetana embankment. Hrnčířská Street formed a section of the important north–south Žitavská road (Kuča 1996, 515–516). The stable cadastre map shows a significant concentration of built-up area in the northern part of this street. During the excavation, approximately one sixteenth of the area later affected by construction was investigated, and 15 kilns were documented – 10 on the western side and five on the eastern side of Hrnčířská Street. (Fig. 24: 1). Seven workshops date to the second half



Fig. 24. Česká Lípa. 1 – the researched area with pottery settlement in Hrnčířská Street. Imperial Obligatory Imprints of the Stable Cadastre map from 1836; ČÚZK. After Gabriel, Panáček 2000. Graphics by M. Filip.

of the 13th and the first two decades of the 14th century, i.e. a time when we can assume that the ground plan of the historic centre was already taking shape. Two kilns were built in the second half of the 14th century. More recent production facilities have not been recorded, although there is written evidence of pottery production up to the early 20th century. Six pits, mostly clay-filled, are thought to relate to pottery production from the late 14th century up to the early second half of the 16th century. Therefore, according to the most recent understanding of these features, the remains of one 'sunken-floored house', which are probably the cellar of a surface house, are synchronous with the latest phase of the revealed kilns. Nonetheless, the spatial relationships of production and other sites have not been evaluated and remain unclear due to the absence of an overall research plan in publications (Gabriel 1979; Gabriel, Panáček 2000, especially 5–15).

Sezimovo Ústí in south Bohemia was a manorial town founded perhaps before the middle of the 13th century by one of the branches of the Vítkovec family (Fig. 1; 25, 26). The town was abandoned and temporarily destroyed in 1420 at the beginning of the Hussite Wars (Krajíc 2020, 765–766; Richter, Krajíc 2001, 4–5).

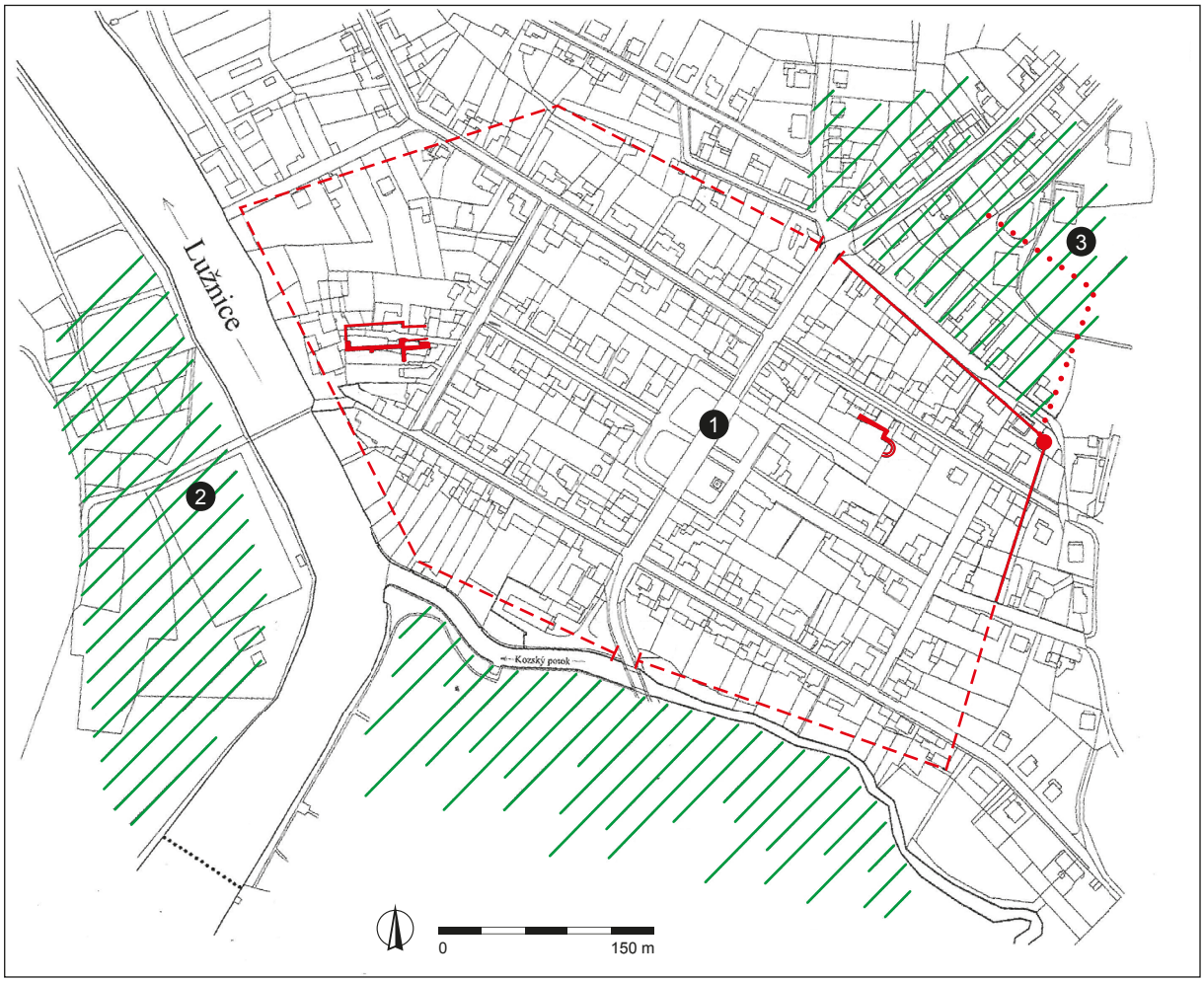
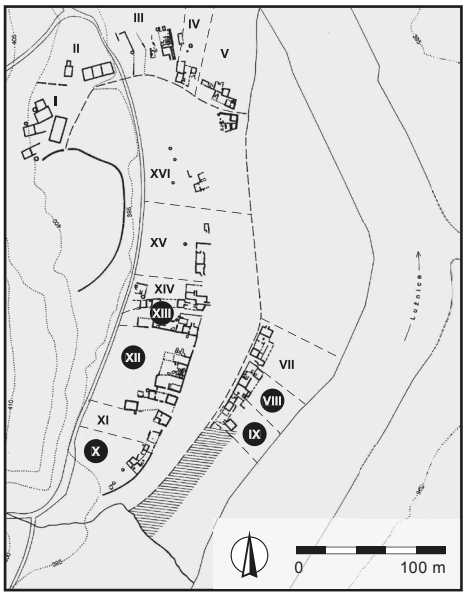


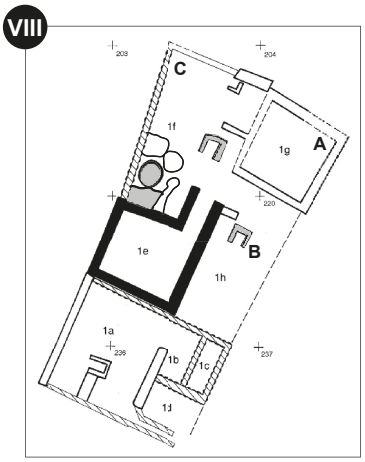
Fig. 25. Sezimovo Ústí. Area of the defuncted medieval town. 1 – the walled town; 2 – the western suburb; 3 – northern suburb, site of the excavated kiln in the Helsinská Street. After Richter, Krajíc 2001, obr. 1. Graphics by M. Filip.

The most complete picture of the relationship between the built-up area, production facilities and individual stages of production processes was provided by the so-called left bank (western) suburb. In the final phase, it consisted of a street with an arc-like bend with plots of unequal size located on both sides. The plan of the settlement area respected the bend of the River Lužnice (for a summary, see Krajíc 2020, 772–779). Evidence of pottery production was found in five homesteads (Fig. 25: 2; 26). In two cases, the firing facilities were in the halls forming a part of the homesteads (VIII and XIII), once in both the hall and the courtyard (X) – here the question of the inter-temporal relationship will have to be resolved. In one case, there were kilns in a shelter near the main building (XII), and no kiln could be found on only one plot (IX). Pit deposits of earth, sometimes with reinforced walls, were found in a separate room (VIII), in a hall and in a separate shelter (XII), and close to a house (at IX); no such feature was found at manors IX and X. In homesteads XII and XIII, several sunken features of the hearths of a drying facility were uncovered either in the open space (XII) or in the production hall (XIII). Vessel storage was documented on the floor above the cellar room (VIII, XII). Sand exploitation pits were uncovered in homestead X (Richter, Krajíc 2001, 53–58, 60–62, 65–72, 74–75, 78–79).

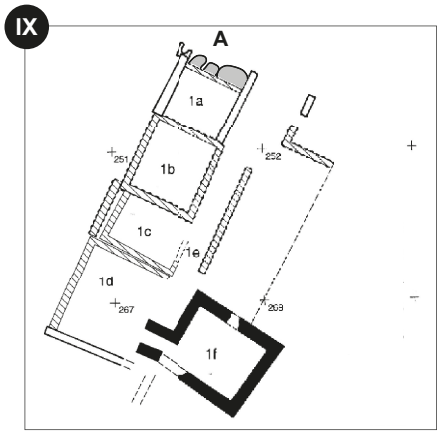
A pottery kiln with ceramics from the second half of the 14th century was explored during construction works in Helsinská Street, now part of the town Tábor, between residential houses No. 2734 and 2735. At the time the kiln was active, this was probably the area of the so-called Pražské (northern) suburb of Sezimovo Ústí on the right-bank terrace of the River Lužnice (Fig. 25: 3). Cultural layers, postholes, larger pits of various shapes and features related to pottery production have been found in the

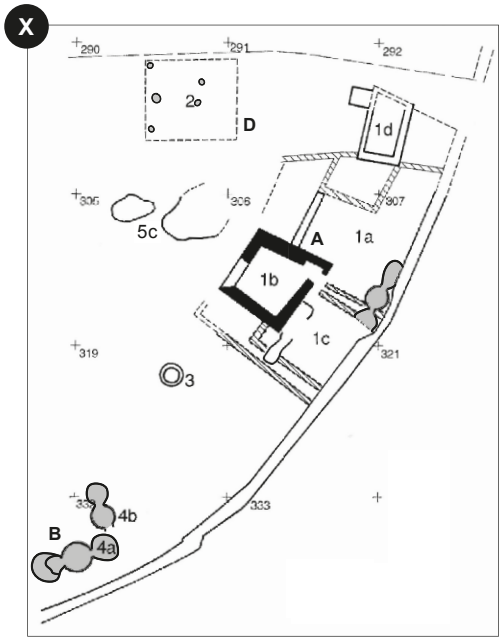
Fig. 26. Sezimovo Ústí. Plan of the excavated part of the western (left bank) suburb of the deserted town; VIII–X, XII–XIII – potter's plots; VIII: A – room with pottery clay dump; B – production hall; IX: A – three pits, pottery clay dumps; X: A – production hall with pottery kilns; B – yard with pottery kilns; C – pits with ceramic waste; D – a shelter – perhaps for drying of ceramics; XII: A, D – pottery kilns, B – half sunken room filled with pottery from the upper floor; C, E, F – channel furnaces, perhaps related to pottery production; XIII: A – pottery kilns, B – channel's furnaces. After Richter, Krajíc 2001, obr. 2. Graphics by M. Filip.

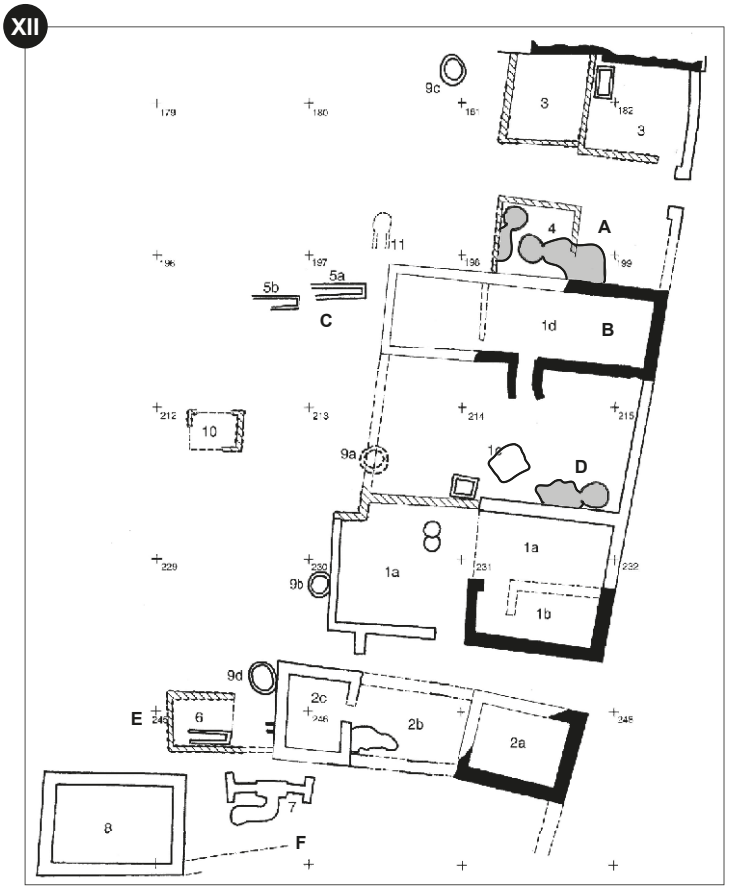


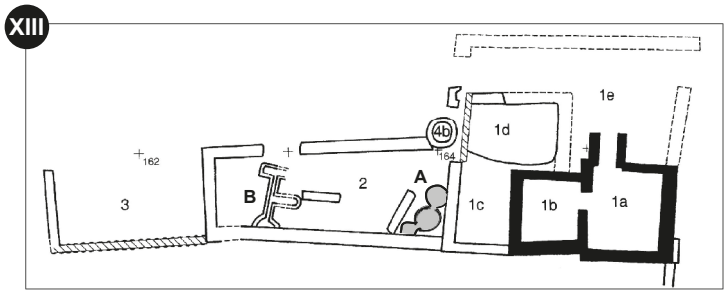












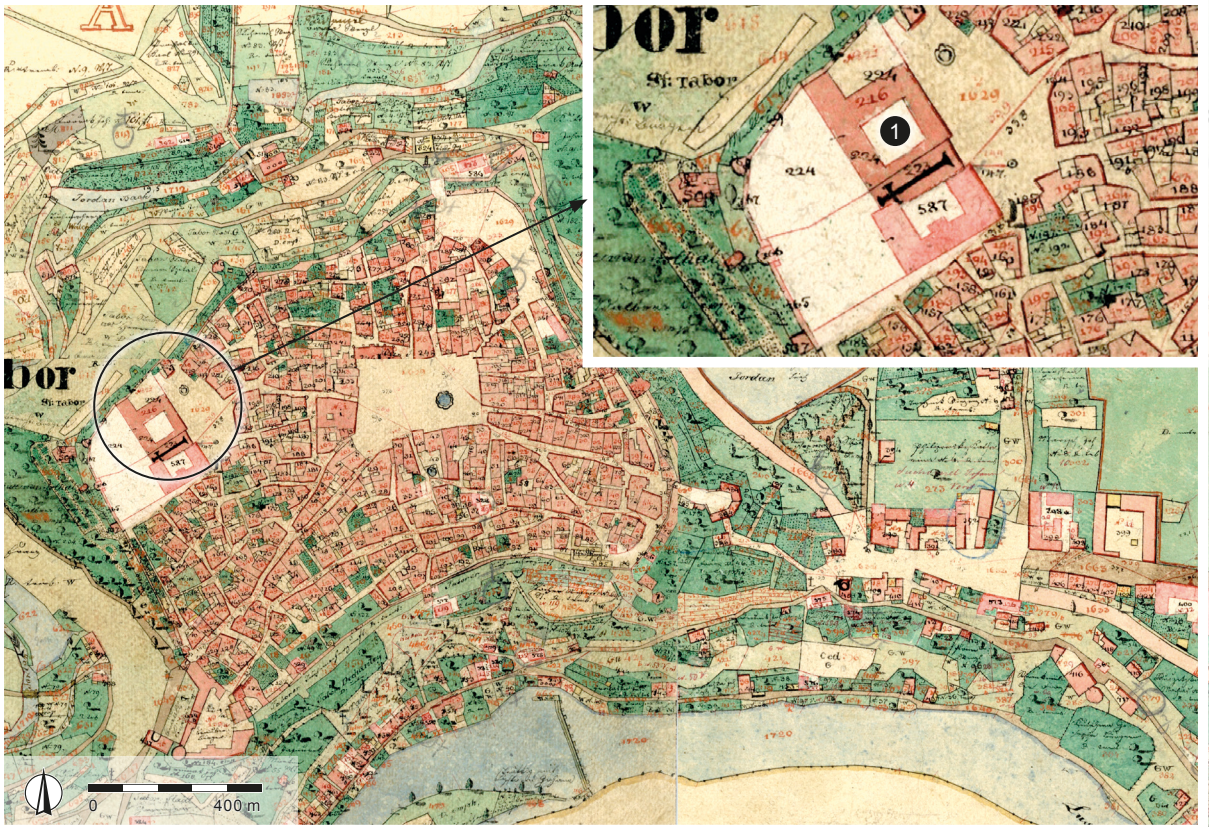


Fig. 27. Tábor. 1 – náměstí Mikuláše z Husi (Mikuláš of Hus Square), house No. 44. Imperial Obligatory Imprints of the Stable Cadastre map from 1830; ČÚZK. After Krajíc 2007. Graphics by M. Filip.

vicinity. It is possible that this was a production area separated from the suburban development, which was perhaps enclosed by a ditch (Krajíc 1982; 2020, 768, obr. 2, 773). In the the town of **Tábor** itself, founded immediately after the destruction of Sezimovo Ústí in 1419, a battery of pottery kilns from the 15th to 17th centuries was uncovered on the western edge of the historic core on today's house No. 44 on náměstí Mikuláše z Husi (Mikuláš of Hus Square) (Fig. 1; 27: 1). So far only a brief annotation of this battery has been completed (Krajíc 2007, 152, 155).

Another town with archaeologically documented pottery production is **Hořice** in eastern Bohemia (Fig. 1), a manorial town in approximately the middle of the 14th century (Kuča 1997, 204–209). A kiln from the late 15th to early 16th centuries was uncovered in a closed street between houses No. 210 and 425 running north from Meixnerova Street (Volfová 2018). It was in the northern suburb of Hořice, but off the main north–south road leading to Kladsko along a secondary road running west–east. According to the stable cadastre map, there was already a vacant space there at the time. The evolution of the built-up area remains unclear (Fig. 28: 1).

The episcopal town known since the 16th century as **Horšovský Týn** in western Bohemia lacks medieval written sources that might provide evidence concerning the composition of its inhabitants (Kuča 1997, 192–197; Fig. 1). Perhaps surprisingly, the pottery kiln from the late 15th to early 16th centuries was not revealed in the Velké (Great) Suburb to the south of the historic core, but within a group of houses isolated by a gap separated from the short eastern suburb around the exit road to Plzeň according to the stable cadastre map (67 Plzeňská Street; Frýda 1; Káčerik 2010, 459–460; Fig. 29: 1).

Pottery kilns have also been studied to a very limited extent in the manorial town of **Horažďovice** in western Bohemia, which was founded around the middle of the 13th century (Kuča 1997, 139; Fig. 1). The first kiln with the remains of its contents from the second half of the 15th century was found at the end of Prácheňská Street in front of the southeastern (so-called Lower) gate in front of house No. 84 (today separated as No. 949; Fig. 30: 1). The second one was found in the garden of house No. 140 in the southern section of Příkopy Street, which after a few dozen metres crosses Prácheňská Street (Fig. 30: 2).



Fig. 28. Hořice. 1 – the place of the kiln in the Meixnerova Street. Imperial Obligatory Imprints of the Stable Cadastre map from 1841; ČÚZK. After Volfová 2018, obr. 27: 1. Graphics by M. Filip.

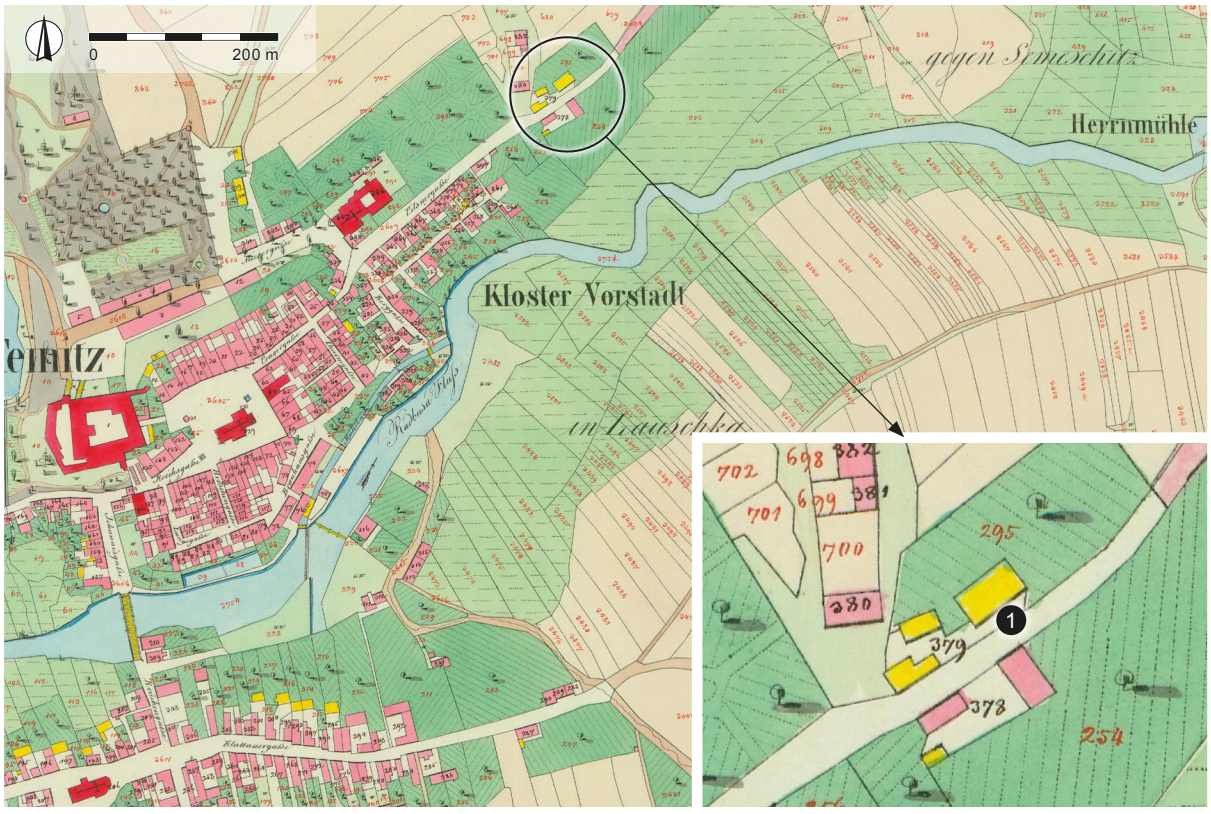


Fig. 29. Horšovský Týn. 1 – Plzeňská Street, house No. 67. Imperial Obligatory Imprints of the Stable Cadastre map from 1838; ČÚZK. After Frýda 1992. Graphics by M. Filip.

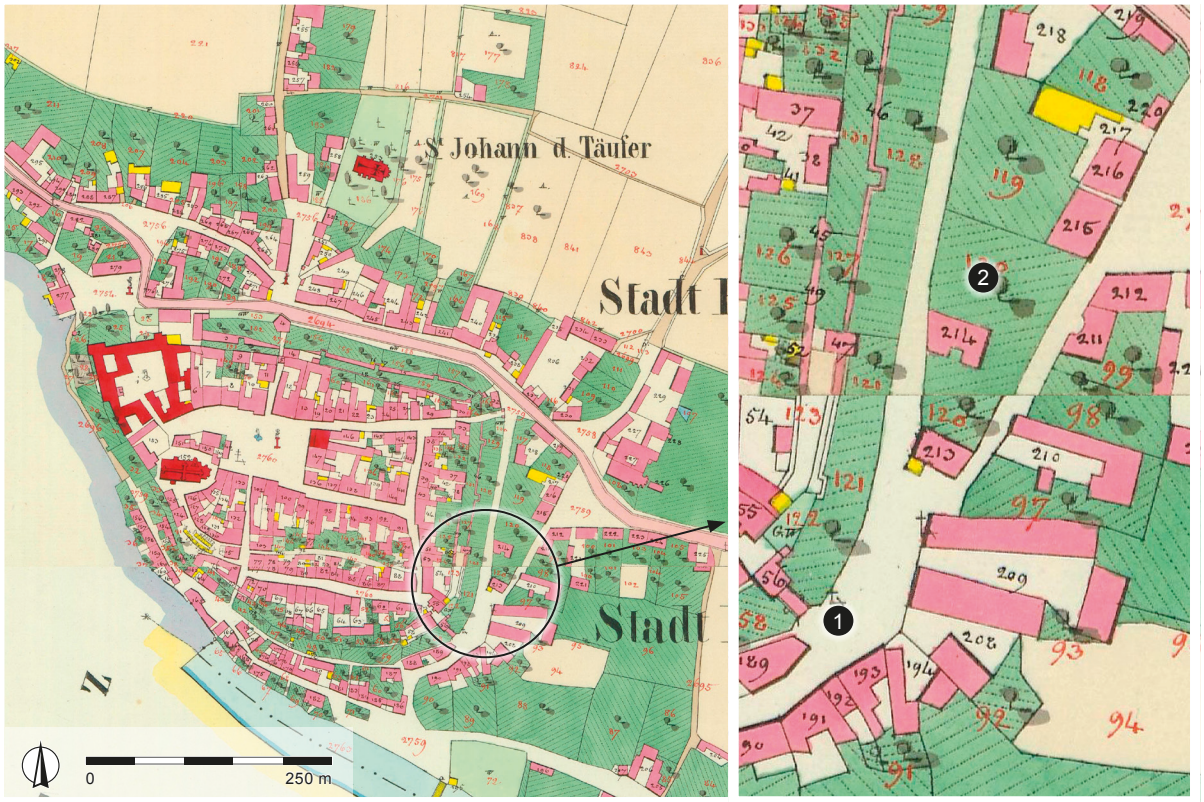


Fig. 30. Horažďovice. 1 – Prácheňská Street, house No. 949; 2 – Příkopy Street, house No. 140. Imperial Obligatory Imprints of the Stable Cadastre map from 1837; ČÚZK. After Tetour 2002, Fig. 8. Graphics by M. Filip.

This kiln yielded pottery from the third quarter of the 15th century. Both sites were located at the outer edge of the town's moat (Tetour 2002). There are no medieval records of local potters, although the existence of a guild in the 15th century cannot be ruled out. However, there is a statute for journeymen from 1585. In the 17th century, local potters worked mainly in the suburbs, but sporadically also within the perimeter of the walls (Smitka, Hazlbauer 2000, 398–400).

Several workshops have also been archaeologically documented in **Vamberk** in northeastern Bohemia, a manorial town, as early as approximately the middle of the 14th century (Kuča 2011, 88; Fig. 1). The first (feature 29) was located at the rear of plot of the house No. 78 where Pekelská Street opens into the northeast corner of Husovo náměstí (Hus Square); the ceramic kiln contents can be dated to the first half of the 15th century (Fig. 31: 1). This is a peripheral location on the northeast edge of the town's centre. Three workshops were recorded at the rear of the plot of house No. 64 in Hlavsova Street, which opens into Pekelská Street from the south in a block enclosed by the square and three streets in the eastern part of the site Fig. 31: 2). Of these, features 7 and 17 belong to the 14th–15th centuries, and kiln 16 to the late 16th to early 17th centuries (Fleknová 2020, especially 46–68).

Ivančice in southwestern Moravia was a royal town from the Middle Ages until the end of the 15th century (Fig. 1). It was already on its way to becoming a town from the first half of the 13th century, but the layout was probably still being formed in the subsequent century (Doležel 1995, 203–204).

Pottery production was already in operation here in the High Middle Ages. The main source of information concerning medieval potters is a memorial book (1442–1509, 1522; Fiala, Jelínková ed. 2022). From 1457 to 1500, we used it to find eight potters, who were relatively affluent house owners. Only one is dated to the third quarter of the 15th century, while the rest are concentrated in the intermediate period from 1481 to 1500, with four documented simultaneously in 1483 and three from 1481 to 1483. Nonetheless, we should assume that these numbers were higher – the memorial book undoubtedly omitted some potters, especially the poorer ones who did not record changes of property in it. Their location is not specified in the source, but from 1474 to 1494, the Hrnčířská brána (Potter's Gate) is mentioned,

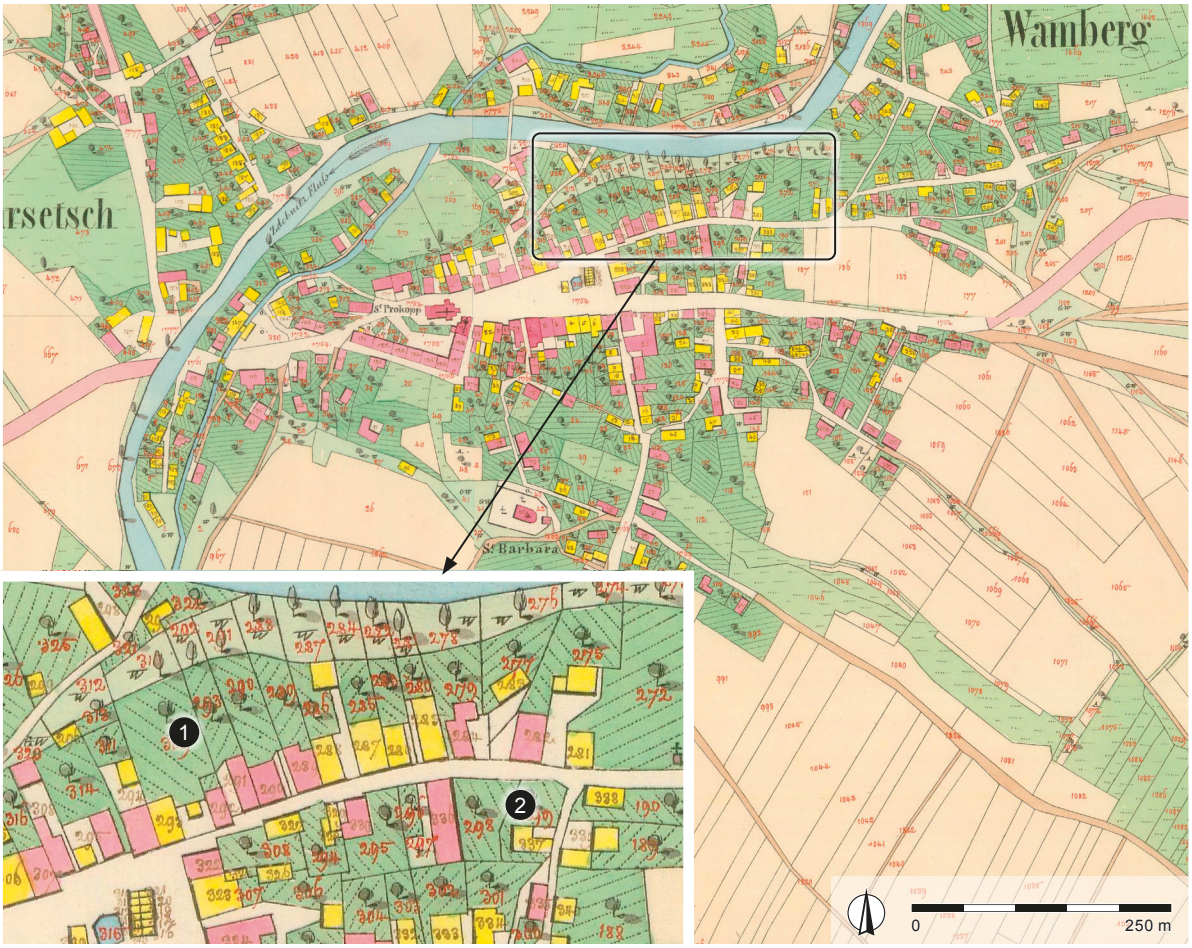


Fig. 31. Vamberk. 1 – náměstí Míru (Peace Square), house No. 25. Imperial Obligatory Imprints of the Stable Cadastre map from 1824; ČÚZK. After Fleknová 2020, obr. 2. Graphics by M. Filip.

which led to the suburban street that can be identified as Hrnčířská Street, now Kounická Street, where potters are also documented archaeologically (Fiala, Jelínková ed. 2022). Here, production is quite clearly documented from the 16th to 19th centuries, when the town was a well-known pottery centre. In 1543, local potters had a guild jug made there, and 33 years later its statute was formulated. The official register in 1672 lists 36 master craftsmen and the same number in 1752 (Svoboda 1927, 158–167; Vykoupil 2002a, 212; 2002b, 278).

For a long time, the only find was a ating to the late 15th / early 16th century in the rear area of the plot of the renaissance house belonging to the Lords of Lipá No. 196/6 on Palackého náměstí (Palacký Square; Fig. 32: 3). The building was constructed on the site of two houses in the late 16th to early 17th centuries along the short street leading from the square to the western Oslavanská brána (Oslavany Gate), and their plots ran along the adjacent town wall (Doležel 2002, 335–338). Unfortunately, the precise location of the kiln is not stated in the publication; it was probably placed in the rear area of the plot farther west (Uhrová 1973). In regard to its location on the access street from the square to the gate, these were probably not small-town buildings but rather those of a representative character. We can hypothesize that pottery production was carried out here by a tenant.

A spectacular find was made in 2024 in the eastern suburb 50–70m from the defunct Hrnčířská Gate (Fig. 32: 1, 2). Under the demolished baroque house No. 1186/3 on the corner of Kounická and Jana Fibicha streets and in the yard of the plot, there were 16 pottery kilns from the 14th and 15th centuries accompanied by the remains of buildings, some partially in complex stratigraphic relationships (Staněk in print).This provides evidence of the extraordinary continuity of the pottery craft in the former Hrnčířská Street and, given that the plot area is approximatively

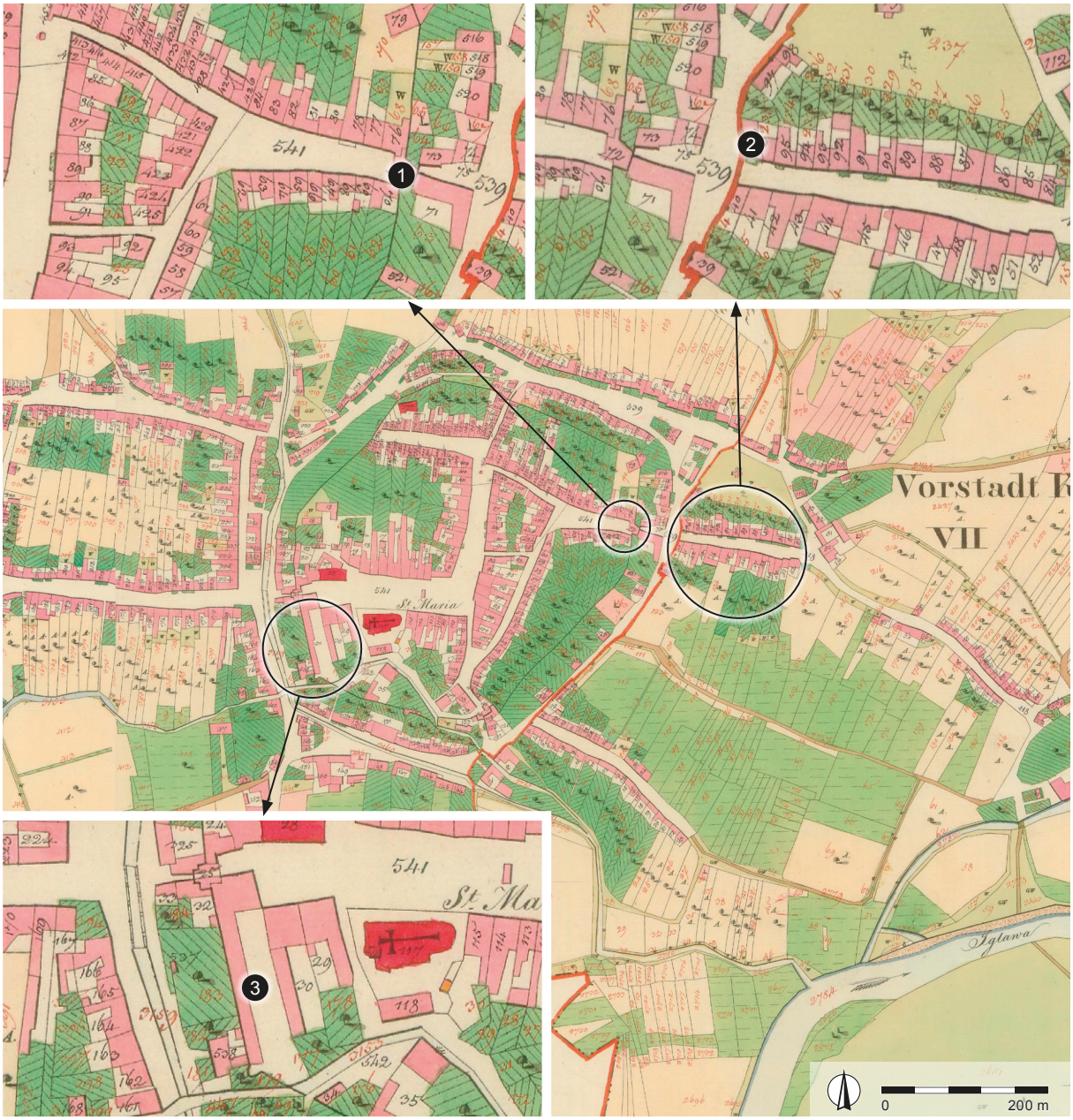


Fig. 32. Ivančice. 1 – the place of the extinct Hrnčířská brána (Potter's Gate); 2 – Kounická Street, house No. 1186/3; 3 – Palackého náměstí, house No. 196/6. Imperial Obligatory Imprints of the Stable Cadastre map from 1825; 3 – after Uhrová 1973. Graphics by M. Filip.

290 m², probably the largest concentration of pottery kilns in such a small area, comparable perhaps only to the density of similar installations in Milíčovo náměstí (Milíč Square) in Kroměříž.

Available documents support the thesis that Ivančice was a regional production and distribution centre already in the Middle Ages. Direct evidence of pottery export to markets in a number of Moravian towns and cities is available only from the Early Modern period (Kratochvíl 1906, 345–346).

In **Moravské Budějovice** in southwestern Moravia, the layout of the village was formed (the term town was not used until the 16th century) and consisted of a built-up area around two squares forming a right angle (Fig. 1). Already in the High Middle Ages, this core was surrounded by several suburban settlements (Kuča 2000, 130–139). A pottery kiln with pottery from the Late Middle Ages to Modern period was uncovered in the courtyard of house No. 25 in the eastern front of the more

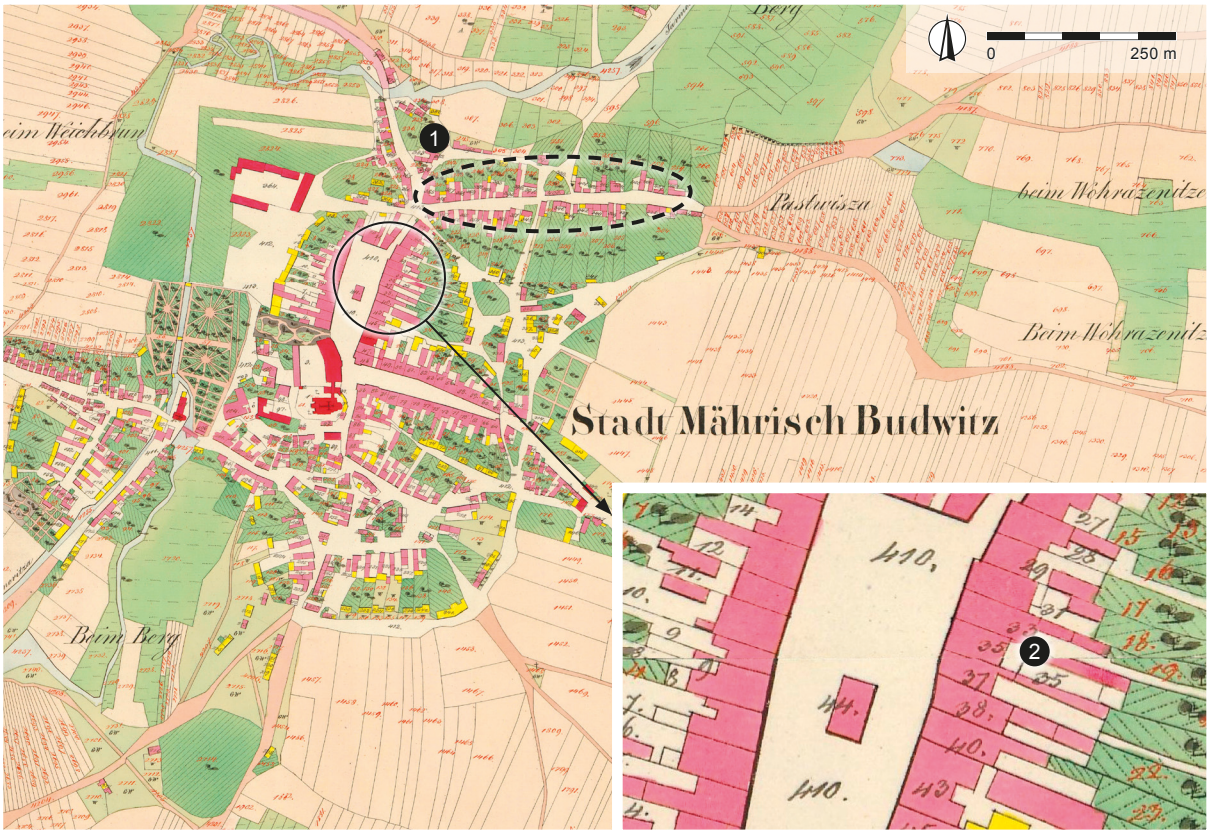


Fig. 33. Moravské Budějovice. 1 – náměstí Míru (Peace Square), house No. 25. Imperial Obligatory Imprints of the Stable Cadastre map from 1824; ČÚZK. After Holub et al. 2018, obr. 1. Graphics by M. Filip.

northern, rectangular square (today náměstí Míru [Peace Square]; Fig. 33: 1). The facility was located less than 7 m from the rear of the present house with what is probably an early modern building line and was accompanied by an extensive sherd layer in its close proximity (Holub et al. 2018). The village may have been fortified at the time the kiln was in operation or shortly afterwards, but it is unclear whether the wall surrounded it completely. The kiln was placed relatively close to the house on the plot which reached the edge of the residential area.

Litovel in northern Moravia was founded as a small royal town during the period of Přemysl Otakar II's reign, and it became a manorial town in the middle of the 15th century (Fig. 1). The suburbs developed along outbound routes, especially in the north, i.e. the Uničovská Route, and in the south, i.e. the Olomoucká Route (Kuča 1998, 570–581; Papajík 2018; Kaňák 2018, 143–144; Šlézar 2018; Štěpán 2018, especially 168, 184). The earliest town book of a memorial character (1359–1577) contains two mentions of Litovel potters, in both cases involving participation in legal acquisitions concerning other persons (Vepřeková 2011, 48–49, 66). It is unclear from the records where the mentioned craftsmen worked. In the Modern period, the potters' workshops were located (without further detail) in the area of Rybníček and Hrnčířská streets in the suburban part of Novosady north of the walls. The development of pottery in the pre-White Mountain battle period (1526–1620) reflects the establishment of an independent guild in 1593, although pottery experienced its greatest boom in the 19th century (Čermák 2018, 293–295).

Rescue excavation revealed the isolated remains of a one-chamber pottery kiln with ceramics from approximately the first half of the 15th century in the northern suburb of Novosady. No other medieval features have allegedly survived on the plot; only clusters of pottery dating from the late 15th or early 16th centuries onwards have been recorded (Novák 2024, and information from the head of research Jakub Novák). The plots in question, No. 341/2 and 317, are bordered by three streets; the kiln also lies at the intersection of Sušilova and Vítězná streets and has been disturbed by a modern house shown on

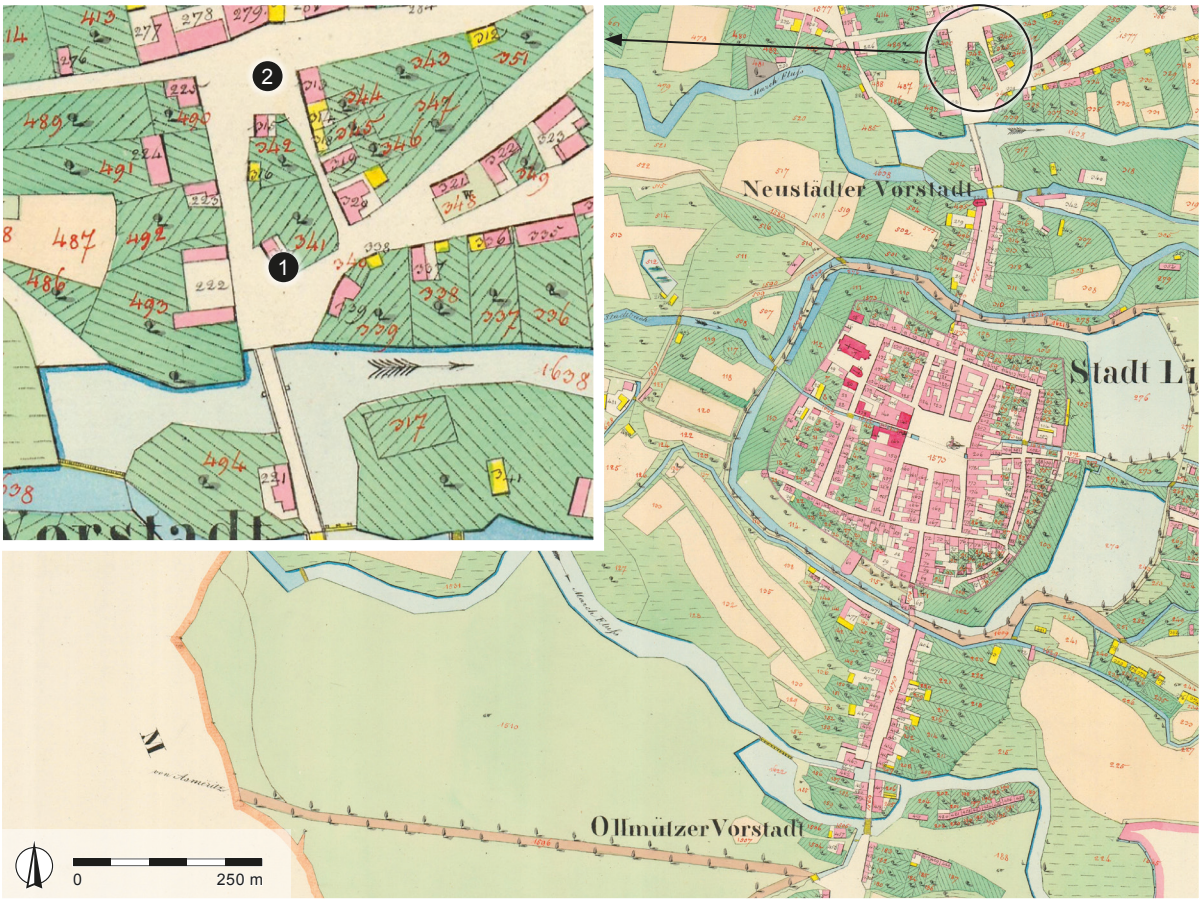


Fig. 34. Litovel. 1 – the site on the corner of Vítězná and Sušilova streets; 2 – Žerotínova Street. Imperial Obligatory Imprints of the Stable Cadastre map from 1835; ČÚZK. After Novák 2024, which specified the exactly location. Graphics by M. Filip.

cadastral maps from the 1st half of the 19th century (Fig. 34: 1). The evolution of Novosady's built-up area is not entirely clear; Žerotínova Street (Fig. 34: 2), which runs west–east, probably has medieval origins (Faltýnek, Šlézar 2013; for various development models, see Kuča 1998, 579; Šlézar 2018, 72). How the built-up area was structured at the time the ceramic kiln existed remains unclear.

The manorial town of **Loštice** in northern Moravia was formed before the mid-14th century (1353 oppidum; Kuča 1998, 640–644; Fig. 1). The town became an important centre of pottery production in the 15th and early 16th centuries, when the characteristic Loštice pottery was produced here, especially the famous cups made of stoneware, which were exported beyond the borders of the Czech lands (e.g. Drobná 1957; Měřínský 1969; Goš 1982; 2007).

The earliest written mention of the Loštice production, i.e. goblets, probably dates to 1486, when a charter of King Vladislav II mentions the duty that the burghers of Chrudim were entitled to impose on imported 'Loštice pots'. Potters are not directly documented until 1545, when their guild is also mentioned (Goš 2007, 96–97).

Over the course of numerous rescue excavations, several kilns in the historic core of the town were explored. Two pottery kilns were found in the rear part of so-called 'Area A' in Komenského Street No. 47/17 Fig. 35: 1). An accumulation of three non-contemporary facilities and a waste pit were also uncovered here. The evidence of pottery production in Hradská Street ('Area B') seems to lack sufficient support (Fig. 35: 2). Pottery waste pits are reported further south on the opposite side of the street ('Area C'; Fig. 35: 3). No dating is listed for a number of features, but judging by the presence of Loštice goblets, they are probably mostly from the 15th century (Goš 1983; 2007, 22–42).

The small, originally royal town of **Hodonín** in southeastern Moravia, which was founded perhaps before the mid-13th century (Kuča 1997, 101–108; Fig. 1), lacks written records of potters due to the lack

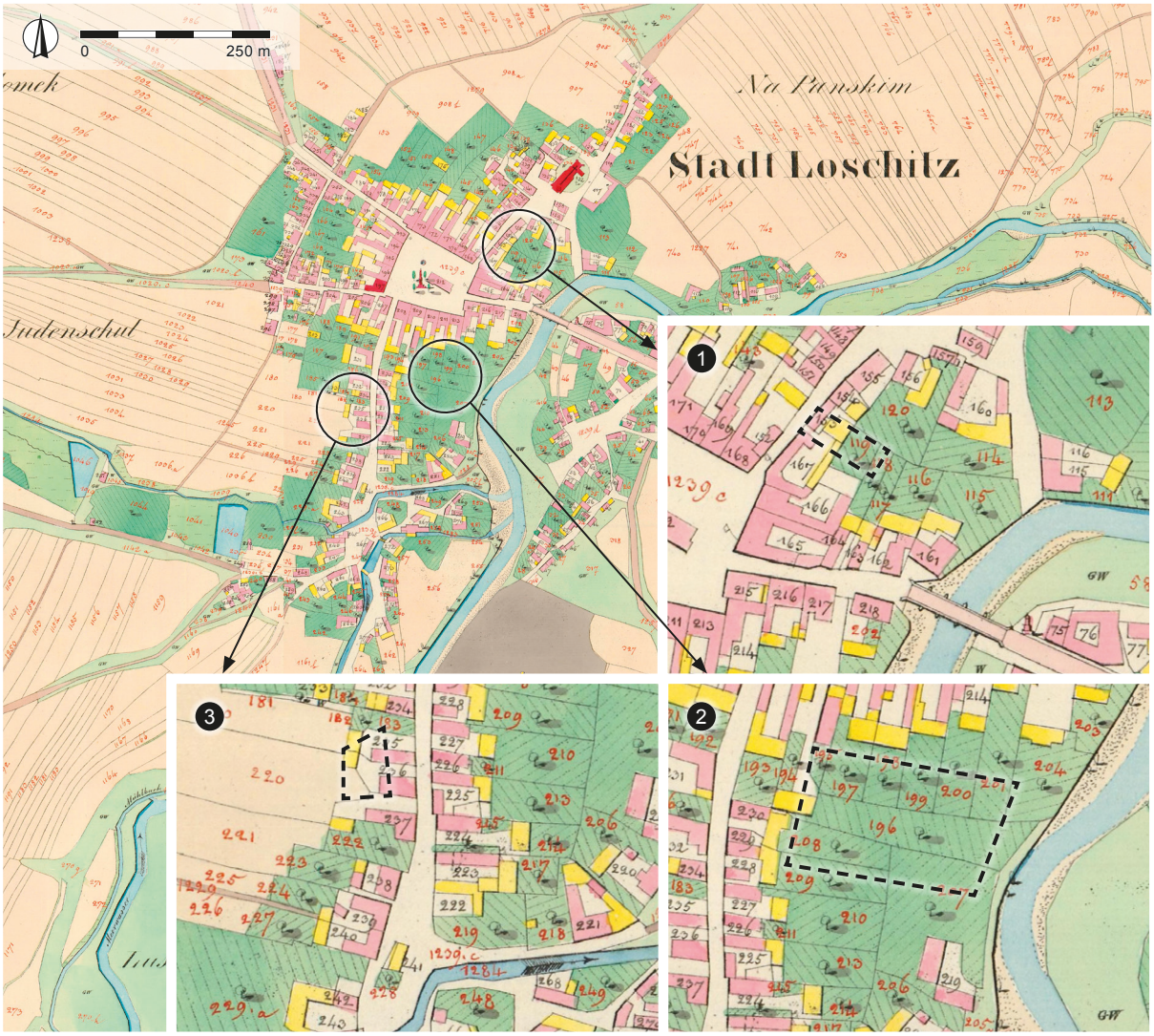


Fig. 35. Loštice. 1 – Komenského Street, house No. 47/17, site A; 2 – Hradská Street, site B; 3 – Hradská Street, site C. Imperial Obligatory Imprints of the Stable Cadastre map from 1834; ČÚZK. After Goš 2007, obr. 7, modified. Graphics by M. Filip.

of existing sources. A pottery kiln, tentatively dated to the second half of the 14th or first half of the 15th centuries, was partially uncovered during gas pipeline excavation in Dobrovolského Street No. 126/6 about 150 m northeast of Masarykovo náměstí (Masaryk Square) on the eastern side of the road, which is an old outbound route to the northeast (Kostrouch 2011, 149–150; Fig. 36: 1). The site is still located within the former fortification walls. The Imperial Obligatory Imprint of the Stable Cadastre from 1827 shows an empty plot here. The position of the kiln facing an originally narrower road is very unusual, although we have encountered this before in Opava. It is probable that the street was narrower in the Middle Ages and the kiln, located unusually at the side of the road, was in the vacant part of the plot.

Kroměříž in central Moravia was founded by the Olomouc bishopric around 1260 (Fig. 1). The origins of the suburb undoubtedly date to the 13th century (Kuča 1998, 204–220; Chybová 2009, 63–75). From the end of the 19th century to the present, perhaps around 17 pottery kilns mostly from the 14th to the early 15th centuries have been uncovered in today's Milíčovo náměstí (Milíč Square) within the historic Kovářské Suburb before the gate of the same name on the western edge of the historic core (Fig. 37: 1). No other features are mentioned in the fragmented publications concerning individual excavations. From the stable cadastre maps, it can be deduced that the built-up area developed along a short, broad street (which later branched off) before the gate in the southwest of the historic core after

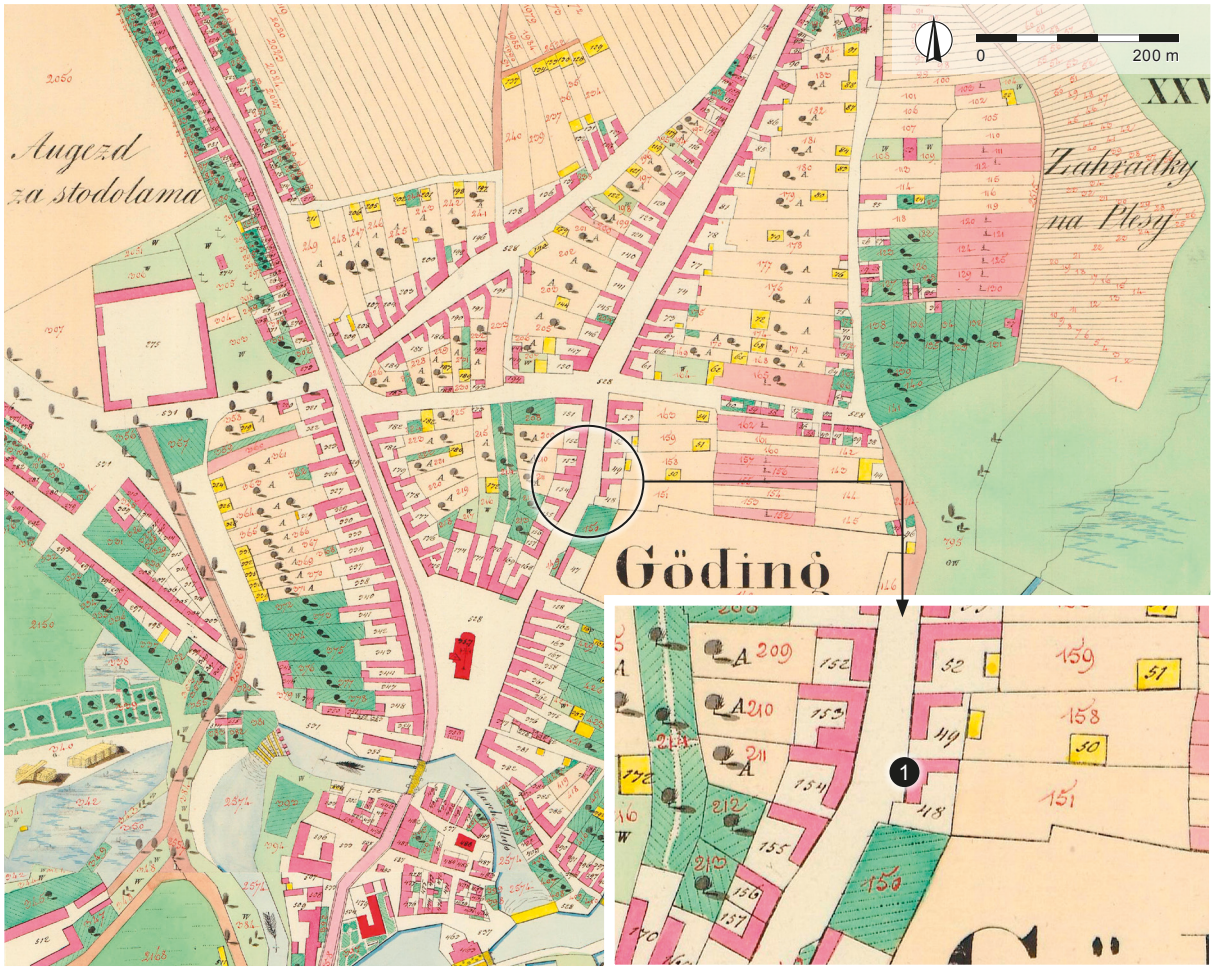


Fig. 36. Hodonín. 1 – Dobrovolského Street, house No. 126/6. Imperial Obligatory Imprints of the Stable Cadastre map from 1827; ČÚZK. After Kostrouch 2011, obr. 35: 1. Graphics by M. Filip.

the cessation of production activity. In the southeast, this road opens into a triangular town square continuously surrounded by houses; here, the kilns were placed in a disorderly manner (Chybová 2009, 115–143). This may be a preserved trace of an earlier ground plan that included the production area.

The large Kroměříž workshop area outside the normal plot division structure is not usual in the contemporary context. However, as in other cases, we are unable to provide a truly reliable interpretation due to the insufficient amount of information.

In the Modern period, potters were allegedly located on today's Riegerovo náměstí ([Rieger Square] formerly Koňský trh – Horse Market) and Ztracená Street on the southern and northeastern edge of the inner city (Peřinka 1948, 87, 373; Chybová 2009, 140; Sobek 2013, 24–25; Fig. 37: 2, 3).

Bruntál in Czech Silesia, originally a royal town, was formed as a successor to the mining town of Starý Bruntál from the last quarter of the 13th century (Kuča 1996, 347–354; Fig. 1; 14). A pottery kiln with ceramics from the 13th century was allegedly found during the digging of a sewer behind the former Piarist monastery in Dukelská Street (Král 1967; Fig. 38: 1). This involves a historical circular road within the Niské Suburb northwest of the wall circuit, which intersects the outbound route to Starý Bruntál and Nisa. The Piarist college replaced several suburban houses, the plots of which can be linked to the find.

Research during the digging of a utility network captured waste sherd layers along the western side of Fügnerova (formerly Hrnčířská) Street, which are probably related to the houses on plots No. 119 and 121 near the town wall on the 1827 stable cadastre map (Krasnokutská, Zezula 2011, 137–138; Fig. 38: 2). A pit with perhaps 16th-century pottery waste was also uncovered in the road of the eastern part of Požárníků Street in the southeastern part of the urban core (Kiecoň, Zezula 2011, 136).

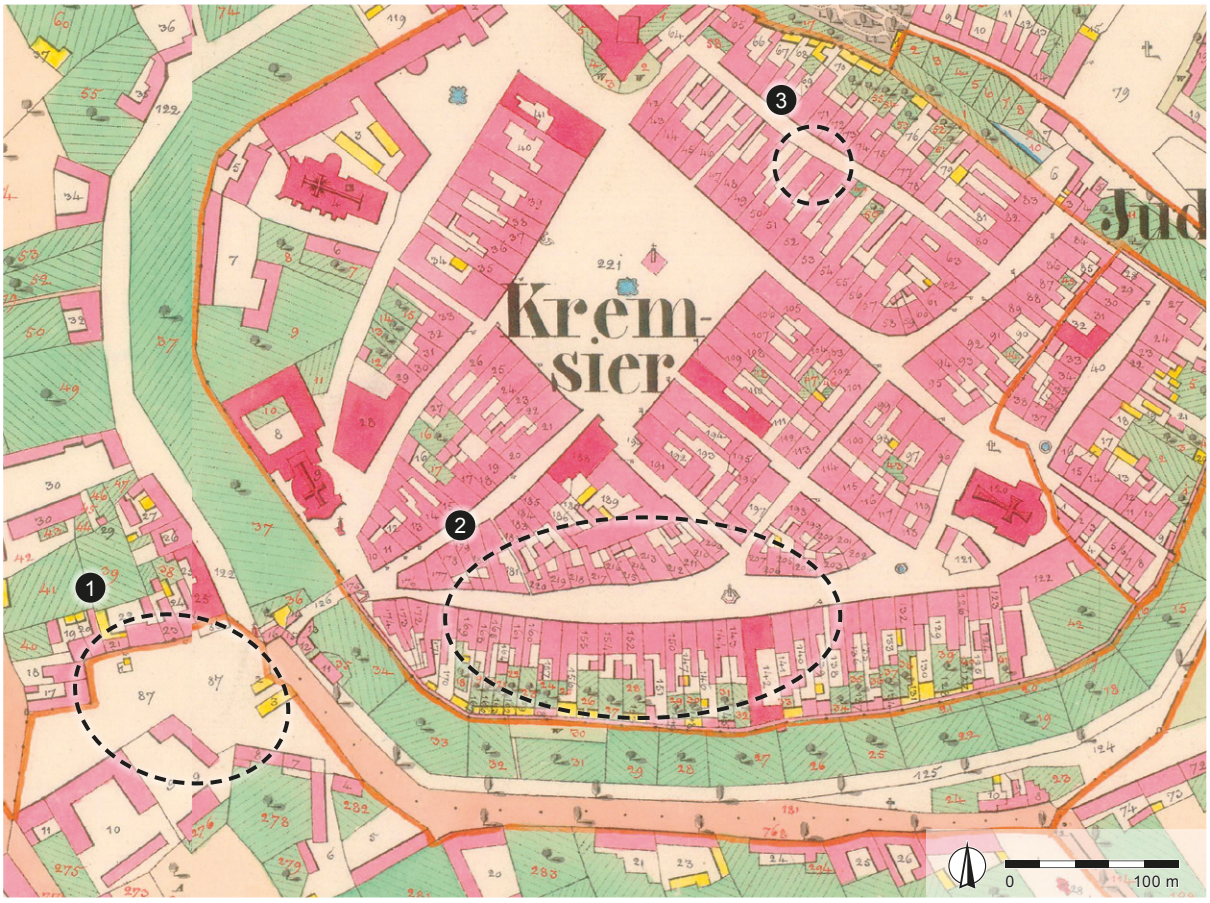


Fig. 37. Kroměříž. 1 – Milíčovo náměstí (Milíč Square); 2 – Riegrovo náměstí (Rieger Square), former Dobytčí trh (Horse's Market); 3 – Ztracená Street. Imperial Obligatory Imprints of the Stable Cadastre map from 1830; ČÚZK. After Chybová 2009, 120. Graphics by M. Filip.

2.2.4 Placement of pottery workshops – facit

Despite limited sources that differ greatly in quality, certain conclusions can nonetheless be drawn from a sample of thirty sites with regard to the spatial context of medieval pottery workshops.

It can be assumed that potters were present in almost all towns and cities in the Middle Ages. In the vast majority of cases, potters numbered in the lower single digits and were also predominantly independent producers living in their own houses. According to the situation in Brno, it can be estimated that the proportion of tenants was marginal, as indicated by data from other towns, e.g. from České Budějovice as of 1384, 1398 (Beer 1915, 49–50; Borská-Urbánková 1964, 145). The data on the number of craftsmen from previous chapters can be supplemented with a score of additional information (see below Tab. 1, 2). Potters mainly supplied a territorially limited group of consumers, who mostly came from the locality where they lived and from surrounding areas that constituted the local market. In some cases, an absolutely higher number of potters can be linked to the size of the locality, which is evidently true for Prague or parts of it – in the earlier period, production was concentrated mainly in Lesser Town and in the Late Middle Ages most significantly in New Town. However, this does not at all exclude the possibility that products from these 'non-exporting' centres also reached more distant markets within the scope of other potters, as annual fairs in large towns within the so-called regional market acted as an attraction. A good example is the small percentage of 'Boskovice' pottery in Brno between 1350 and 1450 (i.e. mere decimals or single-digit percentages – see Sedláčková 2020-2, 129, 137, 149, 172, 181 for supporting data). Special products were also exported, e.g. smoke-fired, burnished ceramics, probably produced in several centres where high-quality clays were available (perhaps Boskovice, Olomouc; Procházka 1995, 114; Chybová 2009, 155–156; Čapek et al. 2022, 166). Archaeometric research, which has yet to be conducted, would play

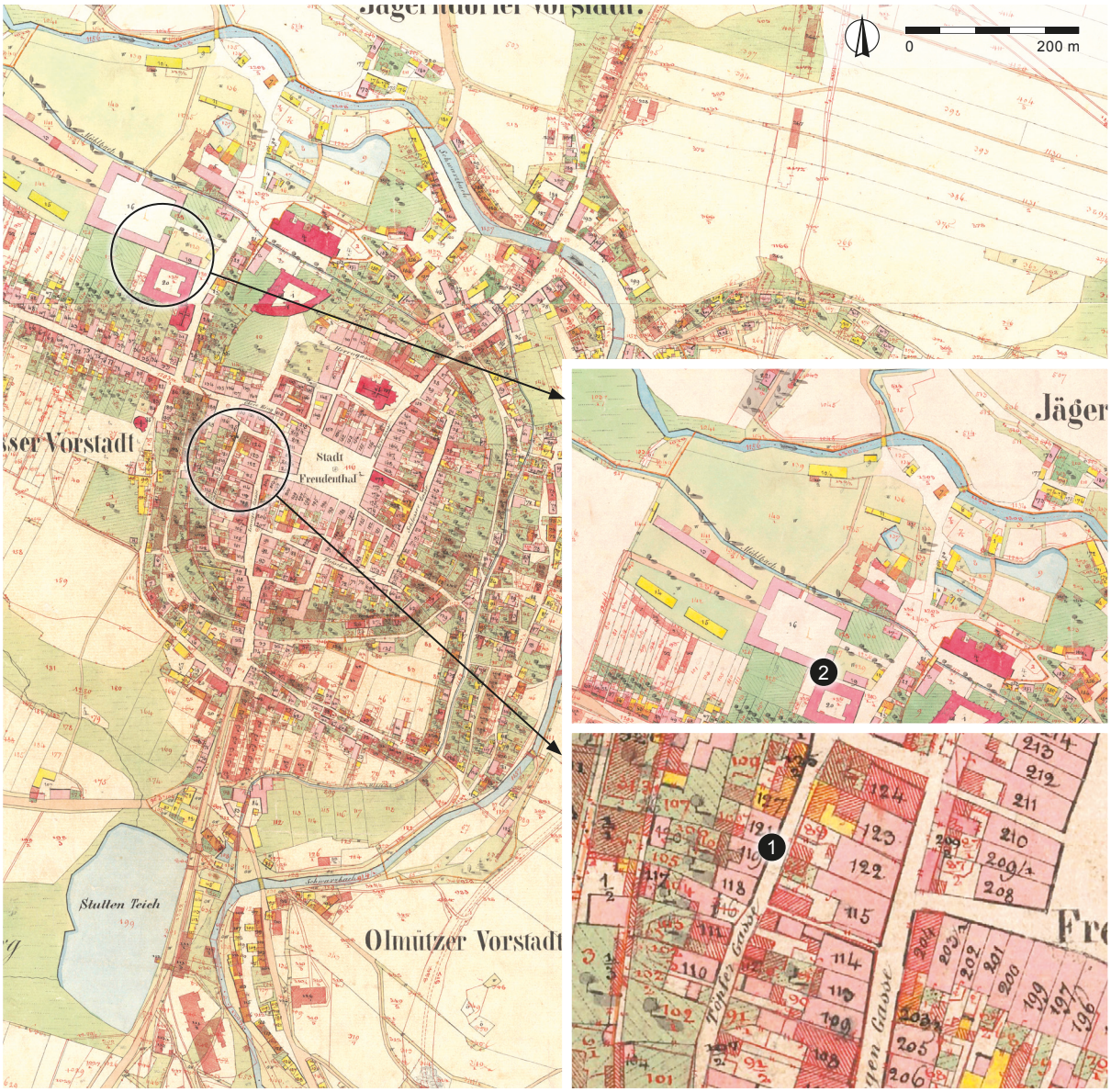


Fig. 38. Bruntál. 1 – Dukelská Street; 2 – Fügnerova Street. Imperial Obligatory Imprints of the Stable Cadastre map from 1836; ČÚZK. 1 – approximatively after Král 1967; 2 – Krasnokutská, Zezula 2011, obr. 3.

a significant role here, e.g. for the already delineated western Bohemian pottery areas (Krasanovská 2015). In some cases, however, we can consider that at least regional centres with a larger share of exports existed perhaps as early as the second half of the 14th century (Česká Lípa, Ivančice) or in the following century (Domažlice) judging by local kiln concentrations. However, the increase in export production seen in small towns can be dated back to the Early Modern period (16th–17th centuries). Technological progress played an important role here – the general spread and further perfection of high-speed throwing technologies[2] from a single piece of clay, the increased use of glazes, the increase in decorative features and, eventually, the emergence of faience production as a result of the establishment of Anabaptist communities particularly in Moravia. At this time, the relatively well-known structure of

2 Vladimír Scheufler believed that the treadle wheel/flywheel in its late phase with a sturdy top plate was only replaced by a kick wheel with a quick-turning base at the end of the 18th century (Scheufler 1974, 67–68, 85–86). Jaromír Žeglitz pointed out a transitional stage in the development of the treadle wheel with a lighter upper plate and an emphasis on driving the lower plate (Žegklitz 1990a).

production and distribution areas of so-called folk pottery culminating in the 18th and 19th centuries was also established (Scheufler 1972, especially 115–160). Unfortunately, a realistic demarcation of similar areas of high and late medieval workshops based on an exact material analysis is still in its initial stages; for the time being, we are still in the phase of discourse concerning areas with certain morphological-typological traditions and approximately distinguished technological features, such as the type of firing (cf. summary by Čapek, Těsnohlídková, Slavíček 2022).

In terms of settlements, we can note the presence of potters both in the perimeter of the walls and in suburbs (e.g. Čapek 2022, 351–352, 357). Their activity only in the inner city can be explained in isolated cases by the simple fact that suburbs were wholly absent or that they were of a negligible size in the Middle Ages. This applies to Old and New Towns of Prague or to Uherské Hradiště. A typical feature of medieval and early modern urban settlement was the high degree of spatial mobility or the demographic instability of the population. In Brno, for which we have relatively high-quality sources that allow us to trace the succession of most house owners over relatively long periods of time (with gaps from 1343 to 1389, continuously from 1442 to 1537), we can consider the average period of a particular person's house ownership to have been around 10 years (Procházka 2013b, 122; Sulitková 2023, 239). Although we can find varying concentrations of craftsmen of a certain specialisation in various town streets, with some exceptions (especially tanners, who were strongly reliant on watercourses), this was for a limited period of time. Moreover, these craftsmen tended to be mixed with burghers with other occupations (e.g. Ostrý, Přibylová 2023; Navrátil, Ostrý 2021; Goliński 1997). Few towns have sources that would allow us to trace sociotopography over a longer period of time before the mid-16th century in at least a somewhat sequential manner.

Within the group of towns that we have mostly dealt with above, potters in the Middle Ages were found both in the inner city and in the suburbs of Brno, Plzeň, Beroun, Ivančice and Litovel, although not always demonstrably simultaneously. Only in terms of inner cities, they have been documented so far in Jihlava, Rakovník and Čáslav (Čermák 1898), Uherský Brod, Loštice, Bakov, Kutná Hora (Šimek 2014, 27–31), Moravské Budějovice, Vamberk and Česká Třebová (Gilar 2000), and further research may lead to the discovery of workshops in suburbs as well. Potters are found exclusively in the suburbs of Znojmo, Opava, Žatec, Horšovský Týn, Kroměříž, Česká Lípa, Domažlice, Horažďovice, Hořice and Sezimovo Ústí.[3] In Znojmo, written sources mention potters in several suburbs, always simultaneously, with one – so-called Pukental on the Thaya – being slightly predominant. The situation was probably similar in Sezimovo Ústí or Plzeň. In Brno, potters are prominent in the largest part of the suburban district in front of Brněnská brána (Brno Gate). In the suburbs, however, potters are more often found in higher concentrations, with the exception of Jihlava, Rakovník and, of course, Prague's New Town. There is an undoubtable tendency among potters to concentrate in one street, in the case of the suburbs usually around the outbound road (especially Brno, Ivančice, Domažlice and Česká Lípa), albeit with a number of exceptions and local hiatuses. The probe into sources that was carried out has, on the whole, unequivocally proved the common claim that potters settled in the peripheral parts of the settlement cores of towns and cities, often on plots of land facing the town wall (e.g. Musílek 2015, 133). Again, however, exceptions can be noted, (11 Starobrněnská Street in Brno; Brněnská Street in Jihlava; Kozí Street in Prague's Old Town; and some of the investigated sites in Loštice). The potters in Prague's New Town (in Truhlářská and Revoluční streets and on Republic Square) are also near the wall, but of the Old Town.

In historical cities, streets are known to have been named according to crafts. However, it is not always possible to prove the occurrence of a particular specialisation from the fragmented records, e.g. there is no evidence of a more frequent occurrence of bakers in Pekařská (i.e. Bakers') Street in Brno, and in Prague, the connection between the name and the craft in the case of Hrnčířská (Potters') Street in the Old Town of Prague cannot be sufficiently proved – the residence of craftsmen of a given profession probably preceded the first written references. 'Potters'' streets, sometimes documented as late as in the Modern period, are related to the craft in question, for example, in the New and Old Towns of Prague, Beroun, Rakovník, Česká Lípa, Žatec, Jihlava, Uherské Hradiště or Ivančice, where the respective town gate was also called Hrnčířská ('Potters') for a certain period. It is only in the 17th century that the potter Martin Hošek and Kamba can

3 References to sources are only included in places that were not mentioned in this context in the previous text.

be linked to Hrnčířská Street on the eastern edge of the historical core of Velká Bíteš, although a potter appears in the local memorial book as early as 1420 (Tirray 1908, 123, 298, 313).

Based on the relatively low percentage of potters among urban craftsmen (mostly one to four producers) evidenced by specific dates in a limited group of sites, the opinion has appeared that pottery was not a typically urban craft, but rather a rural one. At the same time, the extent and significance of rural pottery has not been documented in any way, and it is clear from what has been presented so far that from the 14th century onwards it has been documented only in rare cases (Nekuda, Reichertová 1968, 24, numbers of potters partially according to Janáček 1961, 190).

The following tables show the number of potters from available written sources, mostly those of a tax collection nature (Tab. 1, 2).

The data from the few towns with tax collection sources more or less confirm the statement above concerning the small number of potters, which is usually true for the whole heterogeneous group of specialisations in the field of earth and building (for a classification of crafts, see Mendl 1926, 96; cf. e.g. Janáček 1963, 37–64; Kavka 1959, 265, 282; Hoffmann 1961, 65–66; 2009b, 238–245; Marek 1965, 79–94). The number of potters working simultaneously ranged in the single digits, with four seeming to be quite common. Any production deficits could undoubtedly have been compensated for by importing goods from a neighbouring production centre. However, it must be borne in mind that there are no data from the towns that were already important centres of pottery production in the Middle Ages (Ivančice, Česká Lípa, Domažlice). Some production centres experienced great development in the 16th–19th centuries, which is also reflected in an increase in the number of craftsmen; for example, Ivančice records 36 craftsmen in 1672, which is already quite a significant number for a small town (Svoboda 1927, 158–167). Growth in the number of specialists, not in the concentration of production, was a typical reaction of medieval and early-modern small-scale production to an increase in demand.

It is clear that pottery workshops were almost exclusively located on plots of land that included the potter's dwelling. This is evidenced by the discovery of production facilities in the residential areas of towns or within the built-up area of the suburbs, which in exceptional cases can also be linked to craftsmen in Brno, Prague – New Town), Sezimovo Ústí, Uherský Brod, Ivančice and other towns. The location of production facilities completely outside of the building plot layout seems to be evidenced only

Year	House owners		Tenants		Total	Source
	City	Suburbs	City	Suburbs		
1365				1	1	Mendl ed. 1935
1367		1			1	Urbánková, Wihodová eds. 2008
1375		4			4	AMB, A1, manuscript 15
1376		4			4	AMB, A1, manuscript 15
1387		4		1	5	Urbánková, Wihodová eds. 2008
1389(1)		3		1	4	Urbánková, Wihodová eds. 2008
1389(2)		3		1	4	Urbánková, Wihodová eds. 2008
1389(3)		3		1	4	Urbánková, Wihodová eds. 2008
1432	1	1	1		3	Urbánková, Wihodová eds. 2008
1442		3			3	AMB, A1, manuscript 8
1471	2	1			3	AMB, A1, manuscript 22
1477	2?				2?	AMB, A1, manuscript. 9
1479	1				1	AMB, A1, manuscript 23
1487	1				1	AMB, A1, manuscript 24
1499	1	2			3	AMB, A1, man uscript 25
1504	1	3			4	AMB, A1, manuscript 26
1509	1	3			4	AMB, A1, manuscript 10
1510	1	2 (3)			3 (4)	AMB, A1, manuscript 27
1514(1)		3			3	AMB, A1, manuscript 28
1514(2)		3			3	AMB, A1, manuscript 29
1518	2	2			4	AMB, A1, manuscript 30

Tab. 1. Brno. Number of potters mentioned in tax records 1365–1518.

4 Only in this case does the data come from a memorial book; in the case of Sezimovo Ústí, the source is archaeological research, in other cases tax books and registers.

Town	Location	Year	Number of potters	Source
Znojmo	S	1363	5	Polesný ed. 1928
Znojmo	S	1397	9	Polesný ed. 1928
Znojmo	S	1442	4	Polesný ed. 1932
Plzeň	U	1407	4	Strnad ed. 1909
Plzeň	S	1470	4	Bělohlávek et al. 1965
Rakovník	U	1436	6	Zenklová ed. 2022
Jihlava	I	1425	5	Hoffmann 2004b
Jihlava	I	1426–1428	4	Hoffmann 2004b
Jihlava	I	1432	2	Hoffmann 2004b
Jihlava	I	1438–1442	2	Hoffmann 2004b
Ivančice[4]	S?	1483	4	Fiala, Jelínková eds. 2022
České Budějovice	I	1398	1	Borská-Urbánková 1964
České Budějovice	S	1398	2	Borská-Urbánková 1964
České Budějovice	U	1482	4	Kavka 1959
České Budějovice	U	1514	3	Kavka 1959
Louny	U	1460	4	Kavka 1959
Louny	U	1535	4	Kavka 1959
Kouřim	U	1506	1	Kavka 1959
Sezimovo Ústí	S	1419?	4–5	Richter, Krajíc 2001

Tab. 2. Taxpayer-potters documented in various towns in tax sources. I – inner city; S – suburbs; U – undefined.

in Kroměříž. On a smaller scale, however, a similar phenomenon cannot be ruled out elsewhere. This could be indicated by the isolated location of some facilities, e.g. in Kostelec near Jihlava, but this possibility cannot be completely ignored in Horšovský Týn, Mstěnice or in the case of the 'Na Dvorku' site in Staré Město near Uherské Hradiště.

The placement of a kiln on a plot in relation to contemporaneous residential buildings is known only in a limited number of cases; however, a relatively close position, say within 10 m, is not exceptional – e.g. in Prague's New Town, Uherský Brod, Moravské Budějovice, partially in Sezimovo Ústí, probably also in Brno – Kapucínské náměstí, in Beroun, or in Ivančice – Kounická Street. Multiple written records from the modern period regarding the location of kilns have survived, e.g. in Kroměříž. Local potters could not have fired pottery at Koňský trh within the town walls, because their houses were built of wood (Peřinka 1948, 348).

Among the oldest lists of workshop equipment is a unique record from Tábor's earliest town book concerning the purchase of Jan Hrdoňka's house by Janek, son of the potter Vaněk, in 1439, which also mentions planks (part of the drying room?), a table and (probably a potter's) wheel (Šmahel, Černá eds. 2017, 53).

More detailed lists date back to the early modern period. For example, the inventory of the estate after the sudden death of Pavel Doubek of Kutná Hora in 1561 lists, among other things, seven wagons of 'Labské' clay and five wheels, as well as a kiln full of fired vessels and 90 vessels of 'raw pots'. Another potter, Vít Poledne, left only two wheels in 1559 (Šimek 2014, 31). In Beroun, four wheels were left behind in 1506 by Václav Pulc, and only two by Ludvík Opička (Vávra 1899, 135). In some workshops, several journeymen worked alongside the apprentices (in summary on the equipment of a pottery workshop see Žegklitz 1985).

The micro-context of a pottery workshop has undoubtedly been studied in the most detail in Sezimovo Ústí, where a certain variability in the spatial layout and relationship to the residential area can be observed. The kilns were sometimes placed in the open space of the plots, and sometimes in the halls forming a part of the house, where potters' wheels were probably located. Prague New Town yielded isolated material evidence of a change in the use of a plot, where a malt house was replaced by a pottery kiln and later by a sherd layer from a pottery workshop on the neighbouring plot. Only a short-term pottery workshop has been documented in Uherský Brod, where we are waiting on a detailed evaluation of the settlement context similarly to the cases of Česká Lípa, Brno – Veselá Street, Ivančice or Loštice. Unfortunately, many of the kiln finds are isolated in nature; remnants of other related features are absent or are of poor historical value (Litovel, Hořice, Rakovník, Beroun, Bruntál).

2.3 On reports concerning the sources of pottery clay

Written sources or oral traditions document sites of pottery material extraction mainly from the 16th century onwards. Due to the partially different structure of pottery production from the late 16th century and especially from the 17th century onwards, which was mainly influenced by faience technology as well as the increase in the proportion of glazed pottery (Scheufler 1972, 12–13; Pajer 2010), the sources for medieval and modern production may not be identical. On the other hand, some evidence suggests that as long as so-called 'měkkota' (Czech for 'soft ware'), i.e. pottery fired at temperatures of up to about 950°, was dominant, very similar if not identical sites may have been found in many cases in both periods. This is evidenced, for example, by the important pottery centre of Kunštát, where pottery clay was mined in pits not far below the surface until the second half of the 19th century. It was only from the end of the 19th century that the raw material began to be mined at deeper levels or purchased in nearby Letovice as a result of a shift to stoneware. It is reported that one workshop consumed 30–50 m^3 of refractory clay in addition to other clays (Pražák 1961, 16–51). It can be judged from the few reports from the Bohemian lands in the Middle Ages that clay mining took place mostly near potters' workplaces, i.e. on the cadastral areas of the respective cities and towns. There is information regarding fees for mining clay on the properties of another owner (Rakovník 1436; Zenklová ed. 2022) or of the rulers (Žďár 1407; Zemek, Pohanka 1961, 39, 45, 66, 88). According to Brno's municipal law from the 14th century, the sites / areas of clay and sand extraction on public properties were freely available and could not be occupied by a private individual without the approval of the territorial lord (Rössler 1852, 15; inaccurately in Nekuda, Reichertová 1968, 33). According to the statutes of the potters' guild in Česká Lípa from 1462, the mining pits were supposedly located at intervals in the length of three hoe handles, indicating rather shallow digging (Ebelová et al. 2005, 1015; Gabriel, Panáček 2000, 17). In Znojmo, the town tax book from 1367 mentions *fossato argile*, i.e. probably a place where pottery clay was mined (i.e. a clay deposit), although this is not certain, as common fields are not mentioned in places named as such (Polesný 1928, 7, 29). The earliest modern era reports do not differ much in their historical value. In Ivančice, this concerns the 'Kocperky' and 'Na Kočkách' site, where potters were allowed via an agreement to dig clay since 1625 in the field of one Jan Agrikola (Kratochvíl 1906, 344–345). This was a loess hill west of the historical core of the town above Na Volvách and Ostřihom streets (reported by J. Doležel). At the end of the 16th century, a potter mined clay in the so-called Rumburk Forest between Rumberk and (Horní) Smržov (Hosák 1933, 74; Nekuda, Reichertová 1968, 33) with other examples. According to petrographic analyses, Brno's medieval potters and stove builders took clay from the loess slopes of Petrov and Špilberk, Tertiary calcareous clay (called 'tégel' in Czech), and alluvial sediments of the Svitava and Svratka rivers (Gregerová, Procházka 2007, 277; Himmelová, Procházka, Šmerda 1999, 51–55; Loskotová, Hložek, Tymonová 2021a, 129, 132; 2021b 237; 2021c, 315; Loskotová, Hložek 2021, 190; Loskotová, Hložek, Jagosz-Zarzycka 2021, 287). In this context, an interesting report on pottery-making clay, probably loess clay, on the estates of the Brno Chapter at St Peter's in Bohunice, south of Brno, based upon an agreement with the potters' guild from 1601 and renewed in 1668 (which may be related to the limitation of the opportunity in the town and its immediate surroundings), has escaped scholarly attention (Schirek 1900, 10–11, Nekuda, Reichertová 1968, 33).

According to the latest analyses, the famous Loštice goblets were made from high-quality Tertiary period iron-rich clay with a pyrite addition resistant to temperatures of around 1250°, which was mined in the village of Svinov about 4.5 km west of Loštice. The raw materials for common pottery were obtained by potters from the Masnice site on the Žádlovice cadastre 1.6 km southwest of Loštice (Šťastný, Dudek, Goš 2018, 88–89). The following record of clay extraction near Svinov and on the Masnice field track, which was apparently in operation for a long period of time, was entered by the rulers in 1575 during a property transfer of the Loštice domain into the Land Registers: '... the town of Loštice... with taxes from potters and pots taken as fees; and also the right to extract iron-rich Masnice clay near the village of Svinov....' The name of the field track 'Masnice' suggests the presence of 'fat' clay. However, the first report of the clay deposit at Svinov dates back to 1567, when the bishop of Olomouc confirmed the privilege given to Loštice potters to take 'iron-rich' clay from Svinov, which they had been mining there for a long period of time without fees (ZDO III, 49, No. 69; Houdek 1891, 63; Goš 2007, 54, 97).

Other testimonies also exist concerning the import of clay from similar distances. In the case of Domažlice in 1618, digging was carried out 'deep below the surface' on the town's lands 3.5 km east of the town (Procházka 1983, 2–4). Kutná Hora's potters probably imported fluvial 'Elbe' clay (1561) from a distance of at least 4 km, while Česká Lípa's potters, according to a report from 1579, travelled as far as Robeč 17.5 km south of the town (Gabriel, Panáček 2000, 20). Unregulated clay mining sometimes led to damages and disputes, as evidenced by the rulers' intervention in the case of potters from Počátky and neighbouring Žirovnice (Navrátil, Scheufler 1966, 43). Also, the pits created by Kroměříž potters in the River Morava alluvium on the 'bleachfield' island between bridges provoked an intervention from the town council in 1688, which led to only a small shift in the location of the mining sites on this island (Peřinka 1948, 348).

Although it is a very desirable direction for research, the comparison of the results of analyses of raw materials documented by written sources with findings obtained by archaeometric research on specific pottery is still rather rare. In particular, the aforementioned research on Loštice pottery can be seen as an inspiring example from the Czech context (Šťastný, Dudek, Goš 2018).

2.4 On the question of the social status of urban potters

The position of potters in the world of the medieval burgher population cannot be addressed here in the sufficient and necessary extent and depth; we are limited both by the scarcity and the diverse nature of the relevant sources. For example, ascertaining property ownership according to assessments in tax collection books and registers has its limitations (e.g. Čechura 1998); on the other hand, much can be learned from other types of municipal books with memorial, market, or testamentary records. Comparative studies of individual crafts or branches in individual towns or in even broader frameworks are mostly lacking. Existing studies have mostly examined property stratification across the urban community, culminating in the formation of so-called tax classes (e.g. Kavka 1959; Dřímal 1964). In general, we can claim that potters were both few in number and of a lower social status within the range of other similarly situated urban crafts (e.g. Nekuda, Reichertová 1968, 23; Čapek 2022, 356–357). The rather small significance of potters in Olomouc is indicated by the order of the guilds in the Corpus Christi procession of 1472, where potters took 8th place among the 23 represented guilds. Less important crafts would go first in the procession, with the representatives of the most prominent ones occupying the final rows (Kühndel 1929, 29; Čermák 2002, 38, 123–124; Veselý, Zaoral 2008, 54).

Property ownership can best be assessed in towns where we have a tax cadastre with specific tax information determined via property assessments, and in some cases also taxation according to occupation (mostly craft tax) or the declaration of movable property (Dřímal 1964; for a critical view, see Čechura 1998). These sources have been preserved for only a small number of towns. In addition, each town applied a different system, which may have varied over time even within a single site. A true depiction of property ownership is distorted by the differences between appraisal prices and market values, which can sometimes be several times higher than appraisal amounts (e.g. Jordánková, Sulitková 2020, 137–138). Therefore, tax collection sources mainly record house owners, and the registration of tenants and other 'inhabitants' may not be nearly as consistent. Over the course of time, the number of surnames increases as information concerning profession listed after the first name decreases.

Potters recorded in the suburbs of Brno in the 14th century mostly represented the lowest level of property ownership in terms of craftsmen in the category of house owners. In the 1340s and 1350s, they are usually recorded in the city's tax collection records collectively, including some tenants. Hanuš of Doubravice, who in 1367 was to pay four groschen, was forced to offer his bed and a pillow for collateral. Potters living in houses in the suburbs in the 1360s to 1380s paid only small sums, generally single groschen from houses with low value at a rate of 2 groschen per mark of value, plus a fee of 8 groschen from their craft (on taxation, see e.g. Dřímal 1964). In a wholly exceptional case in the 1480s, the potter Mikuláš managed to deposit his surplus capital into a cheap vineyard in the later abandoned village Rybníky (Mendl ed. 1935; Urbánková, Wihodová eds. 2008; AMB, collection A1, man. 15). We find a somewhat different situation in the second half of the 15th century and the first quarter of the 16th century, when the number of potters in the inner city increased. Some of their houses were valued at over 20 marks of Prague groschen (1 mark = 64 groschen). Jan Kannperger was most prominent in the context, as he was the only one who could afford to invest in vineyards

and, with a total estimated property of 116 marks (the tax collector valued his house at a remarkable 60 marks), he ranked in the top quarter of taxpayers. Although suburban potters on average were worse off in terms of property, not a single one registered in the numerous tax registers and three books was a tenant. The mere fact that a particular burgher appears in the relevant town register as the agent in a probate or other type of transfer of property is an indicator of relatively higher social status. Unlike some other towns, records such as this related to potters are absent in Brno (cf. Flodr 2010).

In the years 1425–1442, Jihlava potters' taxes ranged from 5 to 16 groschen per collection. Although the taxation of immovable property and practice of their craft was lower than in Brno, i.e. ½ groschen on immovable property and 2 groschen on operating their craft, tax payments were relatively higher in Jihlava in most cases. František Hoffmann considered the parts of the town, where potters lived, to be relatively poor (Hoffmann 1961, 16–17, 28; 2004a; 2004b).

Compared to Brno or Jihlava, potters' property situations in the Znojmo registers from 1363 and 1397 are surprisingly good. They were owners of houses or suburban cottages or, in rarer cases, of courtyards. Most of them owned vineyards, which were often valued equally or higher than lowly-appraised houses located in low-valued suburbs – estimates in 1363 ranged from ½ to 4 marks, with maximum values in the town centre between 20 and 30 marks of groschen. The most affluent potter, Michael, declared in 1397 six vineyards along various locations, and the total appraisal of his property, including cash, was 29 marks (Polesný ed. 1928). In contrast to this, Plzeň's potters, with property valued up to 5 marks in 1470, rank among the poorest group of local taxpayers (Bělohlávek 1950, 158). However, a warning against generalising such figures can be found in the will of potter Kunc in Plzeň from 1494, which bequeathed 10 marks to the construction of St Margaret's Church. The potter Krákora, on the other hand, reveals in his testament the difficult life of a master potter burdened with partially or wholly unpaid orders and numerous debts (Strnad 1905, 326, 695–696). Therefore, an estimate in a particular year may be highly simplistic and may not reflect the variability of property situations over time. A similarly ambiguous insight into the property situation of (not only) potters is found in the records of the earliest market-type municipal record of Tábor (1432–1452), which records nine potters / house owners. František Šmahel noted the speculative nature of property purchases and sales carried out by some burghers. These include the potter Vaněk and his son Janek. Vaněk sold one house in 1443, then in 1437–1443 bought two houses in Tábor, a brickworks and a courtyard in Sezimovo Ústí, and a garden; the brickworks was sold by his widow in 1447. However, it is not certain whether we have records of all the transactions. Janek – who bought a bread shop, bought and sold two houses and exchanged one between 1439 and 1446 – was also very economically active. The potters Bušek and Ondrášek also owned land, and their transactions seem to have been an investment rather than a necessary means of subsistence, similarly to the purchase of, for example, the bread shop (Šmahel, Černá eds. 2017, 23, 32, 48, 53, 56, 66, 74, 87, 90, 101, 134, 155, 160, 174, 185, 202; Šmahel 2021, 205–206). Potters' vigorous business activity in houses and yards, probably mostly in the suburbs in front of Hajská brána (Hajská Gate) in the form of instalment payments, is also documented by numerous records in Duchcov's town book (1389–1425; Kochmann ed. 1941). Entries concerning potters in Ivančice's municipal records (1442–1509, 1522) indicate the complex situations of local, probably mostly suburban, potters. For example, the will of the potter Zikmund (1486) deals with 17 threescore (60 groschen), but these represent receivables for instalments from the sale of the house but these represent the settlement of outstanding receivables of instalments from the sale or pledge of the house and vineyard. In 1488, another potter, Martin, settled a debt of 10 marks by pledging his house in the suburbs with a garden. The potter Jan bequeathed a vineyard to his descendant who was not yet of age, and a fur coat and tunic to his father (Fiala, Jelínková eds. 2022). At the same time, we can claim that these were not the poorest representatives of the craft in question in the studied towns, as such individuals would not have appeared at all in memorial books. In Beroun, at the end of the 15th century, craftsmen rented fields from the rich lower nobleman (Czech 'vladyka') Jan Jakoubek of Bezděčí, among whom we also find two potters (Vávra 1899, 51). The potter Jan Sláma owned two houses in Rakovník for a certain time (at least 1438–1442) (Zenklová ed. 2022, 212, 523). We can thus see that the economic deliberations of potters did not deviate from the typical medieval mentality, which led individuals to invest in immovable property in regard to regulations placed on the scale and organisation of production designed predominantly

for the local market (e.g. Janáček 1963, especially 24–32, 94–108, 131–174; Macek 1998, 35–3, 86–95). As far as we can judge from the incomplete sources, most medieval potters owned at most their own house, as is seen particularly in the example of Brno.

A potter's climbing of the social ladder is recorded only rarely; e.g. this may reflect the relocation of a craftsman or his widow from the suburbs to the inner city of Brno. A potter living in Litomyšl in the second half of the 15th century probably also improved his social position when he changed his profession to malting, as his will shows (Hásková 1982, 25).

In smaller towns and villages dominated by craftsmen and regional merchants, potters also joined councils in the second half of the 15th century. This can be documented repeatedly in Ivančice, with three representatives of the craft in question (1458, 1459, 1482, 1483, 1494; Fiala, Jelínková 2022), and four in Česká Třebová in 1433–1436 (Gilar 2000). Vaněk Uhřivý stands out among the potters of Rakovník, as in 1436–1450 he resided in Hrnčířská Street and in 1443 was also a councillor (Zenklová ed. 2022, 581, 1190). In all cases, of course, these were owners of houses or other properties – in Ivančice this mainly involves vineyards. Data are absent for Česká Třebová and Rakovník. In Česká Třebová, no potter / sworn personnel is recorded in the book of legal acquisitions. The composition of the councils in both towns has not been analysed; the situation, namely in the case of Česká Třebová, is complicated by the fact that an occupation is listed only for a minority of council members while surnames are already significantly present. Nonetheless, it is clear that the town's elite sat on councils, which were probably composed in greater part by relatively affluent craftsmen. In Ivančice, this included butchers, bakers, weaver-drapers, coopers, and others. Only the weavers had a guild, which they probably represented in the council at the time. In Česká Třebová, a blacksmith, weaver, and shoemaker are documented by name, but representatives of other crafts were also sure to have been present, especially those concerning food and clothing. Before guilds were established, more prominent craftsmen joined councils individually, as F. Šmahel, for example, assumes in a similar situation in Tábor in the second third of the 15th century (Šmahel 2021, 124). The growing importance of potters in the late Middle Ages can be clearly observed in Česká Lípa, a nascent regional export centre. This trend is reflected in early guild statutes and the presence of craftsmen among the guarantors or beneficiaries of the town's legal status, or their participation as witnesses of the restoration of the Church of St Mary Magdalene in the Hrnčířské Suburb (Gabriel, Panáček 2000, especially 17–19; Ebelová et al. 2005, 101). In 1500, a potter was also a member of the council in Velká Bíteš (Tirray 1908, 301).

In the late Middle Ages, we find potters somewhat surprisingly in the town council of Kutná Hora, the second largest town of the Kingdom of Bohemia. In the first half of the 14th century, the town was largely controlled by a group of families with some features of a classical patriciate similar to cases in Brno or Prague. Later, however, the city's elite transformed and became much more heterogeneous, including craftsmen, new rentiers, etc. to a larger extent. (Borovský 2002; 2019). After the expulsion of the German population from the town in 1422, we can observe the formation of new elites from 1424 to 1436, who were mainly associated with the organisation of mining and coin minting. However, of the 56 identifiable occupations held by council members, 66% can be identified as craftsmen and tradesmen, 40% of whom specialised in clothing or food (Kejř 1958, 186–187). Although certain families continued to maintain control over the town in the second half of the 15th and 16th centuries, a wider range of people continued to be appointed to the town council – 336 burghers held office between 1472 and 1527. We know the occupation of 128 councilmen, 56% of whom were craftsmen and tradesmen. These figures are of course not indicative of the position of the urban elite; however, the significant percentage of so-called 'prominent crafts' and the presence of representatives of other sectors suggest that the highest authority of the town's administration was composed of craftsmen, and later of guilds (Kapavíková 1973, 146–147; Macek 1998, 46).

In 1424–1434, only three potters were still registered in the town; one bought immovable property worth 25 marks, which means he held a relatively high position in Kutná Hora from this perspective (Kejř 1958, 126, 135, 177). From 1433 to 1505, we find nine representatives of this craft on Kutná Hora's council, seven of whom were there from 1433 to 1460, and the rest from 1497 to 1499 (Šimek 2014, 27, lists the first one, probably erroneously, as of 1435; for an accurate account, cf. Kejř 1958, 177; Kapavíková 1973, however, does not list any potters among councilmen from 1472 to 1527). In the 1460s, when 19 guilds are mentioned, a potters' guild did not yet exist. The first report of its existence dates to 1501 (Šimek 2014, 30, Kejř 1958, 140).

The exceptional entrance of potters or representatives of their guilds into the council of an important royal town may have reflected shifts in the local division of power corresponding to broader trends (for Brno, cf. Mezník 1962, 299–309; for Prague, e.g. Jíšová 2004, 94). However, the specific reasons for such a strong increase in the prominence of potters in Kutná Hora will need to be clarified by further research into archival sources and ceramics production.

For a better understanding of the social position of potters in urban society in the Late Middle Ages and Early Modern period, the surviving price lists of pottery products from cities such as Znojmo, Jihlava or Plzeň would deserve deeper analysis. The difficult position of craftsmen is evidenced particularly by the comprehensive discount offered by Plzeň's craftsmen on their products to the town council in 1518 (especially Nekuda, Reichertová 1968, 28; Strnad 1905, 417–418).

In the Late Middle Ages and Early Modern period, there was a certain balance between the oligarchic elite and middle classes while respecting the hierarchical principle. Even great clashes between town councils and the so-called 'great community' (i.e. an association of burghers with full rights), which included the middle classes predominantly made up of craftsmen, were not focused on changing social conditions. In the Late Middle Ages and Early Modern period, however, the political influence of crafts, which were now increasingly organised into guilds, did indeed begin to intensify in cities with all the advantages and disadvantages associated with this phenomenon. Craftsmen especially from Prague and the Moravian royal cities who formed the basis of the 'great community' also managed to increase their influence through fierce clashes with the oligarchic councils (e.g. Dřímal 1963; Janáček 1968, 144; Macek 1998, 45–85; Miller 2006, 168–198; Nodl 2023). Potters also participated in these transformations, although incomparably less significantly than members of the so-called 'strong crafts', especially food crafts. As we have already observed, they even asserted themselves in some localities politically, although probably predominantly as capable and respected individuals and less as the representatives of guilds. At least the elite potters in the emerging regional production centres or in some of the larger towns can be assumed to have held a relatively higher social position within the so-called middle class. Compared to many other specialisations, it is clear that potters were mostly 'relegated to the sidelines' in terms of socio-economic position in the Middle Ages and Early Modern period, as evidenced by their mostly late organisation into guilds. The issue of potters' social standing, their forms of organisation, and their social and property differentiation in the context of urban society deserves more attention than it has been given thus far in a broader temporal and spatial scope.

3
Methodology

3.1 Kilns and their remains

Finds of pottery kilns provide direct evidence of ceramic production at a site, and thus constitute a key source for the study of the pottery craft – especially in cases where the preserved remains include the last batch of vessels or parts thereof. Usually, only the sub-surface components survive – such as heating channels, the stoking pit, the firebox opening, the floor, or the lower parts of the walls. Among the above-ground parts, the most common finds are collapsed domes preserved as daub destruction, or in rare cases, remnants of domes that are vaulted using ceramic vessels coated with daub. Experimental archaeology is instrumental in determining the function of kilns, as it allows for the flexible simulation of production processes using well-constructed replicas of various types of these production features along with appropriate firing strategies while also examining the different types of fired ceramic fabrics.

The possibilities for processing kiln features are limited by the method of their excavation and the current state of the associated artefactual assemblage. Almost all pottery kiln finds in the Bohemian-Moravian Highlands originate from rescue archaeological excavations. The same applies to Staré Město near Uherské Hradiště, although in this case, the excavations were conducted in a developer-led context. The only exceptions are two kilns from Mstěnice, investigated as part of a large-scale, systematic excavation of the site. The earliest kiln find was discovered as early as 1953 in Kostelec, and relatively high-quality documentation has survived (Meduna 1954). The ceramics have been preserved only partially – approximately a quarter of the complete and fragmentarily preserved vessels were available for study, and for a portion of the fragments, it is unclear whether they originated from inside the kiln or from the surrounding area. Kiln finds from Mstěnice in the 1980s are accompanied by both drawing and photographic documentation, which prompted a re-evaluation of the situation of the pottery workshop (Nekuda 2000, 110–112). Some of the material stored in the Moravian Museum in Brno – particularly complete ceramic forms – remains partially inaccessible. For the remaining three sites from the Bohemian-Moravian Highlands (Jihlava – Křížová Street, Jihlava – U Skály Street and Žďár nad Sázavou – 'Staré Město'), as well as for Staré Město near Uherské Hradiště, we possess both drawn and photographic documentation and virtually the entire artefactual assemblage (Zatloukal 1998, 28–30; Slavíček et al. 2023; Procházka et al. 2024).

The typological classification of kilns is based on recent studies that broadly reflect the technical-functional aspects of kiln construction rather than relying solely on the ground plan of the preserved remains (e.g. Weiser 2003; Vágner 2005; Heege 2007; Kaltenberger 2009a, 251–253; Cuomo di Caprio 2017, 503–520), as well as on our own works focusing on Moravian finds (Procházka 2015) and those by L. Čapek for Bohemia (Čapek, Preusz 2019, 313–355). Earlier finds – often less thoroughly examined – were comprehensively published by V. Nekuda and K. Reichertová (Nekuda 1963; Nekuda, Reichertová 1968, 39–49). Most publications concerning pottery kiln finds in the Czech lands do not extend beyond basic descriptions, in part due to the fragmentary nature of many of the remains. Notable exceptions include the work of R. Zatloukal (1998; 2000a) and, more recently, the catalogue publication on the kiln from Hořice (Volfová 2018).

The basic classification of kilns is based on the configuration of their internal space. A distinction is made between single-chamber and two-chamber kilns, depending on whether the ceramics were in direct contact with the fuel – that is, whether or not the firing chamber and stoking area were separated. Another system of classification is based on the direction of flame flow, which may be horizontal, vertical, or diagonal. Horizontal flame movement is typically associated with elongated ground plans, commonly referred to as 'horizontal' kilns, while vertical flow tends to correlate with round or circular kilns. However, in practice, various transitional forms existed, and the direction of flame flow may not be identifiable from the shallow remains of a given pyrotechnological installation.

Two-chamber kilns may be further divided based on the method of separation between fuel and batch, as well as the form of the dividing structure. In the case of the kilns studied here, this is usually interpreted as a grate, although international examples attest to a variety of dividing structures, including partitions, walls, or clay columns. These are most often made of clay, with either slotted vents or radial arrangements. The structure may rest on a central pillar or spoon – either permanent or temporary. Importantly, the central spoon does not necessarily have to be structurally connected to the grate (Weiser 2003; Heege 2007, 15–19; Kaltenberger 2009, 251–253; Procházka 2015, 217–221; Čapek, Preusz 2019, 321–322).

3.2 Processing of ceramic finds from kilns

All the kiln finds presented in this publication contain ceramic material – ranging from complete or reconstructed vessels to their fragments and sherds. The methodology for processing ceramics from kilns follows the same general principles as for other assemblages, but it places a particular emphasis on the proportion of different size categories, especially complete vessels, large fragments, or torso-like forms, as well as their spatial positions and various defects caused during manufacture or as a result of unsuccessful firings. This aims to identify the circumstances surrounding the kiln's abandonment. The central question is whether the ceramic assemblage represents the last fired batch, secondarily deposited ceramic waste, or fragments that entered the kiln space after its disuse. Vessels that could not be physically located were evaluated based on the extent permitted by period documentation or the information provided in earlier publications and reports.

Morphological analysis of the ceramics is based on current standards (Macháček 2001; Procházka 2017, 361–368; Čapek et al. 2022). For the material from the Bohemian-Moravian Highlands, a descriptive system for 13th–14th-century pottery was applied. This system was originally developed as part of K. Těsnohlídková's doctoral thesis and has since been supplemented with additional descriptors (Těsnohlídková 2021; 2022). The system builds on descriptive codes currently used in both Bohemia and Moravia. The rim typology respects local specificities while remaining compatible with the dominant typological codes in both regions (Procházka, Peška 2007, 233–270; Čapek 2013). For the description of pottery from the kilns at Staré Město, a reduced and adapted version of the Brno code was used (Procházka et al. 2024).

Where complete vessels were available, vessel indices were calculated to further define the morphology of their bodies. These include: W – indicating the position of the vessel's maximum diameter, H – defining bulbosity, D – describing the degree of the body's convexity, and V – expressing the degree of narrowing at the base. Index W is calculated as the ratio of the height from the rim to the point of maximum diameter to the total height of the vessel (v2: v1). Index H is the ratio of total vessel height to the maximum diameter (v1: d3) Index D is calculated as the difference between the maximum diameter and the diameter at the neck, divided by the height between these two planes (d3–d2): v4. Index Z is the ratio of maximum diameter to the base diameter (d3: d4; Fig. 39; see Procházka, Peška 2007, 269; Čapek, Těsnohlídková, Sedláčková 2022, 233–235).

The method of technological description is based on a system developed and published by the author (Těsnohlídková 2021, 67–98; 2022, 91–106). This system was created for the analysis of archaeological ceramics from the 13th and 14th centuries in the Bohemian-Moravian Highlands and continues to be refined. It was originally designed for heavily fragmented assemblages. Its application to kiln assemblages with complete vessels thus tested its effectiveness for such material, allowing observation of the combinations of various traits across different parts of vessel forms and their potential relationship to specific processes or technologies (see Těsnohlídková 2021, 67–68).

The technological description of pottery is based on the concept of the *chaîne opératoire*. A broader

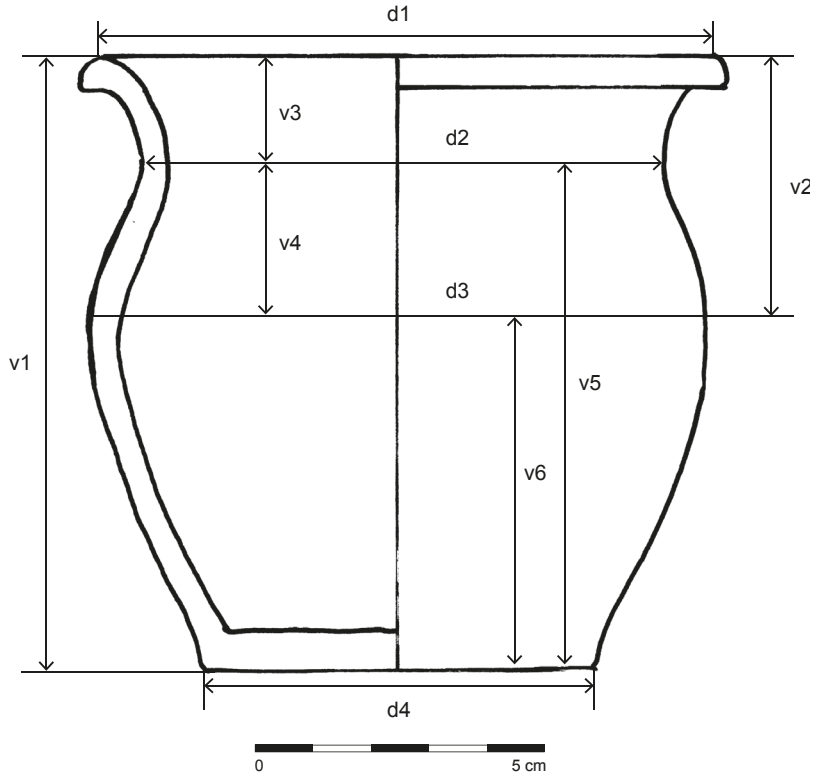


Fig. 39. Morphometry of the medieval pot used in the book for calculating indices.

and narrower interpretation of this concept can be distinguished: the broader one encompasses the entire lifecycle of a ceramic object, from production and use to deposition; the narrower one includes only the production process up to the storage of the vessels after firing. In this narrower sense, the term 'production chain' is also used (e.g. Vitezović, Antonović 2014, 8–9; Roux 2019, 1–14; Čapek 2024).

The basic principles of dividing the production phases are more or less the same among individual authors, differing only in details. The advantage of the *chaîne opératoire* is that the production phases are universal and can be applied to any type of pottery, while at the same time allowing the complexity of production procedures and the degree of their elaboration to be observed. Valentine Roux worked with four stages of pottery production: 1) selection and preparation of raw material, 2) shaping of form, 3) treatment of the outer surface, and 4) firing (Roux 2011, 80–81). Clive Orton and Michael Hughes proposed a more detailed division: 1) extraction of raw materials, 2) preparation of raw materials, 3) forming of vessels, 4) surface treatments before firing, 5) drying, 6) firing, 7) surface treatments after firing (Orton, Hughes 2013, 122). Daniel Albero Santacreu listed six stages of production: 1) selection and extraction of clay, 2) preparation of the fabric, 3) shaping, 4) drying, 5) surface treatment, 6) firing (Santacreu 2014, 59). Ladislav Varadzin worked with eight stages: 1) raw material acquisition (extraction of potter's clay, extraction of temper), 2) storage and processing of raw materials (aging of potter's clay, crushing of rocks, storage of temper), 3) production of pottery items (construction and forming of products, tools for forming, decoration of products), 4) drying of products, 5) waste from production or drying, 6) firing, 7) waste from firing, 8) storage of finished products (Varadzin 2010, 28, obr. 10). The theory of the production chain was analysed in detail by L. Čapek (2024).

The basic unit of technological analysis is the ceramic class, which is defined in a way that allows it to be identified for each individual sherd. Ceramic classes usually group fragments based on a shared macroscopic description of the fabric and common technological features (Vařeka 1998, 124; Nováček 2000, 12). In the context of this book, the ceramic class primarily describes properties related to the composition of the ceramic fabric and/or its firing characteristics, corresponding to the term *fabric* used in the Anglo-American literature (Orton, Hughes 2013, 151).

From each kiln assemblage, a sample of 13–26 vessel fragments was selected for scientific analysis.

The selection was based on macroscopic assessment of the ceramic paste. Samples were chosen to reflect the composition of the given assemblage, ensuring representation of different fabric types. Where possible, fragments from complete or nearly complete forms – most likely to have been part of the kiln batch – were analysed. Available daub fragments from the kiln structure were also analysed. All selected samples were catalogued and photographed. The archaeometric methods used for analysing the fragments and their evaluation are described below.

For the analysis of vessel shape and its regularity in relation to forming techniques, several vessels were selected from each kiln, along with comparative experimental vessels. Due to the high risk of result distortion, vessels reconstructed from many fragments and restored using plaster infill were excluded – this applied especially to most pots from Mstěnice, the inner surfaces of which had been coated with plaster. The analytical method is described below.

3.3 Pottery archaeometry

A multi-method archaeometric approach was applied to investigate the ceramic material in terms of its composition, provenance, and manufacturing technology. The analytical workflow combined thin-section petrography, X-ray fluorescence spectrometry (XRF), X-ray diffraction analysis (XRD), and thermal analysis (DSC/TG). Each method provided a different level of insight. Thin-section petrography served as the primary technique for identifying raw materials, temper types, and technological features of ceramic production. XRF elemental analysis enabled the assessment of chemical variability and potential compositional groupings. Identification of minerals, additional information on firing conditions, and raw material selection was provided by XRD. Thermal analysis was used to identify the content of clay minerals in raw materials. All the named techniques allowed for a comprehensive characterisation of the studied ceramic assemblages and helped to reconstruct both technological choices and possible raw material sources.

3.3.1 Ceramic petrography

Standard 30 µm thin sections observed under a polarising transmitted light microscope were used as the principal method for the detailed examination of ceramic paste, temper, and manufacturing technology. The provenance of the clay and temper materials was assessed by comparing the petrographic composition of the ceramics with the local geological bedrock. This evaluation was supported by geological maps and previously published petroarchaeological studies relevant to the respective sites.

Thin-section petrography has been applied to the study of archaeological ceramics for almost 150 years. The technique was pioneered in the late 19th century by H. C. Sorby, and independently by F. Fouqué and A. Michel-Lévy. Significant methodological advancements were made in the mid-20th century by A. O. Shepard, who fully recognised the potential of thin-section petrography for archaeological ceramics. In the second half of the 20th century, D. Peacock and I. K. Whitbread further developed the method by incorporating detailed studies of textural features, gathering quantitative data, and focusing more systematically on the clay component of ceramic bodies. Comprehensive overviews of the historical development of ceramic petrography have been published, for example, by S. E. Peterson with P. P. Betancourt (2009) and P. S. Quinn (2013).

In former Czechoslovakia and later in the Czech Republic, this method began to take root in the 1960s, but only began to be regularly applied from the late 1980s and during the 1990s. Part of this early research focused on early medieval ceramics (Dvorská 1995). This was followed by a major expansion of ceramic petrography thanks to the academic work of M. Gregerová, whose students produced numerous graduate theses incorporating petrographic analysis (e.g. Hanuláková 2006; Pokorná 2007; Kuljovská 2007). Miroslava Gregerová herself published extensively, with many studies focusing on medieval pottery (Gregerová 1996; 2017; Gregerová, Procházka 1998; 2007; Gregerová, Hložek 2008; Gregerová et al. 2010). Other scholars have also contributed to the development of ceramic petrography in the Czech Republic (Hanykýř, Maryška, Brůček 2002; Hanykýř, Nováček 2010; Kloužková et al. 2014; Kloužková et al. 2020).

Thin sections were examined using a Zeiss Axioscope 5 polarising microscope equipped with an integrated camera for microphotographic documentation. The matrix description considered homogeneity, granularity, colour, calcareous content, and potential technological features. Particular attention was given to traces of vitrification from high firing temperatures, as well as evidence of oxidation or reduction. The non-plastic inclusions were described by estimating grain size, shape, and rounding, and

each inclusion was identified and categorised as a specific mineral, rock fragment, or other component. A semi-quantitative numerical scale, similar to the approach of P. S. Quinn (2013) or R. Sauer and Y. Waksman (2005) was applied to estimate abundance. The quantification criteria are discussed in greater detail in K. Slavíček (2023). Specific features important for the interpretation of technology were also recorded, such as pleochroism changes in iron-bearing minerals (e.g. biotite, amphiboles) caused by oxidation during firing. Pores were described by size, shape, and estimated volume.

3.3.2 Chemical composition analysis (XRF)

Elemental composition was determined by a benchtop ED-XRF Rigaku NexCG spectrometer with a 50 W Pd tube and silicon drift detector of up to 145 eV resolution. The device uses excitation of the secondary targets for better signal-to-noise ratio. Excitation time was 120 seconds for every target. Samples were analysed in the form of pressed powder pellets. Matrix-based error in element quantification was minimised using a calibration library, which is specialised for soils and ceramics. The library runs on suitable international standards produced by the National Institute of Standards and Technology (NIST), the China National Analysis Center for Iron and Steel, the National Research Center for Certified Reference Materials in China, and the National Institute of Advanced Industrial Science and Technology in Japan, and MINTEK. The coefficient of determination for the analysed elements is approximately 0.9 across all elements studied (for the list of standards and calibration curves, see Slavíček 2023).

XRF analysis provided elemental concentrations, which were first screened for measurement errors and potential contamination. Elements prone to post-depositional mobility (e.g. phosphorus, sulphur), or those outside the instrument's optimal concentration range, were excluded. The refined dataset was analysed using principal component analysis (PCA) with the FactoMineR and Factoextra packages in R (Lê et al. 2008; Kassambra, Mundt 2020; R Core Team 2023). PCA reduces the dimensionality of multivariate data by projecting the original variables onto a new set of orthogonal axes (principal components). These components are linear combinations of the original variables and are mutually uncorrelated, with each successive component accounting for a decreasing proportion of the total variance.

3.3.3 X-ray diffraction analysis (XRD)

Powder X-ray diffraction (XRD) analysis was used as a supplementary method in order to support mineralogical composition revealed by petrography, to determine the firing temperature (Heimann 2017), and to assess mineralogical composition of clays. XRD was performed on a Panalytical X'Pert PRO MPD apparatus with a Co-anode and an RMTS detector (X'Celerator) in conventional reflection geometry (for pottery – step: 0.033° 2θ, scan speed: 0.027°/s, measured angular range: 4–100° 2θ, for clays - step: 0.033° 2θ, scan speed: 0.018°/s, measured angular range: 5–100° 2θ). The acquired data were processed using BrukerDIFFRAC plus EVA 2 and Topas 4 software. Quantitative phase analysis was performed using the Rietveld method. The degree of crystallinity of the samples was determined by comparing the integral intensities of the diffraction lines of the crystalline phases and the diffuse background.

3.3.4 Thermal analysis (DSC/TG)

Thermal analysis was carried out using differential scanning calorimetry (DSC) and thermogravimetry (TG) on a Setaram Setsys EVO 1700 instrument. The measurements were performed in dynamic air atmosphere during heating from 40°C to 1000°C at a rate of 10°C/min. The data were processed using Setaram processing software.

3.4 3D scanning, particle orientation, wall-thickness and symmetry analyses

3.4.1 Virtualization – data acquisition

In order to conduct a comparative morphometric analysis of the wheel-coiled vessels, high-resolution 3D models were produced using two complementary documentation techniques: Structure-from-Motion (SfM) photogrammetry and structured light scanning. The selection of the method was determined primarily by the accessibility and handling conditions of the vessels. Photogrammetry was carried out in a controlled laboratory environment, whereas structured light scanning – using a handheld device – was employed on-site in museum depositories.

For the SfM workflow, vessels were photographed under controlled lighting conditions using a Nikon D750 DSLR with a Nikkor 60 mm f/2.8 macro lens, which was mounted on a tripod (cf. McCarthy 2014). Settings were standardised (ISO 100), with aperture and shutter speed adjusted to surface reflectance and

geometry. Image sequences were processed in Agisoft Metashape, producing sub-millimetre accurate 3D meshes exported in *.obj format.

In cases requiring on-site documentation, structured light scanning was performed using a handheld Artec Leo. Its mobility and built-in processing allowed high-resolution scanning without external equipment. Raw data were processed in Artec Studio 18 and exported as *.obj meshes, with comparable sub-millimetre accuracy.

These scans provided a complementary dataset. However, it is important to note that in several cases, it was not possible to capture surface data from concealed or recessed areas, especially beneath the shoulder zone of certain vessel types. Due to the line-of-sight limitations, these regions remained inaccessible, resulting in partial data loss. Consequently, the final meshes contained visible holes or unmeshed gaps in those zones.

3.4.2 Virtual pottery – data extraction methods

All data extraction procedures were conducted using Blender, an open-source 3D modelling environment selected as the primary tool for this study. Blender provides a flexible graphical user interface (GUI), an integrated Python scripting console, and a node-based visual programming language (Geometry Nodes), which together support the development of highly customisable and reproducible analytical workflows. Due to its open-source architecture and adaptability, Blender has recently seen increasing adoption in archaeological research (e.g. Poight et al. 2021; Slavíček 2023). In the present study, the data extraction pipeline was based on the MeshSection toolset, a customisable workflow designed for the processing of archaeological 3D models of pottery (Košťál, Nosek, Macháček 2025).

A consistent spatial orientation of 3D ceramic models is essential for accurate morphometric analysis. This is particularly important for wheel-coiled vessels, which often lack the rotational symmetry of wheel-thrown pottery. Standardised alignment ensures that attributes such as height, diameter, and wall thickness can be measured consistently. The orientation process involves semi-automatic detection of the vessel base by identifying surface facets with normals perpendicular to the Z-axis. The centroid of these facets defines the base centre, which is translated to the origin of the 3D space. The vessel is then aligned so that its principal axis corresponds with the global Z-axis. The model is then translated so that this point coincides with the point zero for all axes of the 3D space. This standardised positioning allows for reliable comparison of geometric attributes and follows established practices in digital pottery analysis (Karasik, Smilanski 2008; Thér, Wilczek 2022).

Following the orientation process, the next step in the data extraction pipeline involved distinguishing between the interior and exterior surfaces of the vessel models. Although most conventional morphometric analyses of ceramics focus primarily on the external surface (e.g. Wilczek et al. 2014; Loftus 2022), identifying both surfaces is essential – not only for the automated calculation of interior and exterior volumes, but also for ensuring that wall thickness measurements are computed orthogonally to the surface curvature.

This distinction was achieved by analysing the orientation of individual mesh facets through the computation of angular deviations. Specifically, for each facet, the angle between the surface normal vector, the facet centre, and the highest point of the vessel (i.e. the apex along the Z-axis) was calculated. Facets facing outward (i.e. forming the vessel's exterior) were distinguished from inward-facing facets (defining the interior cavity) based on whether the resulting angle was acute or obtuse, allowing the mesh to be segmented accordingly.

After orientation, the next step in the morphometric pipeline involves the calculation of both interior and exterior volumes. These calculations are based on surface integration of waterproof meshes, obtained by methods described above. Meshes with holes were automatically closed based on identification of number of faces around an edge. Mesh volumes are computed by triangulating surface geometry into a manifold and integrating over the space enclosed (cf. Zapassky, Finkelstein, Benenson 2006).

A key step in the analysis was the extraction of planar cross-sections from the ceramic body, forming the basis for descriptors such as diameter, symmetry, and curvature. Sections were computed using the Möller–Trumbore ray–triangle intersection algorithm (Möller, Trumbore 1997), as implemented in Blender (Higgsas 2024; Košťál et al. 2025). Vertical sections were generated by rotating a slicing plane around the vessel's axis, creating 360 profiles at 1° intervals. Each profile (Z–Y plane) was then counter-rotated to a standard 0° orientation to ensure consistent comparison and overlay across all vessels.

To reduce asymmetry, all points with negative Y-values were mirrored onto the positive Y-axis, effectively converting the full profile into a single-sided

representation. This allowed for uniform analysis across vessels and preserved both inner and outer contours, enabling accurate wall thickness measurements along the vessel's height.

A key challenge in ceramic morphometrics is the accurate identification of meaningful body parts. In this study, vessel segmentation was based on geometric criteria from vertical profiles: the maximum diameter defined the shoulder, the narrowest upper part defined the neck, and a curvature inflexion marked the transition to the bottom. This allowed classification into four regions: rim/neck, shoulder, lower body, and bottom.

The inflexion point was detected algorithmically using angular deviation analysis. By converting profile curves into line segments, the angle between adjacent vectors revealed zones of maximum curvature change, approximating the second derivative (Nicholas 2004; Bonhomme et al. 2014). To reduce false positives, curves were smoothed and analysis restricted to the lower 5–15% of the profile. The identified point was then mapped back to the original curve by its index.

To calculate the wall thickness of each vessel with high spatial resolution, an iterative ray projection method was applied to each vertical cross-section. Unlike approaches based on direct horizontal slicing, this method aimed to measure the shortest distance between the inner and outer vessel walls, using the actual local orientation of the ceramic surface to ensure geometrical accuracy.

Wall thickness was measured by projecting rays from the inner profile curve, resampled at 0.1 mm intervals. Each point served as the origin of a ray oriented by the original surface normal of the 3D mesh, ensuring projections followed the wall's true curvature. If a ray intersected the outer surface, the distance was recorded; if not – due to mesh gaps – the point was excluded to avoid artefacts. This produced a high-resolution thickness profile for each vertical section.

Comparing wall thickness across vessels is challenging due to variations in size, shape, and preservation. To overcome this, Z-axis coordinates were normalised to a 0–100% scale, creating a dimensionless vertical framework. This allowed consistent comparison of shape and thickness, regardless of the vessel's original height or completeness.

For export, only points at integer percentages (0–100%) along the rescaled Z-axis were retained, except at the bottom, where all points were preserved due to its diagnostic importance. Each point was annotated with attributes including: Y and Z coordinates, maximum Z, object ID, cross-section angle, segment classification, internal/external volume, and wall thickness.

3.4.3 Particle orientation analysis

To gain insight into the forming techniques used in vessel manufacture, thin-section analysis focusing on the orientation of particles such as inclusions and pores was applied. Thin sections were extracted from three distinct vertical positions within each vessel and in two orientations relative to the vessel's vertical axis — tangential and perpendicular (72 in total; Fig. 40). The first sampling position was at or just below the rim, in an area where the wall profile followed an approximately straight line. The second section was taken at the point of maximum vessel diameter ('maximum belly'), and the third just above the base of the vessel wall. All thin sections were carefully oriented during preparation to preserve the original vertical orientation of the vessel – i.e. the top of the section corresponds to the top of the vessel. The prepared thin sections were then digitized using a Nikon LS 50 COOLSCAN IV ED film scanner.

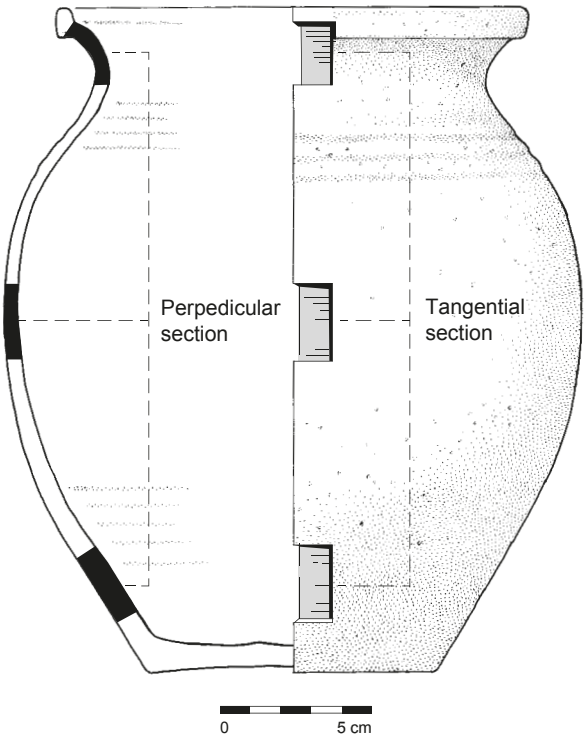


Fig. 40. Schematic representation of the sectioning strategy (inspired by Thér et al. 2015). Thin sections were taken from three vertically distinct levels of each vessel and prepared in two orientations relative to the vessel's vertical axis: tangential (following the vessel wall) and perpendicular (cross-cutting the wall). Graphics by M. Filip.

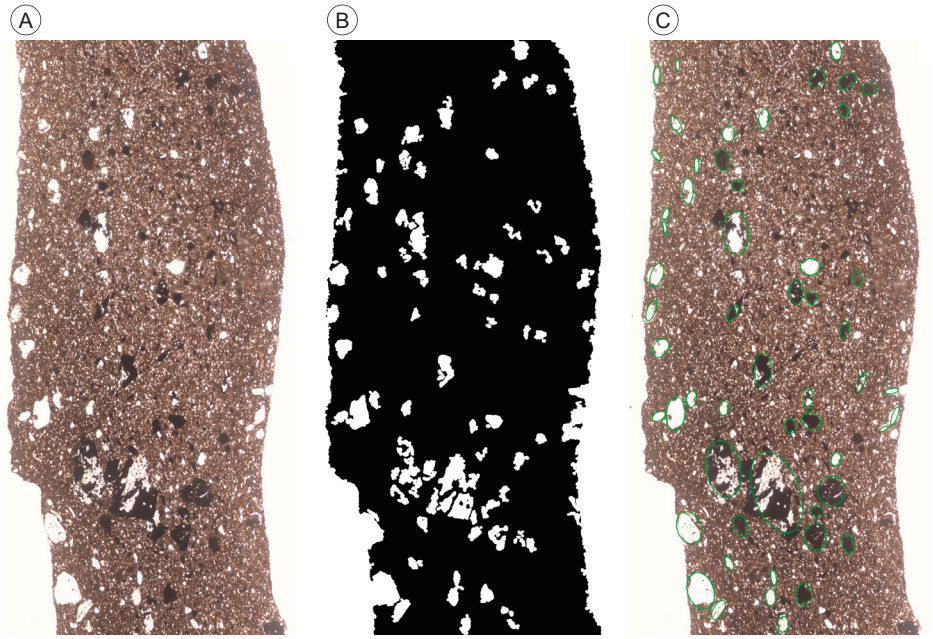


Fig. 41. Illustration of the ellipse identification workflow: A – raw input scan of the sample; B – processed binary image used for ellipse fitting; C – visual inspection and manual correction during post-processing. Author K. Slavíček.

High-resolution scans of thin sections (Fig. 41: A) were subjected to a multi-step digital image analysis pipeline aimed at detecting the orientation of inclusions and pores within ceramic matrices. The pre-processing phase involved converting each image to grayscale, followed by gamma correction and local contrast enhancement using CLAHE (Contrast Limited Adaptive Histogram Equalization) to correct for brightness inconsistencies caused by uneven thin-section thickness. After histogram normalization, the brightest and darkest pixel regions were masked out to emphasize relevant features such as pores, light minerals, or graphite temper. The resulting image was binarized and subjected to a morphological closing operation using an elliptical structuring element, which served to merge fragmented particle boundaries. The cleaned binary image was then inverted to meet the input requirements for OpenCV-based contour detection, with particles appearing as white objects on a black background (Fig. 41: B).

Following this pre-processing, the contours of individual particles were extracted and fitted with ellipses using the *cv2.fitEllipse* function. Ellipses with unsuitable dimensions or unrealistic axis ratios were excluded based on predefined size and shape thresholds. Any remaining issues related to ellipse identification – such as incorrect orientation, distorted shape, or missing ellipses – were manually corrected during the post-processing phase (Fig. 41: C). For each valid ellipse, geometric attributes such as centre coordinates, axis lengths, orientation angle, and axis ratio were recorded and exported into CSV files. These data were then statistically analysed using circular statistics. The angle of the major axis of each ellipse was normalized to a 0–180° range and transformed for bidirectional analysis. Kuiper's test was used to assess whether angle distributions significantly deviated from randomness. In cases where preferred orientation was detected, kernel density estimation (KDE) was applied to model the angular distribution and locate peaks representing dominant directions. Around each peak, the local directional consistency was quantified using circular standard deviation (CSD). The results were then visualized as polar plots displaying all preferred directions, scaled by their respective density peaks, and categorized by vessel ID and forming method.

3.4.4 Wall thickness

The wall thickness variability was assessed on 3D models of the vessels, which were digitally sectioned to obtain cross-sectional profiles. Each cross-section was processed by assigning individual wall thickness measurements to specific parts of the vessel, following the typology established by R. Procházka and M. Peška (2007): v3 (from the rim edge to the narrowest point of the neck), v4 (from the neck to the maximum diameter of the belly), and v6 (from the belly to the base). Variability in wall thickness may reflect the presence of grooves related to the forming technique, such as traces of coil junctions or shallow furrows resulting from

slow rotation on a potter's wheel. To minimize the influence of potential artificial outliers introduced during the rendering of measuring lines and subsequent wall thickness extraction, an interquartile range (IQR) method was applied for outlier detection and removal (following the procedure in Slavíček et al. 2023). For each vessel and individual segment, the first (Q1) and third (Q3) quartiles were calculated, and data points falling outside the range Q1 − 1.5 × IQR to Q3 + 1.5 × IQR were excluded. This filtering ensured a more robust and consistent representation of wall thickness variation across vessel parts. Following the data cleaning, for each vessel and its respective segments (v3, v4, v6), the mean wall thickness, standard deviation, and coefficient of variation were calculated. These parameters were subsequently used to quantify the variability within and between vessels.

3.4.5 Pot symmetry

The axial symmetry of experimentally produced vessels was assessed based on the coordinates of points located on the outer surface of each vessel. The primary hypothesis tested was that wheel-coiled vessels would exhibit lower axial symmetry compared to wheel-thrown ones. Within the 3D model, the vessel wall (bottom excluded) was evenly divided into one hundred horizontal levels along the vertical axis. For each of these horizontal slices, the standard deviation of the distances from the rotational axis was calculated using up to 360 points, corresponding to the number of vertical cross-sections. Due to imperfections in the model, not all slices contained the full 360 points. Additionally, the coefficient of variation was calculated for each defined section of the vessel wall.

3.5 Methodology of experimental pottery making

An important part of this book is the presentation and evaluation of the results of experiments carried out at several locations across the Vysočina Region. Until 2020, the experiments were conducted as part of the author's doctoral thesis at the Research Station of the Department of Archaeology and Museology, Faculty of Arts, Masaryk University in Panská Lhota near Jihlava. Between 2020 and 2022, they continued at the château in Žďár nad Sázavou as part of the *Chytrá ruka* (*Smart Hand*) project, which focused on preserving and presenting traditional crafts. Since 2023, experiments have been carried out at the Vlkovsko site of the Gallery and Museum of Vysočina in Havlíčkův Brod and at a private facility in Malý Beranov under the *Staré hrnce* (*Historical Pottery*) project. Some experiments involving wheel shaping and two pit firings were conducted in the years mentioned above at Šelmberk near Mladá Vožice in cooperation with *DANAR – Historická řemesla* (*Historical Crafts*). Throughout, the experiments have been conducted under the auspices of the UNESCO Chair of Museology and World Heritage at Masaryk University in Brno.

Since 2012, the experiments have involved a wide range of participants – archaeologists, archaeology students and those from related disciplines, both professional and amateur potters, and enthusiastic laypeople. Without their work, ideas, and dedication, it would not have been possible to carry out the project on such a scale.

The first findings from the experiments were published in 2014 (Bočková et al. 2014, 119–137), followed by a comprehensive study in 2017 (Těsnohlídková et al. 2017). The results were used more extensively in the monograph *Technologie výroby a archeometrické studium středověké keramiky* (*Production Technology and Archaeometric Analysis of Medieval Pottery*), published within the framework of the NAKI project, involving several academic institutions (Čapek et al. 2018). A separate study focused on firings of smoked pottery (Těsnohlídková, Slavíček 2021). The most detailed treatment is presented in the doctoral thesis (Těsnohlídková 2021). A more general overview of the experiments was later included in the monograph *Vrcholně a pozdně středověká keramika v českých zemích* (*High and Late Mediaeval Ceramics in Bohemia and Moravia*) (Těsnohlídková 2022b, 430–437).

The main stages of the experiment mirror the phases of the *chaîne opératoire* and, in its advanced stages, and seek to explore the interrelations between them. The experiments are based on the premise that their scholarly interpretation of archaeological data must rely as much as possible on specific excavation contexts. Experimental archaeology is also closely linked to ethnology and ethnoarchaeology, and it employs scientific analyses. The objective is to build a model of technological behaviour (Thér 2009, 27, 118; Santacreu 2014, 118–120).

This work reflects the originally broad intention to adopt a comprehensive approach to reconstructing the production process of High and Late Medieval pottery. Over time, the focus narrowed to the ceramic production of the 13th and early 14th

centuries in the Bohemian-Moravian Highlands. In connection with the GAČR project *Emergence of the High Medieval Pottery – the pottery kilns and their batches* (*No. 23-07863S*), the experiments increasingly aligned with the themes of this research. Earlier, more general data were used to design experimental models addressing the specific technological aspects of vessels found in the studied pottery kilns, as well as different firing strategies and firing traces observed on vessels from kilns reconstructed on the basis of archaeological remains or simplified structures.

Experimental archaeology was employed as one method of addressing questions regarding the sources and quality of clays matching the ceramic fabrics found in kilns in the Bohemian-Moravian Highlands, the replication of forming procedures, and the interrelation between forming techniques and raw material quality. Another issue explored was the use of graphite in ceramic fabrics during the 13th century – a practice that was already fading when the first kilns appeared, yet graphite ceramics are still clearly represented in two kiln contexts. The most extensive section of experimentation focused on firings. In addition to firings conducted in reconstructed kilns corresponding to two discovered types, several other types of firings were carried out in provisional or structureless conditions. The goal was to obtain ceramics whose properties corresponded to the goods of the observed period (13th and early 14th centuries) and to address the question of how ceramics were fired during the emergence of pottery kilns. Attention was given to the types of firing marks found on vessels as a result of controlled firings, as well as to the conditions necessary for the production of overfired ceramics, again with regard to ceramic fabric types, which may have played a decisive role in the choice of firing strategy.

The experiments are composed of both theoretical and practical parts. The theoretical part can be divided into preparatory and final phases. The preparatory phase involves evaluating archaeological, ethnographic, or historical sources, as well as scientific analyses. Subsequently, research questions are formulated and a model for the experiment is developed, including its documentation framework and the protocol for recording its execution. The final theoretical phase involves evaluating the outcomes: to what extent the experiment answered the research questions, and whether it was able to confirm or refute the proposed model in whole or in part. The concluding analysis also includes a comparison with the initial source material and a critical evaluation. This may result in a proposal to repeat the experiment or to modify the conditions under which it is conducted.

The practical part can be divided into field and laboratory experiments – one or both may be employed. The field component refers to a controlled field experiment as defined by R. Thér, characterized by the monitoring and recording of conditions and the intentional modelling of specific situations (Thér 2009, 191). A protocol is kept throughout the process, including photographic documentation and measurement records. The laboratory component addresses the research questions using modern instruments capable of simulating some of the techniques presumed to have been used in the past, in an effort to approximate original production methods.

The methodology of the experiments and the approach to documentation are largely original and based on the characteristics of the studied ceramic production and the research questions arising from archaeological analysis. Nonetheless, they also reflect methods used in other experimental projects, as well as direct cooperation with the Labor für Experimentelle Archäologie in Mayen (part of the Römisch-Germanisches Zentralmuseum in Mainz) from 2014 to 2016 (e.g., Hanning et al. 2014; Herdick 2024, 11–16).

In the context of ceramic raw materials and additions and the preparation of test samples, it was possible to draw on studies focused on the sources and quality of ceramic fabrics, as well as ethnographic research on pottery (Johnson et al. 1988, 403–414; Skibo, Schiffer, Reid 1989, 122–146; Buko 1990; Abbink 1999, 125–150; Dvorská 2001, 45–58; Wasilczyk 2007, 23–34; Nogaj-Chachaj 2007, 17–22; Auch 2007, 35–44; Stoksik 2007; Wasilczyk, Wasilczyk 2014).

Experimental forming, aimed at approximating techniques used for shaping ceramics in the 13th–14th centuries, is based on macroscopic analysis of archaeological ceramics and on analogies from ethnography, cultural anthropology, and ethnoarchaeology (e.g. Hołubowicz 1965; Bobrinskij 1978; Rye 1981; Rzeźnik 1995; Thér, Květina, Neumannová 2019; Roux 2019, 72–90; Djordjević, Carlton 2013; Jenjić 2018). Further inspiration was drawn from parallel experimental work (notably, Roux, Courty 1998, 748–749; Roux 2009, 2011, 2016; Rogier 2015; Macků 2016; Gunnarssone et al. 2021).

Attention was also paid to the construction and use of replicas of pottery kilns based on archaeological finds (e.g. Görler, Kohtz 1991, 291–298;

Gheorghiu 2014; Hanning et al. 2014, 422–440; Döhner, Herdick, Axtmann 2018, 71–83; Amicone et al. 2023). As analogies for the conducted experimental firings, data from long-term research in the UK since the 1950s were also used (Bryant 1973; Dawson, Kent 1984, 13–15; Dawson, Kent 1999, 168). Studies focusing not only on the technology of medieval and post-medieval ceramic firings but also on experimental firings simulating production processes from various prehistoric periods were utilised, including firings in open hearths or different types of pit kilns (Tintěra, Červinková, Červinka 1986, 273–292; Lüdtke, Dammers 1990, 321–326; Böttcher 1991; 1997, 87–93; Wasilczyk 2007, 28–33; Thér 2008, 129–142; 2009; Wasilczyk, Wasilczyk 2014, 31–42; Daszkiewicz, Wetendorf 2017, 7–13).

4

Kilns and their batches

The following chapter presents nine kilns from six sites (Fig. 42): three in Jihlava (one at U Skály Street, two at Křížová Street), one in Kostelec near Jihlava, two in Mstěnice, one in Žďár nad Sázavou, and two in Staré Město near Uherské Hradiště ('Na Kostelíku' and 'Na Dvorku'). As a comparative study, a separate chapter is devoted to pottery production in the Lower Austrian town of St. Pölten.

The ceramic assemblages were not evaluated with the same degree of detail. Some have already been published in greater depth, while others were not preserved in their entirety or were not fully accessible (particularly those from Mstěnice and Kostelec near Jihlava). In two cases, analysis was carried out not on the kiln contents themselves, but on assemblages recovered from stoking pits (Jihlava,

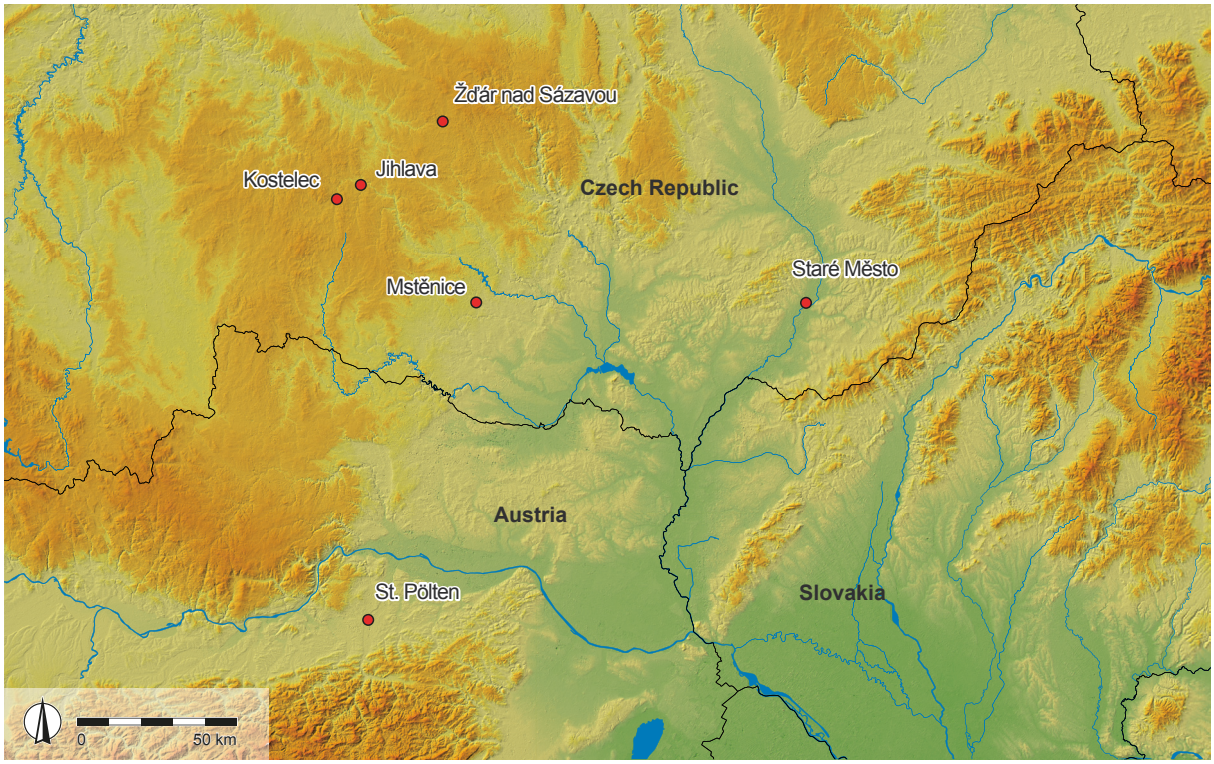


Fig. 42. Map of sites with analysed pottery kilns and teheir batches. Source: mapy.cz. Author M. Filip.

feature 925; Staré Město near Uherské Hradiště, feature 11). The most attention was devoted to the exceptionally large assemblage of preserved and reconstructed vessels from Jihlava – U Skály Street.

Each entry includes a description of the production feature in its settlement context, a characterization of the kiln remains and their contents, and a detailed analysis of the ceramic material. The morphological and metric properties of the vessels are examined alongside a comprehensive technological assessment (raw materials, forming, firing), based on interdisciplinary research.

4.1 Jihlava – U Skály Street

The site is located approximately 300 m northeast of the Church of St. John the Baptist, around which the earlier settlement developed (Fig. 43). This was most likely a market village, first mentioned in written sources in 1233 in a charter associated with the Želiv Monastery. At that time, the village was held by the Order of Teutonic Knights. This settlement, known as 'Old Jihlava', continued to exist even after the discovery of silver ores in the first half of the 13th century, when the main habitation shifted to the right bank of the river, eventually giving rise to the royal town in the present-day urban core (Pisková et al. 2009, 38–45; Kochan et al. 2021, 118–120). The ceramic assemblage from the kiln dates to the second half of the 13th century and the early 14th century.

The institut Archaia Brno carried out archaeological excavations in September 2019 as part of a rescue project prompted by the construction of a residential building (plot. No. 4563/7, today house No. 5876). The pottery kiln was exposed in the profile of the construction pit, which destroyed roughly 10% of the feature, specifically in its rear part (Těsnohlídek, Kochan 2019, 6).

All of the investigated features were documented in the profile of the construction pit. In addition to the kiln, the remains of a sunken-featured building of either industrial or domestic function were recorded, along with two postholes and a cultural layer containing medieval finds. About 5 m northeast of the kiln, a pit approximately 80 cm deep with a flat bottom and a stone debris leading toward the kiln was documented. Its ground plan could not be reconstructed, as in profile it measured 140 cm in width but extended northwest beyond the excavation area. The bottom was formed by a compact clayey layer with only a sparse assemblage of highly fragmented pottery dating to the 13th and 14th centuries (Těsnohlídek, Kochan 2019, 9).

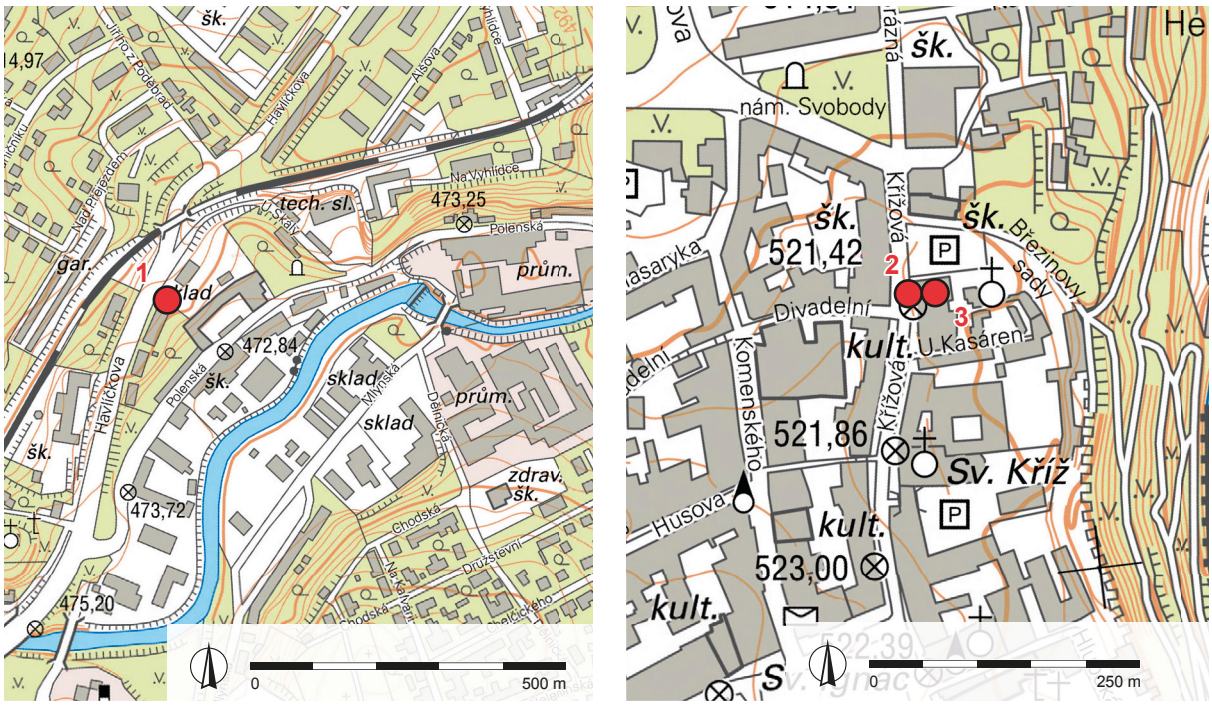


Fig. 43. Location of the kilns in Jihlava on the current map. 1 – U Skály Street; 2, 3 – Křížová Street. Source: mapy.cz. Graphics by M. Filip.

4.1.1 Kiln relic

The remains of a single-chamber kiln with a vertical to diagonal draft were cut into the sandy subsoil and oriented southwest–northeast (Fig. 44, 45). The walls rose concavely from the bottom and were preserved to a height of 60 cm, above which lay the kiln backfill. The interior surface was coated with a thin layer (2–3 cm) of grey fired clay, occasionally with small ceramic sherds adhering to it, which graded into strongly fired orange-red subsoil. The walls were thermally altered several centimetres deep from the surface of the kiln (locally up to 15 cm), with more intense burning around the stoking channel. Stones were apparently not used in the kiln construction. The bottom, measuring 124 × 118 cm, sloped gently toward the stoking channel and was cut into the sandy subsoil. No traces of a grate, central pillar, or any device separating the fire from the vessels were observed on the interior walls or on the floor (Těsnohlídek, Kochan 2019, 8–9).

The stoking channel had the form of a narrow oval flue, separated from the kiln floor by a small step. It narrowed towards the exterior: at its junction with the kiln, it measured about 80 cm in width and 40 cm in height, but at the furthest point investigated – toward the presumed stoking pit, approximately 26 cm from its junction – it narrowed to about 60 cm in width and only 6–10 cm in height. The fuel inlet was therefore relatively low. The kiln's stoking pit lay outside the excavation area and could not be explored.

Neither a loading opening nor a chimney was preserved, but one can be assumed in the rear part of the kiln opposite the stoking channel, as the wall here was not arched slightly inward as elsewhere along the circumference. The form of the superstructure remains uncertain. Only a few poorly fired lumps of daub were recovered, suggesting that the kiln may not have been topped by a permanent dome. Instead, once the batch (possibly mixed with fuel) was inserted, the structure may have been covered temporarily for firing (e.g. with turf, wattle, and clay), with a rear opening left for draught.

At the base of the kiln lay the already mentioned clay lining, overlain by a thin layer of charcoal. Above it followed a 40–50 cm thick fill of dark brown to red- and orange-fired sandy clay, densely mixed with ceramic vessels and their fragments. Pottery made up approximately 80–90% of the layer's volume. The vessels were overlain with unfired yellow-brown sandy clay, which contained only occasional small charcoal fragments. Within the fill, this clay appeared either as continuous patches or as irregular lenses. On top of it lay a thin black layer (approximately 1 cm), composed mainly of ash and minor sandy clay. The sequence was capped by a layer that gradually merged with the soil horizon, probably representing the original organic ground level, above which only early modern layers accumulated (Fig. 44, 45).

The assemblage was overwhelmingly dominated by ceramic material, ranging from complete or partially preserved vessels to sherds of varying sizes. A few smaller fragments of daub, occasionally with impressions, were also recovered; these may provide some clues about the kiln's superstructure. Several medium- to large-sized stones were present in the fill as well, but their low frequency and unsystematic spatial distribution preclude any meaningful contribution to reconstructing the kiln's form.

Charcoal fragments were also part of the fill and were analysed by R. Kočárová and P. Kočár. The samples contained fragments of beech (*Fagus*) and fir (*Abies*), with additional identifications of spruce (*Picea*), spruce/fir (*Picea/Abies*), and an indeterminate broadleaved tree (*Dicotyledonae*). The preserved material was insufficient to establish the relative proportions of these taxa. Nevertheless, the identified spectrum corresponds well to the natural woodland composition in the Jihlava region during the High Middle Ages. No evidence was found for selective use of particular fuel woods in the kiln (Kočárová 2021, 1–2).

The kiln fill was excavated in layers, corresponding to the stratigraphic units described above, and subdivided into several arbitrary levels in order to capture potential arrangements and concentrations of individual vessels within the kiln. Unfortunately, no vessel positions could be documented across the kiln, not even in its lower parts, that could be confidently interpreted as reflecting their placement during firing – for example, vessels arranged directly on the kiln floor. Additional evidence that the vessels were not in their original firing positions is provided by the concentration of several vessels within the stoking channel, including a jug 'wedged' into its excavated opening. Such placement would have effectively prevented the proper operation of the kiln during firing.

The brown to reddish-orange fired layer containing ceramic material was excavated in three arbitrary levels, separated mechanically from the top down: level A (15–20 cm thick), level B (15 cm), and level C (15 cm). In terms of content, only level C differed, as it contained a higher proportion of charcoal.

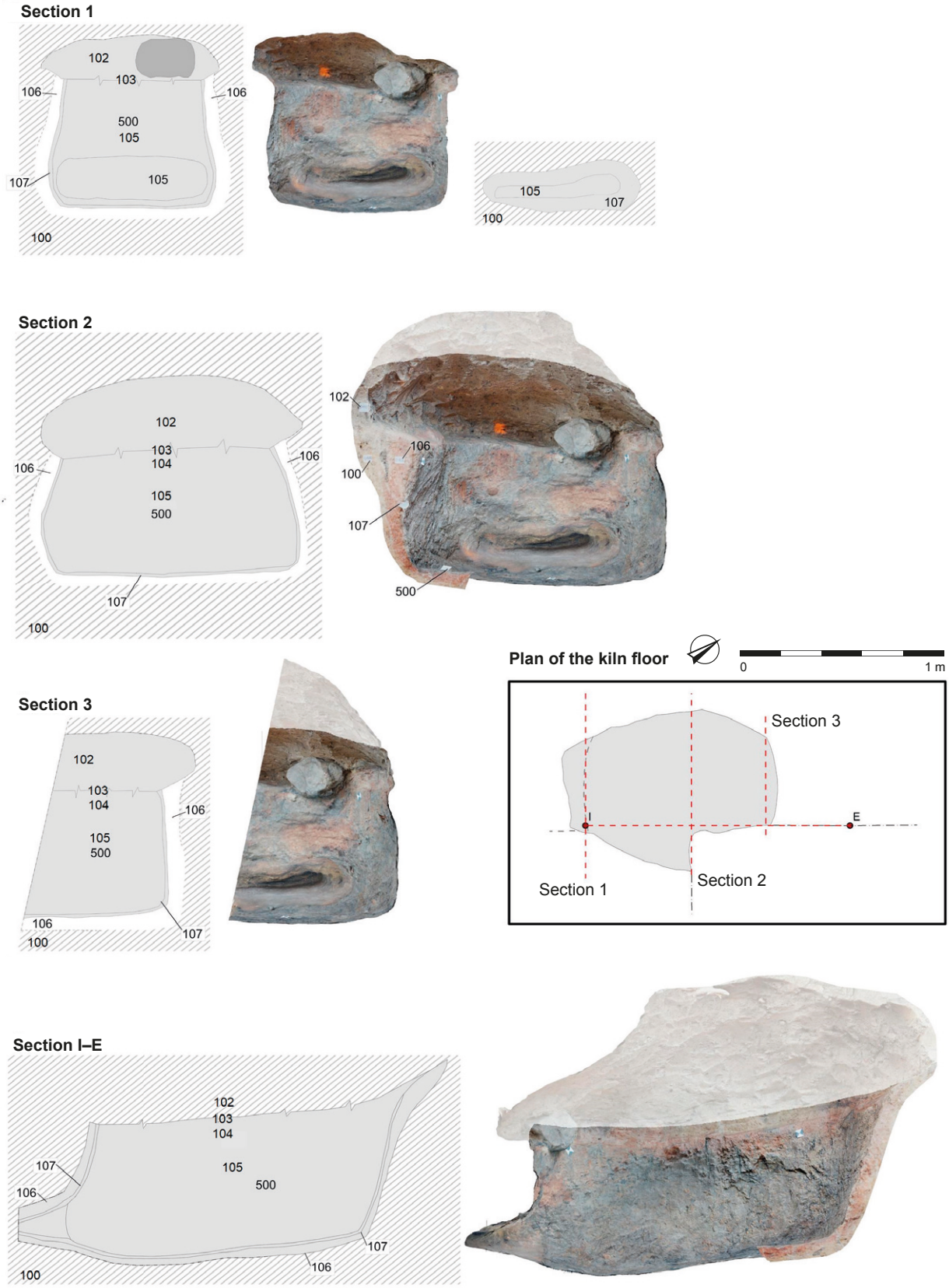


Fig. 44. Jihlava – U Skály Street. Plan and sections of the pottery kiln (feature 0500): 100 – subsoil; 102 – topsoil horizont; 103 – thin black layer of ash with sandy clay; 104 – unfired yellow-brown sandy clay; 105 – dark brown to red sandy clay with pottery vessels and fragments; 106 – subsoil – strongly fired, orange-red; 107 – kiln coating – grey fired clay with occasional pottery fragments or charcoal on the surface. After Kochan et al. 2021, 122, obr. 7, modified by M. Filip.

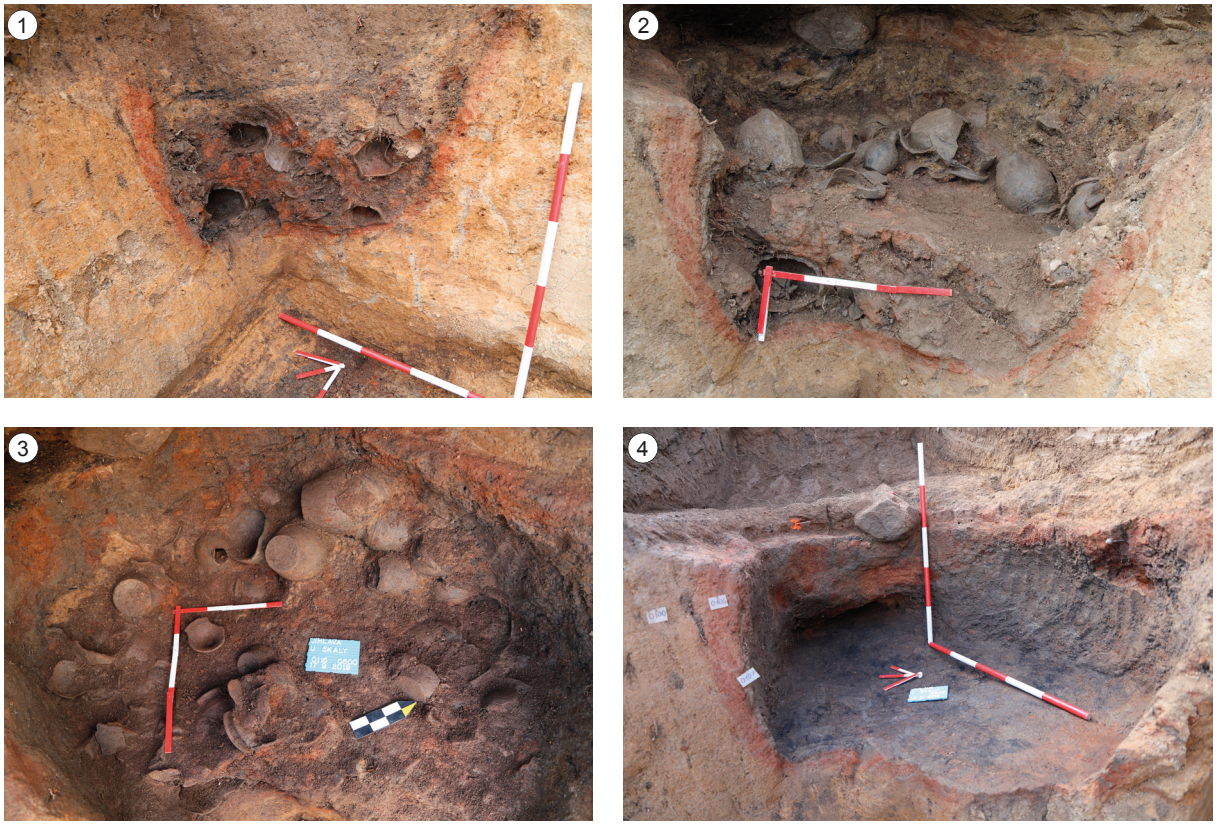


Fig. 45. Jihlava – U Skály Street. Photographic documentation: 1 – profile after cleaning the excavation context, showing damage to the feature; 2, 3 – vessels in the kiln fill, complete and partially preserved, mostly found along the kiln wall (layer 105); 4 – kiln relic after removal of vessels. Photo from the Archaia Brno archive.

In all three levels, concentrations of complete vessels were observed along the arched walls, where they were to some extent protected from pressure from above, whereas material in the central area was much more fragmented. In the rear part of the kiln, beneath the presumed chimney opening, ceramics were present in the lowest level (C) only. Vessels situated directly against the walls occasionally survived in one or two tiers, and in some cases traces of their destruction by being pressed against the kiln wall – i.e. by pressure from the central part of the fill – were visible. These vessels may represent the finds closest to their original positions during firing, although their orientation varied: they were preserved upside down, upright, inclined at different angles, or lying on their sides. In the lowest level (C), no vessel was recorded directly 'standing' on the kiln floor, not even near the edges. The batch may have collapsed either during firing or shortly after its termination, once it became apparent that the load was overfired. Subsequent infilling of the feature and later activities above it further contributed to the fragmentation of the assemblage. The relatively low frequency of ceramics directly above the floor may suggest that during firing the vessels were placed on some form of temporary grate creating stoking or draught channels, although no traces of such a structure have been preserved.

4.1.2 Morphology, typology and metric properties of pottery

The assemblage of vessels preserved within this kiln represents the largest set among all studied contexts. Ten vessels were recovered intact, though with minor defects. Several others had been damaged, most likely by pressure during the backfilling of the feature, yet their fragments were still found clustered together within the kiln. Due to the high density of ceramics, in some areas the fragments of multiple vessels were intermixed. Restoration of the batch was complicated by thermal damage: in some cases, reconstruction was impossible because the fabric, once overfired, disintegrated easily. To quantify the total number of vessels in the kiln, in addition to counting complete vessels, the number of preserved vessel bases was also taken into account.

A total of 50 complete vessels were reconstructed, comprising 36 cooking pots, six bell-shaped lids, four jugs, two atypical bottle-shaped vessels, one small flask, and one handled mug (Fig. 46–48). In addition, the kiln contained 27 bases with adjoining body sherds preserving more than half of the circumference, clearly representing further individual vessels. This raises the total number of vessels in the kiln to 77. Many

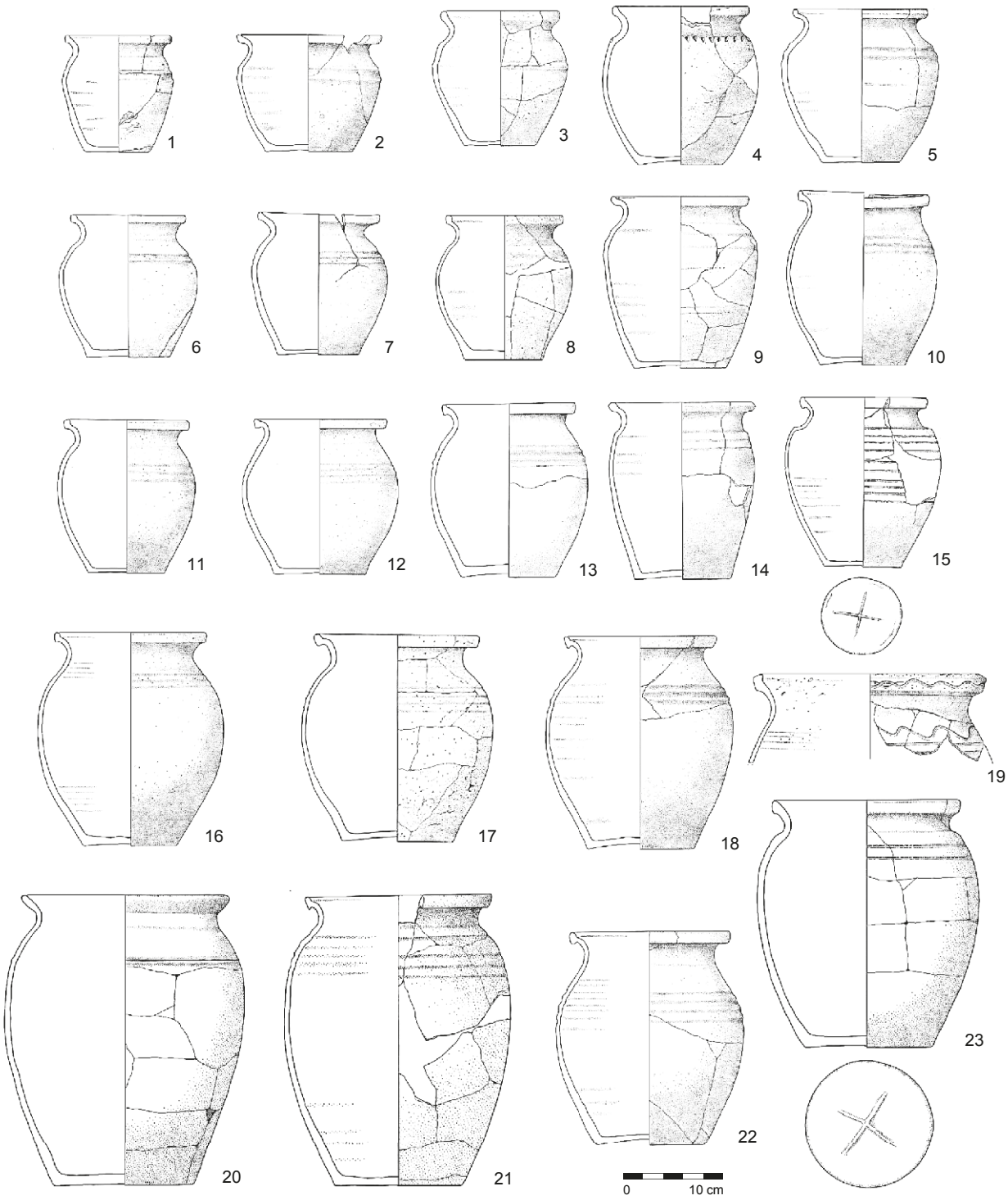


Fig. 46. Jihlava – U Skály Street. Pots, inv. No.: 1 – JiA40/2020-060; 2 – JiA40/2020-039; 3 – JiA40/2020-097; 4 – JiA40/2020-032; 5 – JiA40/2020-016; 6 – JiA40/2020-015; 7 – JiA40/2020-003; 8 – JiA40/2020-067; 9 – JiA40/2020-024; 10 – JiA40/2020-004; 11 – JiA40/2020-011; 12 – JiA40/2020-002; 13 – JiA40/2020-020; 14 – JiA40/2020-408; 15 – JiA40/2020-045; 16 – JiA40/2020-018; 17 – JiA40/2020-039; 18 – JiA40/2020-048; 19 – JiA40/2020-094; 20 – JiA40/2020-023; 21 – JiA40/2020-100; 22 – JiA40/2020-047; 23 – JiA40/2020-030. Drawings by S. Plchová.

of these bases likely belonged to vessels whose upper parts could not be reconstructed, primarily due to heavy fragmentation of the middle sections. These bases could plausibly be associated with the numerous rim and neck fragments present in the assemblage. In contrast, two upper parts survived intact: one bottle-shaped ewer and one jug, though their bases could not be rejoined. Substantial upper portions,

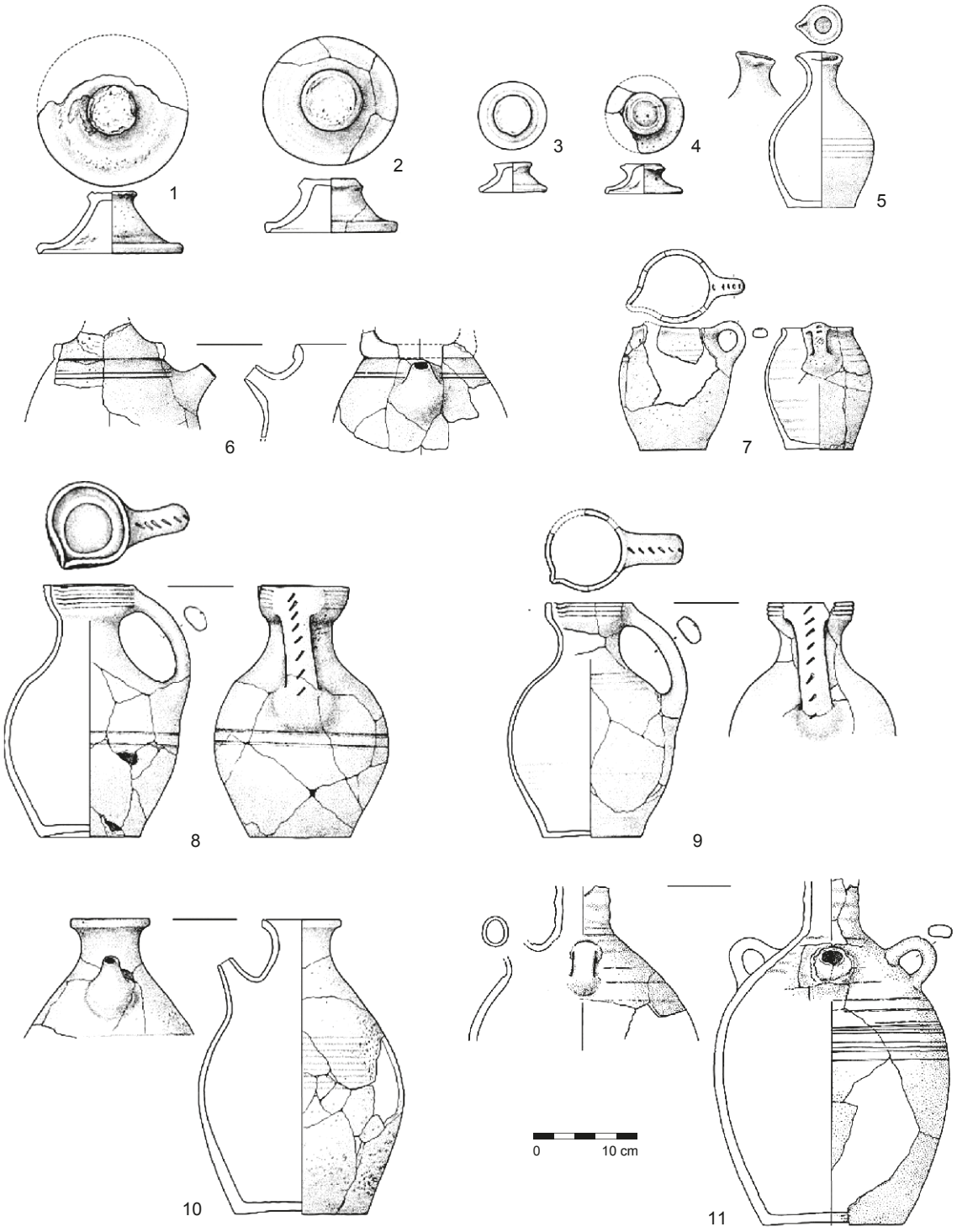


Fig. 47. Jihlava – U Skály Street. Vessels, inv. No.: 1 – lid, JiA40/2020-035; 2 – lid, JiA40/2020-037; 3 – miniature lid, JiA40/2020-010; 4 – miniature lid, JiA40/2020-009; 5 – flasks, JiA40/2020-001; 6 – stirrup-handled ewer, JiA40/2020-099; 7 – pot with handle, JiA40/2020-057; 8 – jug, JiA40/2020-019; 9 – jug, JiA40/2020-021; 10 – bottle-shaped pitcher ewer, JiA40/2020-020a; 11 – bottle/bottle-shaped ewer, JiA40/2020-031. Drawings by S. Plchová.





Fig. 48. Jihlava – U Skály Street. Photograph of a representative group of vessels. 1 – various forms; 2 – pots. Photo by K. Těsnohlídková.

including rims and handles, were also preserved from two stirrup-handle ewers. The material is stored in the depository of the Vysočina Museum in Jihlava.

Some additional vessels were identified only fragmentarily and were likely never present in the kiln as complete vessels. These include two further spouts of stirrup-handle ewers, each with a surviving portion of the body and rim and, in one case, the beginning of a stirrup handle; a base fragment of a storage jar; fragments of two handles probably belonging to a jug and a stirrup-handle ewer; and the rims of two more bottles.

When analysing and quantifying the ceramic material from the kiln batch, it is necessary to take into account the heterogeneous character of the assemblage. One component consists of complete or near-complete vessels. Another is represented by smaller, more fragmentary material, mainly body sherds that could not be refitted to specific vessels. In addition, isolated fragments are present, which must have entered the kiln already as sherds. Unfortunately, these two categories of fragmentary material cannot be clearly distinguished. Owing to the large volume of ceramic material, this batch was therefore documented and analysed in the greatest detail.

Pots

The dimensions of the pots were examined on 33 vessels that could be measured in full. These included ten pots made of sandy paste, ten of graphite-tempered paste, six of fine-mica paste, and seven of overfired fabrics. Pot size was evaluated on the basis of absolute measurements, proportional ratios, and calculated volume. These parameters were analysed primarily in relation to ceramic paste, and in some cases also in connection with rim type.

The primary parameters examined were the pot's overall height, rim diameter, and base diameter. The height of the measured pots ranged from 12.5 to 31 cm, with two-thirds falling between 16 and 22.5 cm. The tallest and shortest pots in the assemblage were both made of graphite-tempered paste. Within both the graphite and sandy groups, vessels occur across the full range of heights. The smallest sandy pot measured 13 cm, while the largest reached 30 cm. The diameters of pot bases ranged from 6.5 to 15 cm. Graphite-tempered pottery displayed the widest variability, with 50% of bases measuring between 8 and 9.5 cm. Sandy pottery showed base diameters most often between 7 and 11.5 cm (16 cases), with only a single example reaching 13 cm.

The graphite-tempered vessels thus display the greatest variability in base size. Rim diameters, in contrast, were less variable, suggesting that rim size was more closely controlled during production than base size. Overall, rims range between 11–21 cm, with 66% falling between 12–14 cm. Roughly one quarter of the pots had rims of 12–12.5 cm, and another quarter around 14 cm.

Among the sandy-paste vessels, 12 out of 16 had rims between 11 and 14 cm, while the remaining four measured 15.5 cm, two between 17–17.5 cm, and the largest between 19–19.5 cm. Graphite-tempered pots included four with rims of 14 cm, three with smaller diameters between 11–13 cm, and another three with larger rims measuring 16 cm, 19 cm, and 21 cm.

	No. of pots	W	H	D	Z
Index range	33	0.30–0.54	0.83–1.29	0.5–1.33	1.56–2.12
Mean	33	0.44	0.11	0.82	1.76
Median	33	0.43	0.12	0.78	1.74

Tab. 3. Jihlava – U Skály Street. Pot index values.

For the jar-shaped vessels, indices W, D, H, and Z were calculated (Tab. 3), and their relation to ceramic paste groups was also examined. In terms of the W index (the position of the vessel's maximum diameter), vessels with a moderately placed maximum diameter (egg-shaped profiles) predominate, though forms with a low-set bulge (barrel-shaped profiles) are also represented. The maximum vessel diameter is usually located in the upper third of the body, occasionally closer to the midpoint. Among the graphite-tempered vessels, there is a clear tendency toward a higher placement of the maximum diameter, and most of them fall into the egg-shaped category. In contrast, sandy-paste ceramics are more frequently represented by barrel-shaped forms.

The index (D) describing the degree of the body's convexity is predominantly high, with only five vessels falling into the category of moderately swollen forms. The sandy-paste pots exhibit consistently high swelling. Graphite-tempered ceramics are more variable in this respect, encompassing the entire spectrum of swelling represented in the assemblage.

The index of bulbosity (H) also highlights the greater morphological variability of the graphite-tempered group. The degree of convexity ranges from low to high, with graphite-tempered pots represented across the full scale. In contrast, the sandy-paste group falls predominantly within the middle to lower values. Both the mean and median of the sandy vessels fall within the medium category; four pots are classified as low, while two reach the lower threshold of the 'high' category. The mean and median index Z values, which represent the narrowing of the vessel bases, correspond to a medium degree.

The internal volume of 24 pots was measured using 3D scan data. For incomplete vessels, the forms were virtually reconstructed to calculate volume. The smallest measured pot held 0.65 l and the largest 8.5 l. Both were produced from graphite-tempered paste with a JH rim type. Five additional graphite-tempered pots had capacities of 1.5 l, 2 × 1.6 l, 2.4 l, and 6.5 l. Eleven sandy-paste pots yielded volumes of 0.8 l, 0.9 l, 1 l, 1.6 l, 1. 75 l, 2 × 3.1 l, 3.6 l, 3.8 l, and 7.2 l. The remaining six vessels, made from overfired paste, measured 0.9 l, 1.35 l, 1.9 l, 2 × 3.7 l, and 4.4 l. Two main size clusters can be observed: around 1.5 l (7 cases, ±0.2 l) and around 3.4 l (6 cases, ±0.3 l).

Generally, vessels from sandy and graphite-tempered pastes occurred across a broader size spectrum, although the sandy-paste group shows a stronger tendency toward dimensional standardization. In terms of vessel shape, sandy paste pots are also more closely related, reflecting an effort to produce specific types.Within the sandy paste assemblages, several recurring types can be identified: two main groups cluster around volumes of approximately 1.3–1.7 l and 3.1–3.7 l. These vessels are similar in shape and decoration, with closely matching dimensions. By contrast, graphite-tempered pots tend to be more individual in both form and size.

In total, 208 rim sherds of cooking pots were classified (counting reconstructed pieces), representing eight rim types (Fig. 49). The distribution is as follows: VN (46%), V (33%), S (10%), VZ (6%), JH (5%), J (3%), P (1%), and OV (1%).

Among the rims preserved over more than 15% of the vessel's circumference – 52 cases, or 25% of the total – 35 were preserved or reconstructed to half or more of the original rim. These two categories are most likely to represent vessels from the kiln's final batch. Within them, five rim types occur, with proportions nearly identical in both categories: VN (48%), V (25%), VZ (13%), JH (8%), and S (6%).

The analysis suggests that the rim types J, P and OV (a total of 11 pieces) represent intrusions, which entered the kiln in already highly fragmented form, most likely from its immediate surroundings. Their paste does not differ from the rest of the assemblage: ten fragments were from sandy paste, and the only identified rounded rim was graphite-tempered. Among the rims preserving more than 15% of the original vessel circumference, a correlation can be observed between graphite-tempered paste and rim type JH, while graphite-tempered fabrics are notably absent among rim type V.

Decoration was recorded on 33 pots. It is likely that all vessels were originally decorated, although on some examples the decoration is only faintly visible – either executed shallowly or partially erased due to surface damage from overfiring. The decoration consists mainly of incised, continuous, and relatively shallow grooves and lines. In 30 cases, the decoration is highly uniform: 1–4 shallow continuous grooves, placed in 80% of cases above the vessel's maximum diameter and in 20% around the bulge, extending both upwards and downwards. Within this group of incised decoration, one graphite-tempered pot stands out by its distinct execution: in addition to a base mark, it bears nine sharply cut incised lines (Fig. 46: 15).

Another type of decoration was recorded on two sandy-paste pots, both with rim type VN.4.9. One was ornamented with a single row of incisions running

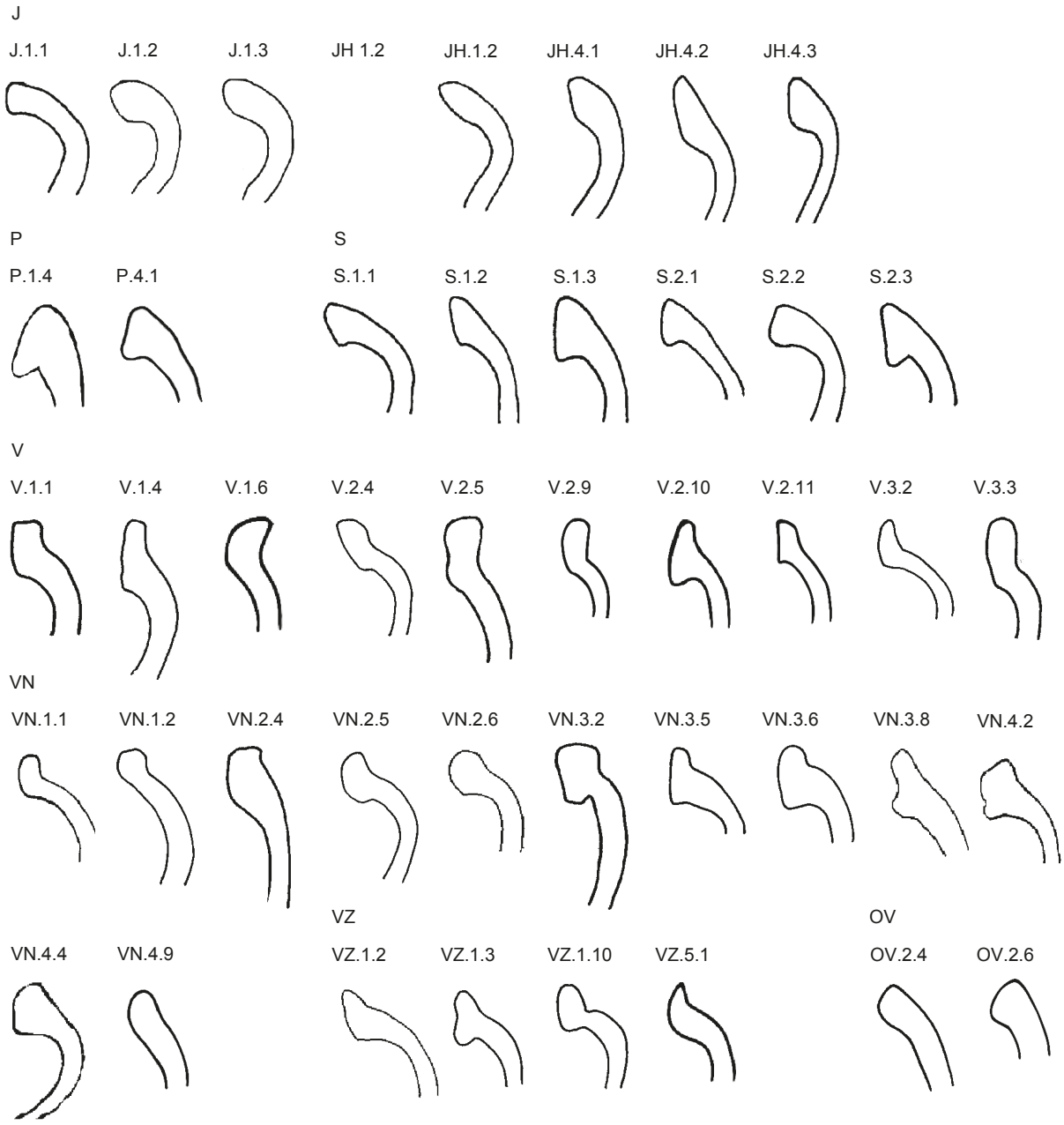


Fig. 49. Jihlava – U Skály Street. Rim types of pots. Drawings by K. Těsnohlídková.

across the sharp transition between the bulge and the neck (Fig. 46: 4). The other was decorated with a plastic rib placed at the vessel's maximum diameter.

Among the fragmentarily preserved material, one sherd belonged to a pot decorated with a wavy line on a rim of type V.1.6, accompanied by another wavy line below the neck and at least two additional grooves on the bulge. This represents the only decorated rim preserved in the assemblage.

For the sandy-paste pots (15 in total), decoration consists of three grooves above the bulge in eight cases, two grooves in two cases, and four grooves in three cases. Among the eight graphite-tempered pots, five carry two grooves (four above the bulge, one encircling it), two have a single groove, and one has four grooves above the bulge. No clear correlation with rim type could be observed.

An atypical form, also classified among the pots, was a small mug with a handle. It was not included in the overall analysis and is described here separately (Fig. 47: 7). It was reconstructed to approximately 60% of its original form, although the process was hindered by significant overfiring of the paste. The mug featured a small handle with five notches on its

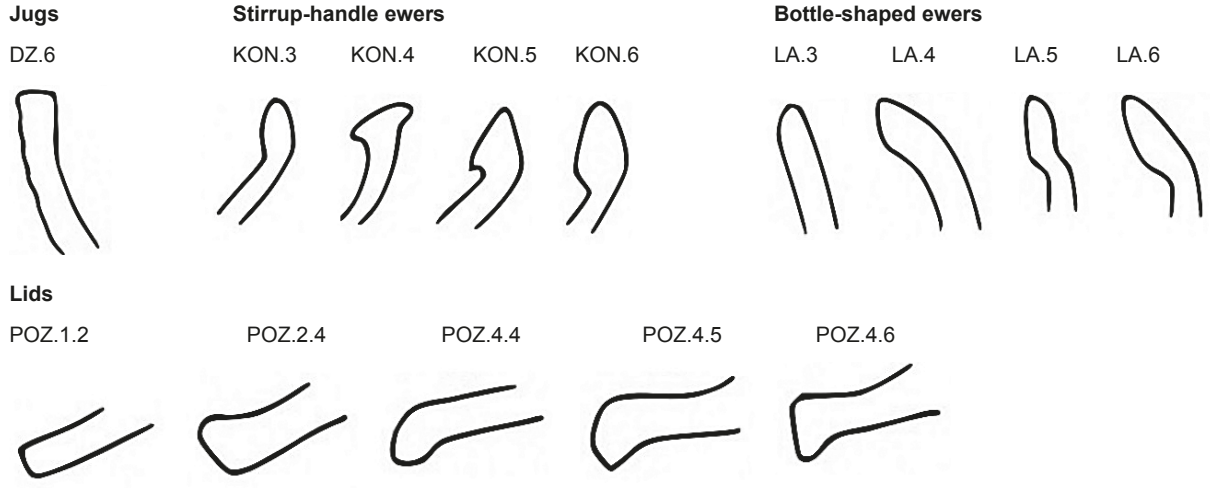


Fig. 50. Jihlava – U Skály Street. Rim types of other vessels. Drawings by K. Těsnohlídková.

upper part and was decorated with three grooves at the point of handle attachment. The rim also seems to have preserved the remains of a spout. The body, almost without a neck, extended directly from a rim of type OV.2.4. (Fig. 49). The vessel measured 12.5 cm in height, with a base diameter of 6.5 cm and a rim diameter of 7 cm.

Lids

After pots, the second most numerous vessel type in the assemblage are conical lids, represented by six examples: four standard-sized lids and two miniature ones. Of the larger lids, two were made of graphite-tempered paste and two of overfired paste (Fig. 47: 1, 2). The graphite-tempered lids have rim types POZ.2.4 and POZ.4.4 with rim diameters of 14 cm and 14.5 cm, while the overfired examples bear rims of types POZ.4.5 and POZ.4.6, measuring 13.5 cm and 12 cm respectively (Fig. 50). The two miniature lids are both overfired (Fig. 47: 3, 4). One has a POZ.4.6 rim with a diameter of 7 cm, and the other a POZ.1.2 rim with a diameter of 6 cm (Fig. 50).

Jugs, bottle-shaped ewers and flasks

The assemblage contained five jugs, three of which are nearly complete (Fig. 47: 8, 9), while the remaining two are preserved to more than half of their original form. Their heights range from 21.5 to 24 cm, with base diameters between 8.5 and 11 cm and rim diameters of approximately 8 cm.

All jugs represent a single morphological type and are made of sandy paste. Each has a single handle decorated with incised notches and a spout incorporated into the rim, set at a 90° angle to the handle. The rims correspond to type DZ.6, with grooves applied just below the rim (Fig. 50). The jug bodies are also typically decorated with shallow grooves, although their number and placement vary slightly between examples.

Two large bottle-shaped ewers were reconstructed fully and a third one was reconstructed in the upper part. These vessels with narrow necks and tubular spouts represent two types – without handles and with two handles. The first bottle-shaped ewer was made from sandy paste, and has a smooth body. The handleless bottle has a relatively slender body and was completely reconstructed (Fig. 47: 10). The vessel has a rim of type LA.4 and its body is decorated with 6–7 grooves placed between the maximum diameter and the spout, which interrupts the vessel wall just below the neck (Fig. 50). Its total height is 27.5 cm. The second bottle of this type was reconstructed only in its upper half; its paste was heavily overfired, preventing more complete restoration of the form.

The bottle-shaped ewer with two handles has a globular body and relatively thick walls (Fig. 47: 11). It was largely reconstructed, with only fragments of the mid-bulge and the rim termination missing. The vessel is equipped with two small handles set at the same height as the spout, i.e. between the maximum diameter and the neck. The neck is narrow and cylindrical. The preserved height of the vessel is 34 cm, though the original may have been 1–3 cm taller. It was made from graphite-tempered paste.

A distinctive form is found in a small flask with a spout, measuring 15.5 cm in height (Fig. 47: 5). It belongs to the sandy paste. The rim, type L.3, is slightly deformed and slanted to one side. Two additional small rim fragments most likely also belonged to bottles; their necks measured 7 and 8 cm in diameter and were preserved only fragmentarily (LA.5, LA.6); (Fig. 50).

Stirrup-handle ewers and storage vessels

Several additional vessels were preserved only fragmentarily. These include four spouts of stirrup-handle ewers, with rims and, in some cases, the junction with the stirrup handle still preserved (Fig. 47: 6). Another fragment, a broader handle with three notches, also most likely belonged to this vessel type. In two cases, larger portions of the upper halves of the jugs were preserved, and it is possible that they were originally complete when deposited in the kiln (Fig. 47: 6). For three examples, the rim diameter could be reconstructed, ranging between 11–13.5 cm, corresponding to rim types KON.3–6 (Fig. 50).

A storage vessel was represented by a base fragment with a maximum dimension of 12 cm and a reconstructed rim diameter of 25 cm, with a wall thickness of 2 cm. This piece was made of paste containing medium- to coarse-grained graphite (KT G2).

4.1.3 Ceramic technology

Ceramic paste

Based on macroscopic examination of the paste, six ceramic classes were distinguished. Two represent overfired material: class X1 (overfired) and class X2 (heavily overfired), where the precise identification of the paste was distorted by firing conditions, and therefore they were separated as distinct categories. In addition, a sandy paste (P) and a paste with a higher content of fine mica (S) were identified. However, archaeometric analyses demonstrated that the sandy and micaceous groups are compositionally identical and cannot be rigorously distinguished. The limitations of macroscopic classification lie not only in the restricted observation of vessel surfaces or fractures, but also in the inherent subjectivity of assessment. The distinction of a micaceous group was mainly based on the more visible concentration of mica on the surface of some vessels, which could be accentuated by particular firing conditions or surface abrasion. In reality, the overall mica content was similar across samples from both the originally sandy and micaceous classes. Consequently, they were merged into a single sandy class (P). Graphitic ceramics occur in two variants: G1, with only a few grains and predominantly fine graphite dispersed in the matrix, and G2, with a medium to high abundance of graphite particles.

The distribution of ceramic pastes was quantified on the basis of individual vessels. In the kiln assemblage, 59% of the vessels were produced from sandy paste (P) and 18% from graphitic paste (G1), with class G2 being represented only by a single fragment of a storage vessel base. The remaining 23% of the material showed traces of overfiring (X1: 10%; X2: 13%). The high proportion of overfired ceramics, often fragmented and crumbling, points to damage to the batch by heat stress, but also to the rather low quality of the raw clays used. These non-loessic 'brick clays', characterised by low clay-mineral content and high quartz abundance, tend to disintegrate at higher firing temperatures (around and above 1000°C) rather than to sinter.

Among the complete cooking pots, 53% were made of sandy paste, 28% of graphitic paste and 19%

ID	Inv. No.	Vessel type	Ceramic class
1	JiA40/2020/73	Stirrup-handle ewer	Sandy
2	JiA40/2020/99	Stirrup-handle ewer	Sandy
3	JiA40/2020/31	Ewer	Graphitic
4	JiA40/2020/20	Ewer	Sandy
5	JiA40/2020/38	Jug	Sandy
6	JiA40/2020/40	Jug	Overfired
7	JiA40/2020/63	Jug	Sandy
8	JiA40/2020/89	Storage vessel	Graphitic-coarse
9	JiA40/2020/35	Lid	Overfired
10	JiA40/2020/36	Lid	Overfired
11	JiA40/2020/57	Mug	Overfired
12	JiA40/2020/32	Pot	Sandy
13	JiA40/2020/39	Pot	Graphitic
14	JiA40/2020/45	Pot	Graphitic
15	JiA40/2020/46	Pot	Sandy
16	JiA40/2020/56	Pot	Graphitic
17	JiA40/2020/62	Pot	Overfired
18	JiA40/2020/64	Pot	Overfired
19	JiA40/2020/67	Pot	Micaceous
20	JiA40/2020/94	Pot	Graphitic
21	JiA40/2020/96	Pot	Sandy
22	JiA40/2020/97	Pot	Sandy
23	JiA40/2020/100	Pot	Sandy
24	JiA40/2020/111	Pot	Sandy
25	JiA40/2020/408	Pot	Sandy
26	-	Daub	-

Tab. 4. Jihlava – U Skály Street. Samples selected for analyses.



Fig. 51. Jihlava – U Skály Street. Photographs of analysed samples. Photo by K. Slavíček.

of overfired paste. Of the lids, two were produced from graphitic paste and four from overfired paste. Jugs, bottle-shaped ewers, and stirrup-handled ewers were predominantly manufactured from sandy paste, with the exception of one bottle-shaped ewer with a spout and two handles, which contained a graphitic component. The small flask was made of sandy paste, while the handled mug was so heavily overfired that its paste could not be reliably identified. A storage vessel fragment represented class G2, characterised by a medium to high content of graphite particles.

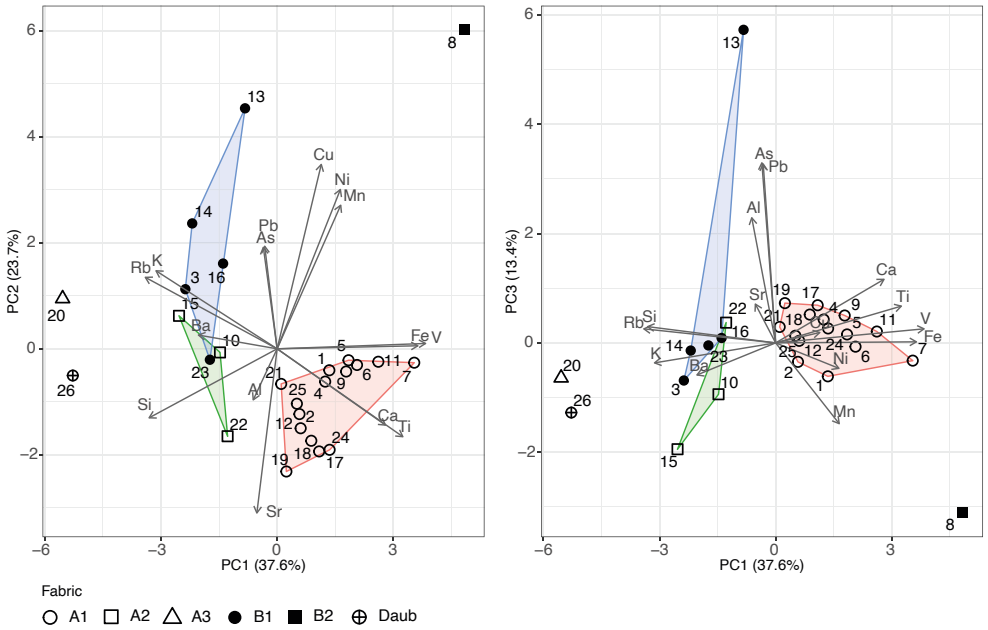
A total of 25 ceramic samples and a sample of kiln daub were subjected to archaeometric analysis (Tab. 4; Fig. 51). Based on petrographic characteristics (Appendix 1-A, 2-A) and chemical composition, the material was classified into two fabric fabrics (Tab. 5): fabric A (sandy-micaceous) and fabric B (graphitic-gneiss tempered). Fabric A comprised 19 samples, which were further subdivided into subfabrics A1 (15 samples), A2 (3 samples), and A3 (1 sample). Fabric A1 is characterised by generally elevated concentrations of Ca, Ti, Fe, and V,

Fabric	Sample IDs	Fabric description	Fabric features	Mineralogical markers	Chemical markers	Possible sources
A1	1, 2, 4, 5, 6, 7, 9, 11, 12, 17, 18, 19, 21, 24, 25	Sandy-micaceous, clayey matrix low in silt particles, sand tempered	Weakly parallel microstructure, bimodal grain size distribution, matrix heterogeneous, iron rich bands, iron-rich clay pellets	Granitoid, gneiss, chlorite and sillimanite gneiss, mylonite; quartz, alkali feldspar, plagioclase, biotite, chlorite, muscovite, amphibole, sillimanite, garnet, zircon	Within fabric A: generally elevated Ca, Ti, Fe, V	Freshwater Tertiary clays, Quaternary alluvial clays, or limonitized tectonic clays all within close vicinity of the site
A2	10, 15, 22	Sandy-micaceous, non tempered silty clay, natural admixture of sand	Weakly parallel microstructure, unimodal grain size distribution, matrix homogeneous, iron-rich clay pellets	Granitoid, gneiss, chlorite and sillimanite gneiss, mylonite; quartz, alkali feldspar, plagioclase, biotite, chlorite, muscovite, amphibole, sillimanite, garnet, zircon	Within fabric A: lower Ca, Ti, Fe, V; slightly elevated Si, K	
A3	20	Sandy-micaceous, non tempered silty clay, natural admixture of sand	Weakly parallel microstructure, unimodal grain size distribution, matrix heterogeneous, clay mixing, iron-rich clay pellets	Granitoid; sericite, quartz, alkali feldspar, plagioclase, muscovite, biotite, amphibole	Within fabric A: Elevated Rb	
B1	3, 13, 14, 16, 23	Graphitic-gneiss tempered, fine graphite within matrix	Weakly parallel microstructure, unimodal grain size distribution, iron-rich clay pellets	Graphitic gneiss (some with garnet), graphitic metaquartzite, granitoid; graphite, quartz, chlorite, alkali feldspar, plagioclase, biotite, garnet, sericite, muscovite, amphibole, sillimanite	Afinity to A2 with elevated Pb, As, Cu, Ni, Mn	Clay – probably the same as fabric A; Temper – Graphitic gneiss and metaquartzite within Jihlava ore district
B2	8	Graphitic-gneiss tempered, fine graphite within matrix	Weakly parallel microstructure, unimodal grain size distribution, iron-rich clay pellets		Compared to B1: elevated Cr, Mn, Fe, Cu; lower Si, Al	

Tab. 5. Jihlava – U Skály Street. General description of fabrics (petrographic markers are listed in order of relative abundance).

	Fabric A1				Fabric A2				Fabric A3	Fabric B1				Fabric B2	Daub
	mean	sd	min	max	mean	sd	min	max	mean	mean	sd	min	max	-	-
SiO_2	60.8	2.1	57.9	64.9	66.1	0.5	65.5	66.4	65.4	64.1	2	61.9	66.3	56.9	71.9
Al_2O_3	21.3	0.8	20	22.5	19.5	0.9	18.5	20.2	22.6	21.6	0.8	20.6	22.4	19.5	17.2
Fe_2O_3	12.1	2.1	8.6	16	8.7	0.6	8	9.1	6.4	8.3	1	7	9.8	16.2	5.2
K_2O	3.2	0.1	3	3.4	3.4	0.3	3	3.7	3.7	3.6	0.2	3.3	4	3.8	3.7
CaO	1.3	0	1.3	1.4	1.1	0.1	1.1	1.3	0.9	1.2	0.1	1.1	1.3	1.4	1
TiO_2	1.1	0.1	1	1.2	0.9	0	0.9	1	0.7	0.9	0.1	0.8	1	1.1	0.8
V	164	8	152	181	129	4	125	132	106	136	17	121	159	194	108
Mn	522	123	429	945	450	53	413	510	311	732	396	407	1330	10100	628
Ni	50	5	41	55	43	1	42	44	47	57	6	51	67	83	37
Cu	45	5	38	54	39	2	37	41	42	59	10	46	70	90	38
As	13	1	12	15	13	1	13	14	12	22	15	15	48	11	13
Rb	146	11	113	159	175	20	156	195	232	190	13	178	212	135	186
Sr	89	12	64	104	80	16	70	99	73	80	14	68	103	50	91
Ba	609	163	308	980	606	177	483	809	969	619	11	602	630	551	891
Pb	33	3	28	37	32	2	31	34	29	78	88	38	235	27	31

Tab. 6. Jihlava – U Skály Street. Summary of the chemical composition of fabrics (major oxides in wt %, trace elements in ppm).



Graph 1. Jihlava – U Skály Street. Principal component analysis of chemical composition – scatter plots of the first component against the second and third. The diagram shows the chemical homogeneity of fabric A1, the affinity between fabrics A2 and B1, and the close relationship between fabric A3 and daub. Author K. Slavíček.

whereas fabric A2 shows reduced concentrations of these elements combined with slightly increased Si and K levels. Fabric A3 is distinguished by elevated Rb content (Tab. 6; Graph 1). In addition to chemical composition, the grain-size distribution of the non-plastic fraction served as a further subdivision criterion. Fabric A1 displays a bimodal distribution, while fabrics A2 and A3 are unimodal. The graphite-tempered fabric was divided into subfabrics B1, which corresponds to macrogroup G1 (5 samples) and B2 corresponding to G2 (1 sample). Fabric B2 is characterised by lower Si and Al contents, combined with markedly elevated concentrations of Cr, Mn, Fe, and Cu.

The main group (fabric A1; Fig. 52: A, B) was manufactured from highly clayey raw material with a very low silt content (typically around 1%, occasionally 5%, and rarely up to 10%). The clay is heterogeneous; on orthogonal sections, this heterogeneity appears as thin iron-enriched bands (Fig. 53: A). Iron nodules are characteristic of all analysed samples and occur in frequent to abundant quantities. Microstructure is often weakly parallel with planar and vugh shaped voids. The temper consists of sand (fine, medium, and often coarse, occasionally even pebbles; grain size of ~100–3500 µm, avg. 600 µm), forming 10–20 vol.% of the fabric (occasionally up to 30 vol.%). The sand grains are typically angular to sub-angular (or sub-rounded) and are rich in micas, primarily biotite (common to abundant), while muscovite is present only rarely or in trace amounts. Quartz, alkali feldspars, and plagioclase are present in balanced amounts, mostly common, occasionally frequent. Polycrystalline quartz is less common, typically occasional. Among accessory minerals, chlorite or relics of chlorite are most frequent, generally occurring occasionally. Amphiboles are present in only three samples, most notably up to occasional abundance in sample 34. Sillimanite was identified in two samples in rare amounts, as was garnet. Zircon occurred in trace amounts in two samples. The lithic component of the temper is dominated by granitoid fragments, ranging from common to abundant (Fig. 53: B). Gneiss and chlorite-bearing gneiss occur in approximately half of the samples, at occasional to common quantities (Fig. 53: C). Sample 33 contained abundant sillimanite gneiss, while sample 40 contained a fragment of mylonite. Notably, samples 36 and 40 also contained remnants of unburnt plant tissue.

Fabric A2 represents a variant of the main sandy-micaceous fabric, produced from a more silty clay with a natural addition of sand, which is predominantly angular to sub-angular (Fig. 52: C, D). The non-plastic fraction constitutes 15–25 vol.%. Average grain size is 400 µm, while the largest grains are up to 2200 µm. In contrast to Fabric A1, the clay

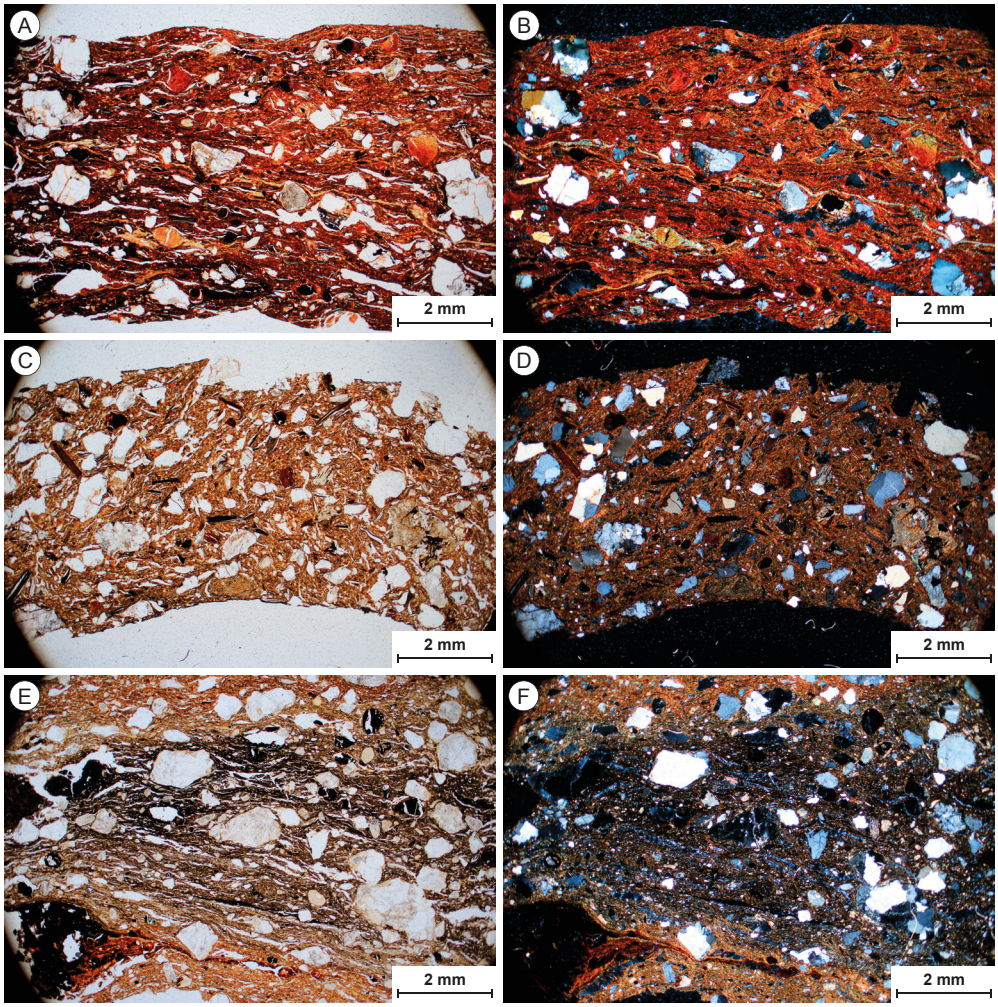
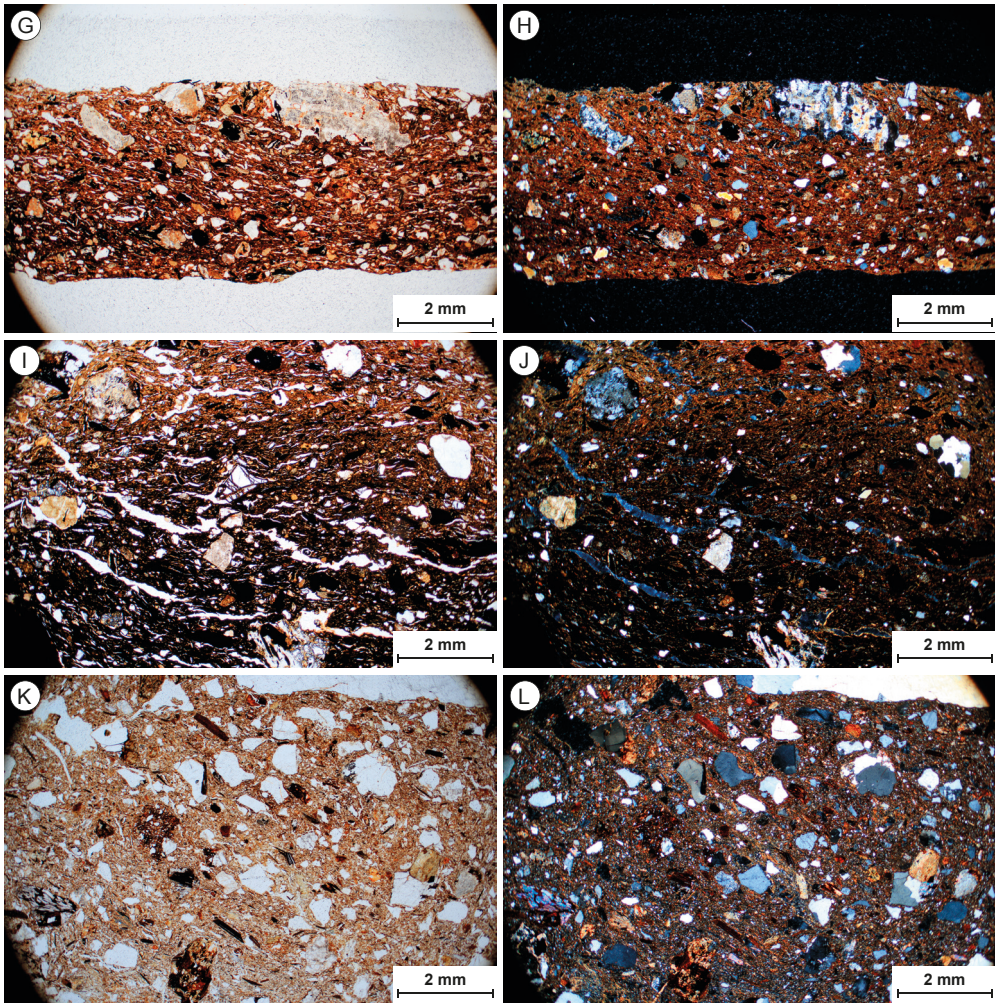


Fig. 52. Jihlava – U Skály Street. Overview of the microstructure of each fabric in PPL (left) and XPL (right): A, B – sandy-micaceous fabric A1, sample 6; C, D – sandy-micaceous fabric A2, sample 22; E, F – sandy fabric A3, sample 20; G, H – graphitic fabric B1, sample 14; I, J – graphitic fabric B2, sample 8; K, L – daub (kiln coating), sample 26. Author K. Slavíček. Fig. 52 continues on the next page.

matrix is homogeneous. Petrographically, however, the mineralogical composition is identical to fabric A1. Fabric A3 (sample 35) is distinguished by a heterogeneous matrix (Fig. 52: E, F), indicating in this particular case mixing of multiple clay sources (Fig. 53: D). The sample contains a natural addition (15 vol.%) of silty and sandy grains, which are angular to sub-angular in shape (avg. grain size is 400 µm, the largest grains up to 1800 µm). Petrographically, it differs from the other Fabric A subgroups primarily in mica and feldspar content: biotite is present only in trace amounts, while muscovite occurs occasionally. Alkali feldspars and plagioclase are also less abundant, occurring occasionally. Notably, sericite is present in frequent amounts. Petrographically and chemically, this sample closely resembles the reference sample of daub from the pottery kiln (Fig. 52: K, L), and it was most likely manufactured from the same raw material.

The graphitic-gneiss tempered fabrics' (B; Fig. 52: G–J) non-plastic fraction (15–20 vol.%) exhibits a unimodal grain-size distribution, with the exception of one sample (13). Graphite flakes, including relatively fine particles (as fine as 20 µm), are present and appear to have been naturally incorporated into the clay. However, intentional tempering cannot be entirely excluded. In addition to frequent to abundant graphite flakes, quartz is present at common to frequent levels (occasional in fabric B2). Polycrystalline quartz, alkali feldspars, and plagioclase occur occasionally to commonly. Micas are less abundant, with muscovite being rare and biotite occasional. Accessory minerals include chlorite (common to frequent in samples 3, 16, 23), sericite (common to frequent in samples 3, 16), garnet (occasional to common in samples 3, 8, 13, 23), amphiboles (rare), and sillimanite (rare, identified in sample 14). Lithic fragments (of size up to 3500 µm, while 400 µm on



average) are dominated by graphitic gneisses, including the garnet-bearing variety (Fig. 53: E–G), both generally occurring at common frequencies, though not in all samples. Occasional graphitic metaquartzite was identified in sample 23. In addition to graphitic rocks, non-graphitic gneisses, metaquartzites, and occasional granitoid fragments are also present. Plant tissue remains were preserved in samples 3, 16.

The interpretation of the clay source and tempering materials corresponds to that proposed for the material from the Křížová Street kiln, given the close petrographic similarities. The sandy-micaceous fabrics A1–A3 appear to have been derived from local Moldanubian crystalline bedrock, reflecting the geological setting of the Jihlava region. Iron-rich nodules, ubiquitous in the pastes, support the hypothesis of a common clay source rich in weathered ore-related material. In contrast, the graphitic-gneiss tempered fabrics (B) suggest exploitation of deposits containing graphitic gneiss and metaquartzite, which occur naturally in the Jihlava ore district. However, unlike the Křížová kiln assemblage, where graphite is more evenly distributed in the matrix, in this case its occurrence is sparser, mostly restricted to lithic fragments.

Forming

For 36 cooking pots with completely preserved profiles, traces of forming were examined in relation to the vessel as a whole. Surface traces on the interior body were observed in 34 cases, and traces on the exterior of the base in 31 cases; in the remaining examples, the traces were strongly abraded. Across all two main paste groups, the forming traces were identical, suggesting that the vessels were produced using the same technique.

All bases preserve evidence of fine sandy dusting, usually accompanied by marks around the perimeter of the base. These indicate either the attachment

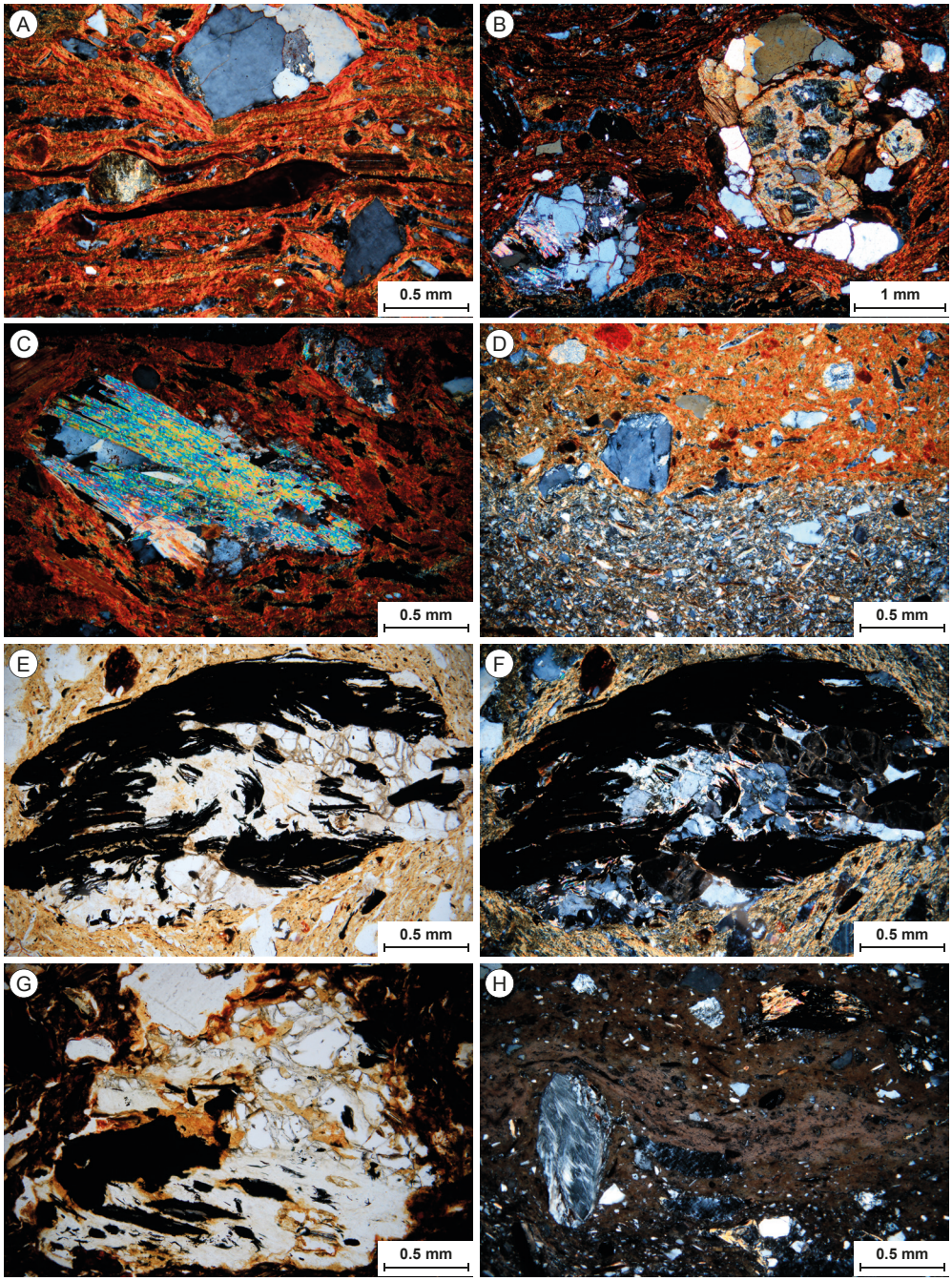


Fig. 53. Jihlava – U Skály Street. Photomicrographs highlighting key features in detail: A – heterogeneous matrix of fabric A1 with layers of iron-rich fine-grained material (sample 25, XPL); B – granitoid rock fragments used as temper (fabric A1, sample 7, XPL); C – gneiss fragment (fabric A1, sample 5, XPL); D – mixing of two clay types: less silty clay in the upper half and more silty clay in the lower half (fabric A3, sample 20, XPL); E, F – graphitic gniess with garnet in sample 23 (fabric B1) shown in PPL (E) and XPL (F); G – graphitic gneiss with garnet in sample 8 (fabric B2, PPL); H – optically inactive matrix and sillimanite grain in sample 15 (fabric A2). Author K. Slavíček.

of the base edge to the forming surface or its removal from the surface after completion, either by scraping or by light cutting around the perimeter (Fig. 54: 1d, 2b, 3b, 4–7). In some cases, the effect of an apparently inserted base is visible, but this is actually a result of the combination of surface dusting and attachment of the base edges (Fig. 54: 5, 6). Occasionally, imprints of wooden boards were also documented (Fig. 54: 8) On three bases, identical potters' marks were identified (Fig. 46: 15, 23; 55: 10c). The mark, in the form of a cross, was preserved on one base made of graphitic paste with rim type S.1.2, on another graphitic pot with rim type VN.3.2, and, though worn, also on a graphitic pot with rim type JH.4.3.



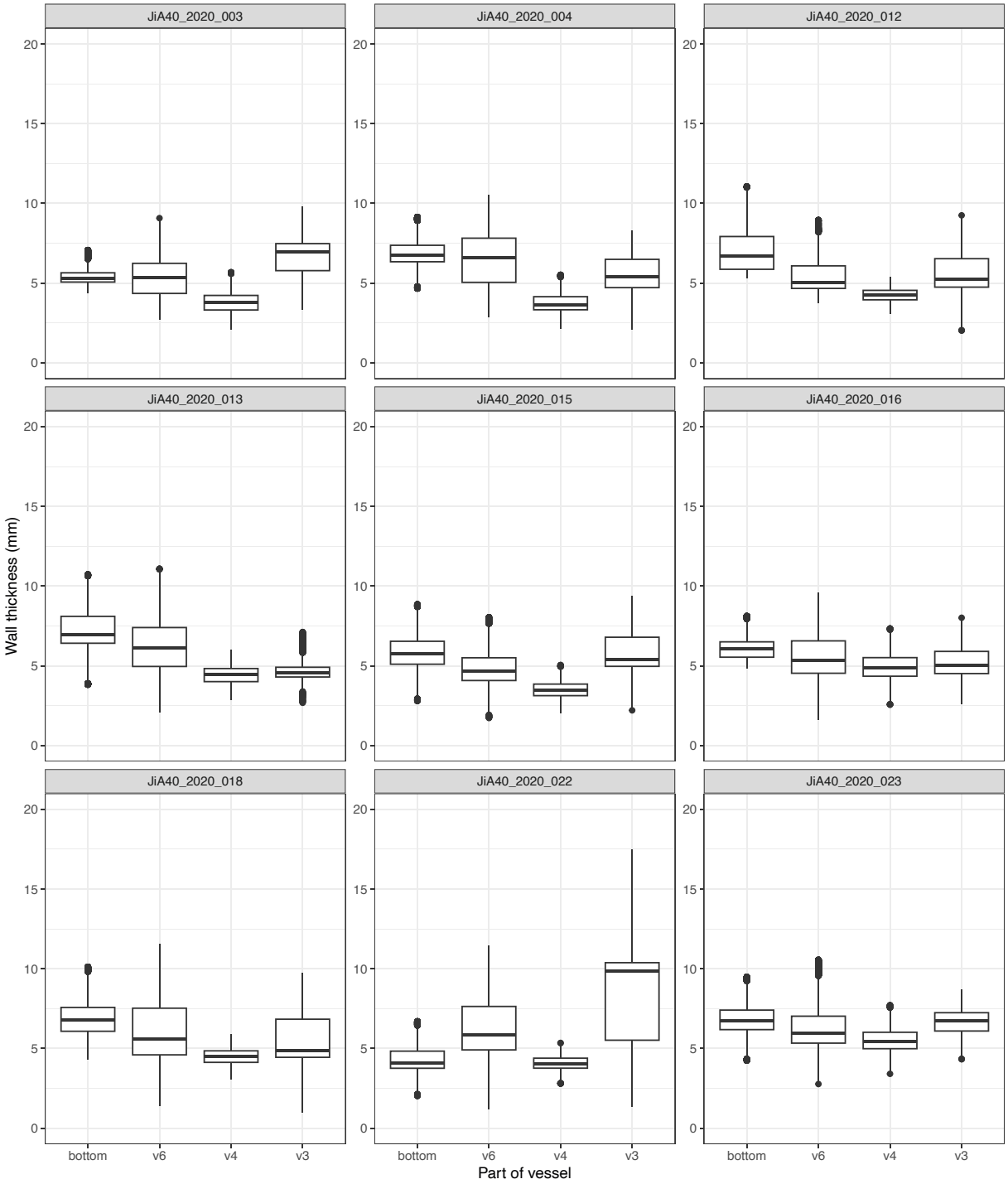
Fig. 54. Jihlava – U Skály Street. Technological traces, inv. No.: 1 – pot damaged by firing – crack in wall, torn rim, deformation of shape, bottom with traces of sand dusting and detachment/cutting from the forming board at the periphery (Ji40/2020-003); 2 – pot with deformed neck after firing, bottom with traces of sand dusting and detachment/cutting from the forming board at the periphery (Ji40/2020-013); 3 – pot with rim and wall torn during firing, bottom showing traces of sand coating and peripheral attachment (Ji40/2020-016); 4 – pot bottom with traces of sand dusting and detachment/cutting from the forming board (Ji40/2020-034); 5 – pot with heavily overfired clay, bottom showing sand dusting traces and peripheral attachment (Ji40/2020-012); 6 – pot bottom with sand dusting and peripheral attachment (Ji40/2020-025); 7 – pot with overfired clay, slightly undulated inner wall, traces of sand dusting and detachment/cutting from the forming board at the bottom periphery (Ji40/2020-046); 8 – impression of a wooden board on pot bottom (Ji40/2020-087); 9 – bottle-shaped tangard with two handles and spout, traces of coils at the vessel mouth (Ji40/2020-031). Photo by M. Košťál, V. Nosek, K. Slavíček.

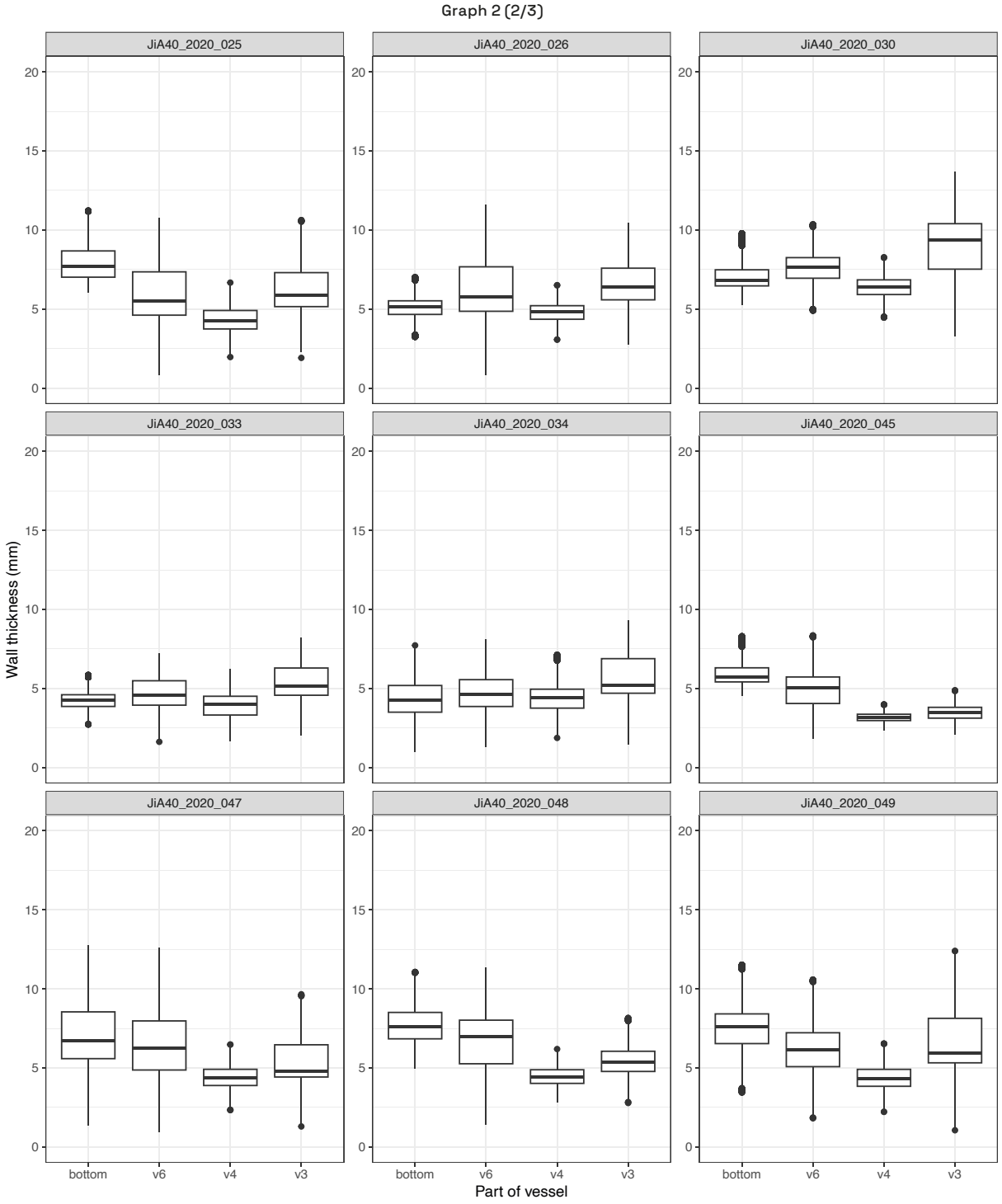


Fig. 55. Jihlava – U Skály Street. Technological traces, inv. No.: 1 – rings and grooves (Ji40/2020-075); 2 – lines, depressions, and vacuoles (Ji40/2020-133); 3 – lines and vacuoles (Ji40/2020-122); 4 – wall indentation caused by manipulation shortly after production (Ji40/2020-185); 5 – minor depressions and lines (Ji40/2020-103); 6 – depressions, lines, vacuoles, depressions (Ji40/2020-060); 7 – depressions covered by rings, lines (Ji40/2020-066); 8 – grooves, lines, depressions covered by rings (Ji40/2020-061); 9 – depressions covered by rings, lines, vacuoles on the inner wall, bottom with sand coating and peripheral traces from detachment from the forming board (Ji40/2020-059); 10 – grooves and lines on the inner wall, bottom with potter's mark, sand coating, and peripheral attachment traces (Ji40/2020-045); 11 – heavily overfired clay with trace of a small vessel placed on the inner side of the bottom, worn traces of rings and coils, bottom showing sand coating (Ji40/2020-064). Photo by M. Košťál, V. Nosek, K. Slavíček.

The wall thickness of the cooking pots (measured just above the first pronounced coil) up to the vessel rim ranged between 2 and 6 mm. In 20 cases, the thickness was between 3–4 mm; in 11 cases, between 4–5 mm; three vessels were thin-walled (2–3 mm); and two were thicker and less regular (4–6 mm). No correlation with paste type was observed. The thinnest walls (2–3 mm) occurred in graphitic pastes, while vessels made from micaceous pastes, which are morphologically more slender, typically showed wall thicknesses of 4–5 mm. Thickness appears instead to reflect vessel size, as the two thickest examples (4–6 mm) corresponded to the two tallest pots in the assemblage. Near the base, at the level of the first pronounced coil, the walls could reach up to 10 mm. 3D scanning of 23 vessels and subsequent data analysis enabled a more detailed assessment of wall-thickness variability (Graph 2;

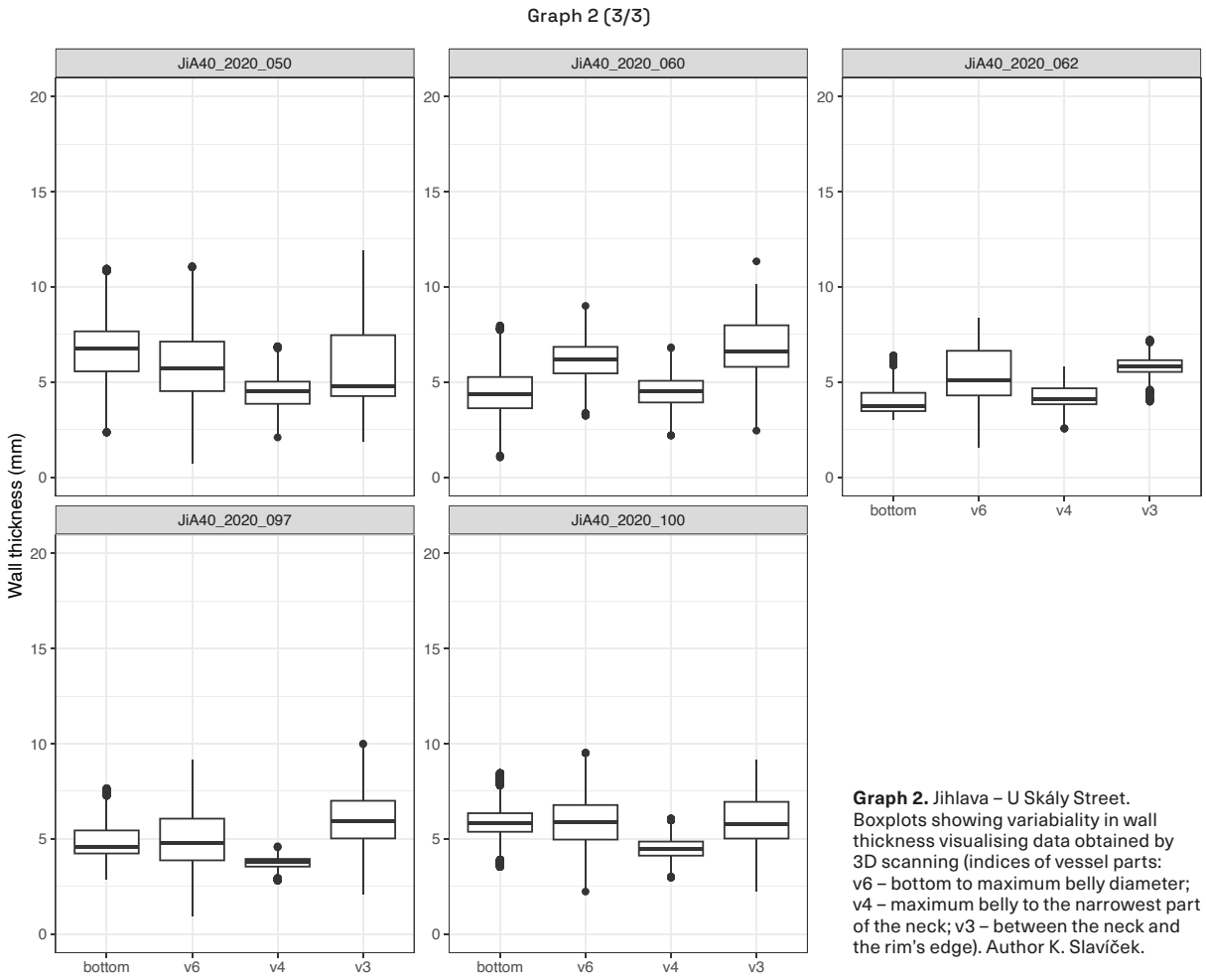
Graph 2 (1/3)





Appendix 3-A). The lowest variability was observed in the area of the maximum diameter (coefficient of variation 8.8–15.4%), whereas values were slightly higher near the base and the rim (13.6–28.7% for v6 and 11.4–33.3% for v3, respectively). Some vessels displayed consistently thin walls with very low deviations (JiA40/2020-13, 16, 33, 34, 45, 62).

The majority of traces are, as usual, preserved in the lower parts of the inner walls, which were more difficult to reach during final surface treatment. Two-thirds of the pots bear a pronounced coil above the base, extending 2–5 cm from the inner surface of the bottom (Fig. 55: 8 ,11a). In the lower body, depressions or concentric ridges frequently occur, in



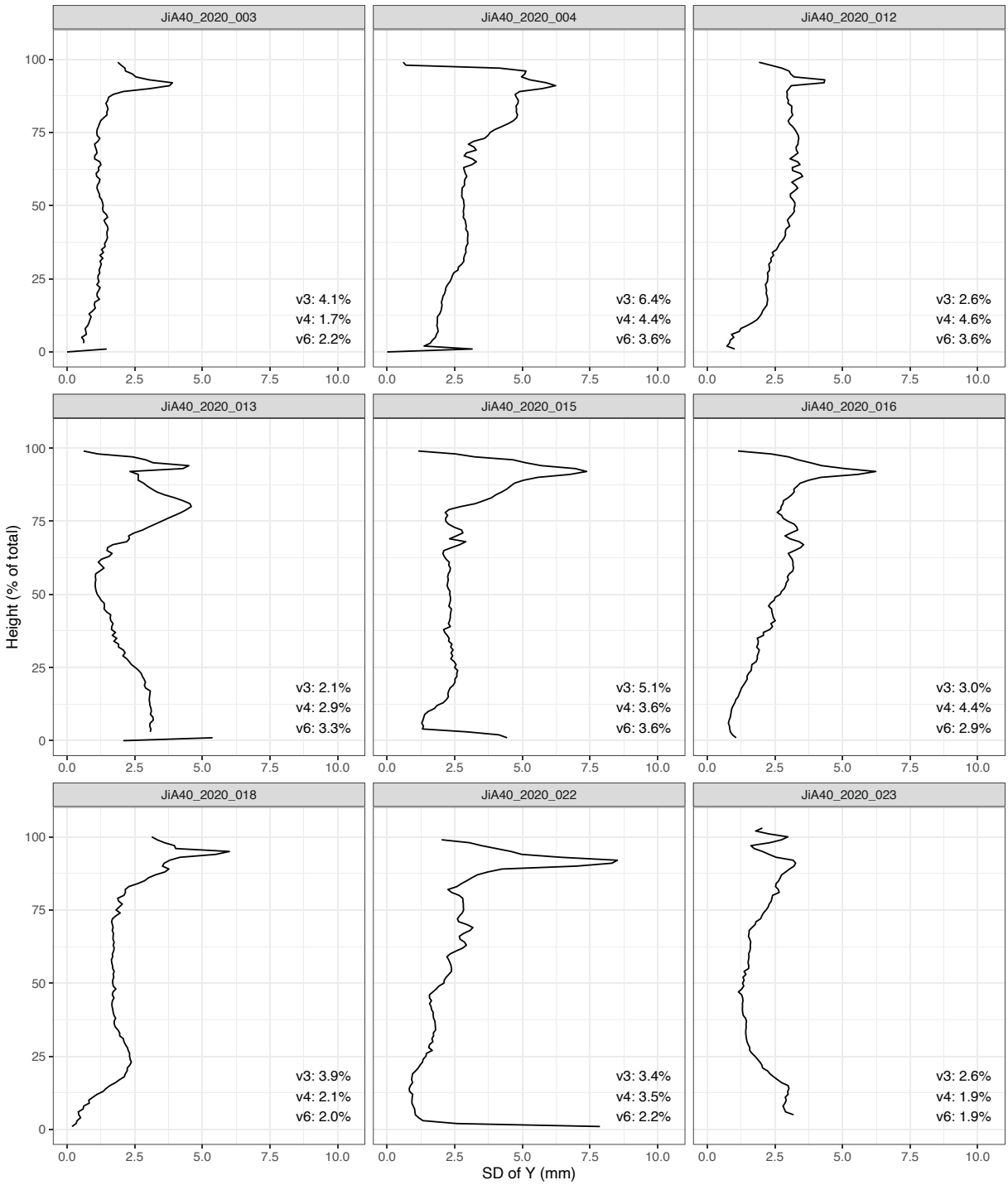
Graph 2. Jihlava – U Skály Street. Boxplots showing variability in wall thickness visualising data obtained by 3D scanning (indices of vessel parts: v6 – bottom to maximum belly diameter; v4 – maximum belly to the narrowest part of the neck; v3 – between the neck and the rim's edge). Author K. Slavíček.

some cases extending up to the maximum diameter or even below the neck (Fig. 55: 7–9, 11a). In many instances, especially in the lower parts of the vessel bodies, these traces correspond to the coils visible in the walls. Coils are also evidenced in several cases by linear features and vacuoles Fig. 55: 2, 3, 6). Occasional traces of squeezing indicate attempts to adjust wall thickness in the lower sections. Some vessels have relatively even bodies, marked only by grooves or papillary ridges produced by fast wheel rotation (Fig. 54: 7; 55: 8, 10a, b). The use of fast rotation for final surface treatment is further supported by a slight twisting of the clay observed in the lower w all of one vessel. Handling immediately after completion is evidenced by clear impressions of a finger pressing into the wall, which is recorded in several cases (Fig. 55: 4).

Traces on the inner body walls demonstrate the presence of coils within the vessel walls as well as the use of fast wheel rotation. This was facilitated by the firm attachment of the base along its perimeter; in some cases, simple pulling was not sufficient to detach the finished vessel from the wheel, and the base was additionally released by slight cutting or undercutting along the edge (Fig. 54: 1, 2, 4). Occasional slight twisting of the clay in the lower part, but above all the thin-walled character of certain vessels in combination with their evenly shaped walls and groove marks, indicate that rotational energy was deliberately used to thin the vessel walls. These features suggest that among the wheel-coiling techniques employed, more advanced forms of profiling and finishing were applied.

The successful application of fast wheel rotation during vessel finishing is further supported by their overall symmetry, documented through 3D scanning. For most vessels, the standard deviation of points on the outer surface from the rotational axis remained consistently low up to the rim, where it increased only slightly – likely due to rim morphology or handling after removal from the wheel (Graph 3; Fig. 56–58; Appendix 3-A). The coefficient of variation by vessel

Graph 3 (1/3)

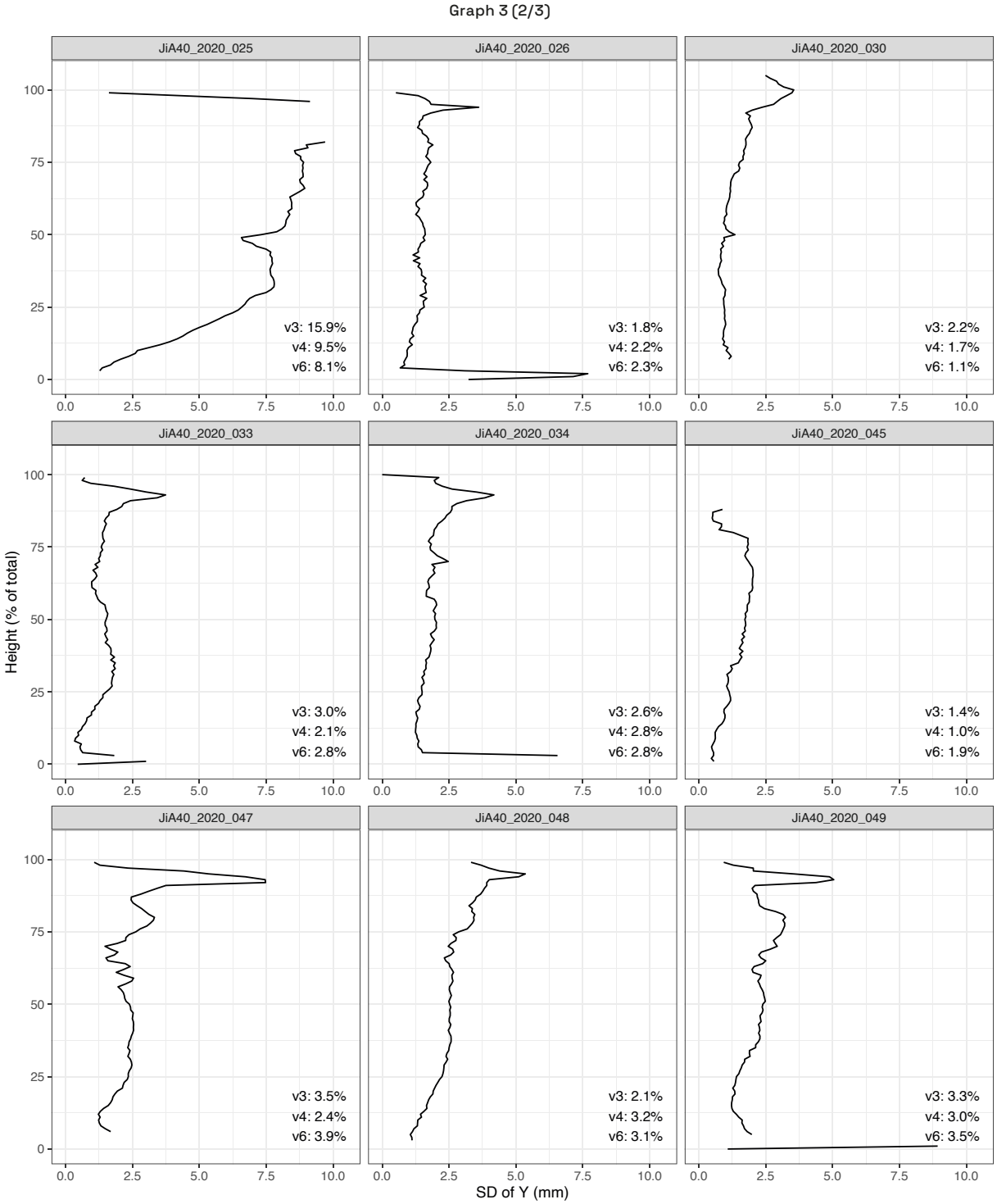


segment was generally within 1–4% (v6), 1–4,5% (v4) and 1.4–6.3% (v6). Two vessels, JiA40/2020-25 and JiA40/2020-60, exhibited markedly lower symmetry, with values around 8% (v6), 6.9–9.5% (v4) and 8–16% (v3).

On the lids, traces of sandy dusting are visible on the knobs, while in two cases marks on the inner walls indicate clay pulling during rotation. On other lids, the orientation of clay movement during forming is reflected in cracks caused by overfiring.

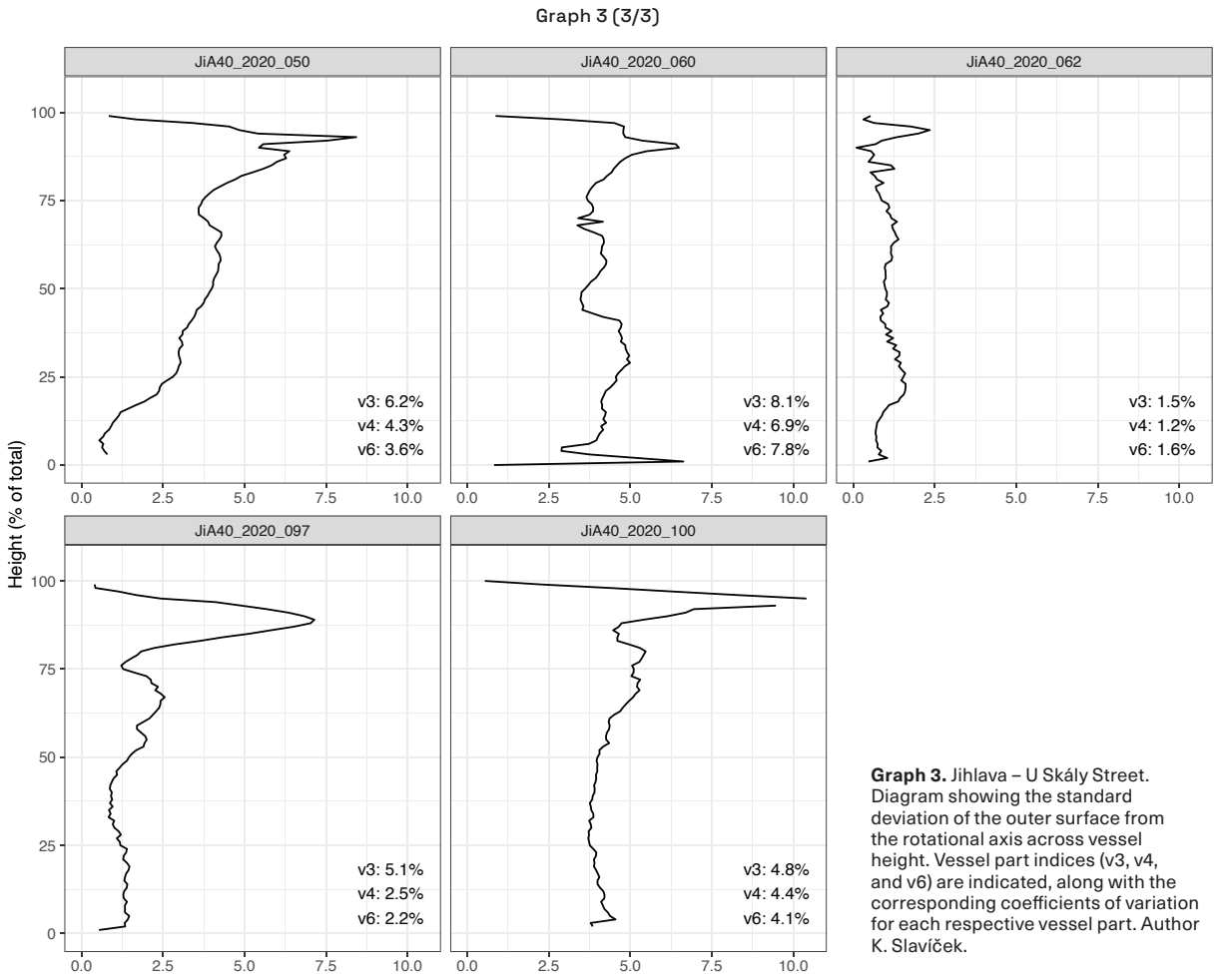
The jugs also display sandy dusting on the bases, with edges bearing traces related to detaching the vessel from the wheel. In some cases, the inner surfaces of the lower body preserve evidence of coiling – depressions and squeezing marks.

Interesting technological features can be observed on bottle-shaped forms, where the limited



space during final closure of the vessel left little room to smooth out the last coils. As a result, traces of the final coils may remain just below the neck, where they could not be completely erased due to the narrowing of the vessel body (Fig. 54: 9b).

The bases of the bottles also bear traces of sandy dusting and attachment to the wheel along the base perimeter. Inside, especially in the lower parts, coil traces are evident in the form of lines, vacuoles, and depressions. Bottle-shaped vessels equipped with tubular spouts had the opening cut secondarily; pulling the clay outward at the cut created a base for the spout, which was then completed by attaching an additional strip of clay. Similar manufacturing of bottles has been documented at Hradišťko near Davle (Richter 1982, 146). In the



Graph 3. Jihlava – U Skály Street. Diagram showing the standard deviation of the outer surface from the rotational axis across vessel height. Vessel part indices (v3, v4, and v6) are indicated, along with the corresponding coefficients of variation for each respective vessel part. Author K. Slavíček.

case of the stirrup-handled ewers, the spout was pressed into a slit made in the wall, with the joints carefully smoothed from both the inside and outside, and in one instance reinforced by adding extra clay on the exterior.

Firing

Traces of firing are not homogeneous, reflecting an irregular course of firing in which the temperatures suitable for these clay pastes were sometimes exceeded, or maintained for too long. Some vessels contain dark cores with oxidised surfaces (in shades of ochre, orange, or red, and in a few cases light grey to beige). Others show predominantly reduced surfaces in various shades of grey (Fig. 54). Among the 36 pots with fully preserved profiles, six were evaluated as overfired and one as severely overfired (Fig. 54: 5; 55: 11). However, the prevailing firing regime was also considered in the evaluation, and signs of overfiring occurred on a number of additional vessels. In three cases, firing resulted in characteristics typical of smoked ceramics, always in vessels made from sandy paste. The surface colour of most vessels is heterogeneous, and colour variations are also present in the core of the sherds, sometimes even within the same vessel. In addition to overfiring of the entire vessel or parts of it, mechanical defects such as cracks and fissures – especially along the rims – were also recorded (Fig. 54: 1–3).

The same range of firing effects is represented on other ceramic forms as well, most often in the form of a combination of reduction and surface oxidation, in some cases progressing to overfiring. The jug that became wedged in the stoking channel was particularly heavily overfired.

The firing characteristics on archaeometrically analysed samples were similar for both fabric A and fabric B. Most samples exhibit oxidising firing conditions in the cross-section. In some cases, black reduced cores were observed, or reduction was present on only one side of the vessel wall. In five samples, smoke-darkened external surfaces were identified in

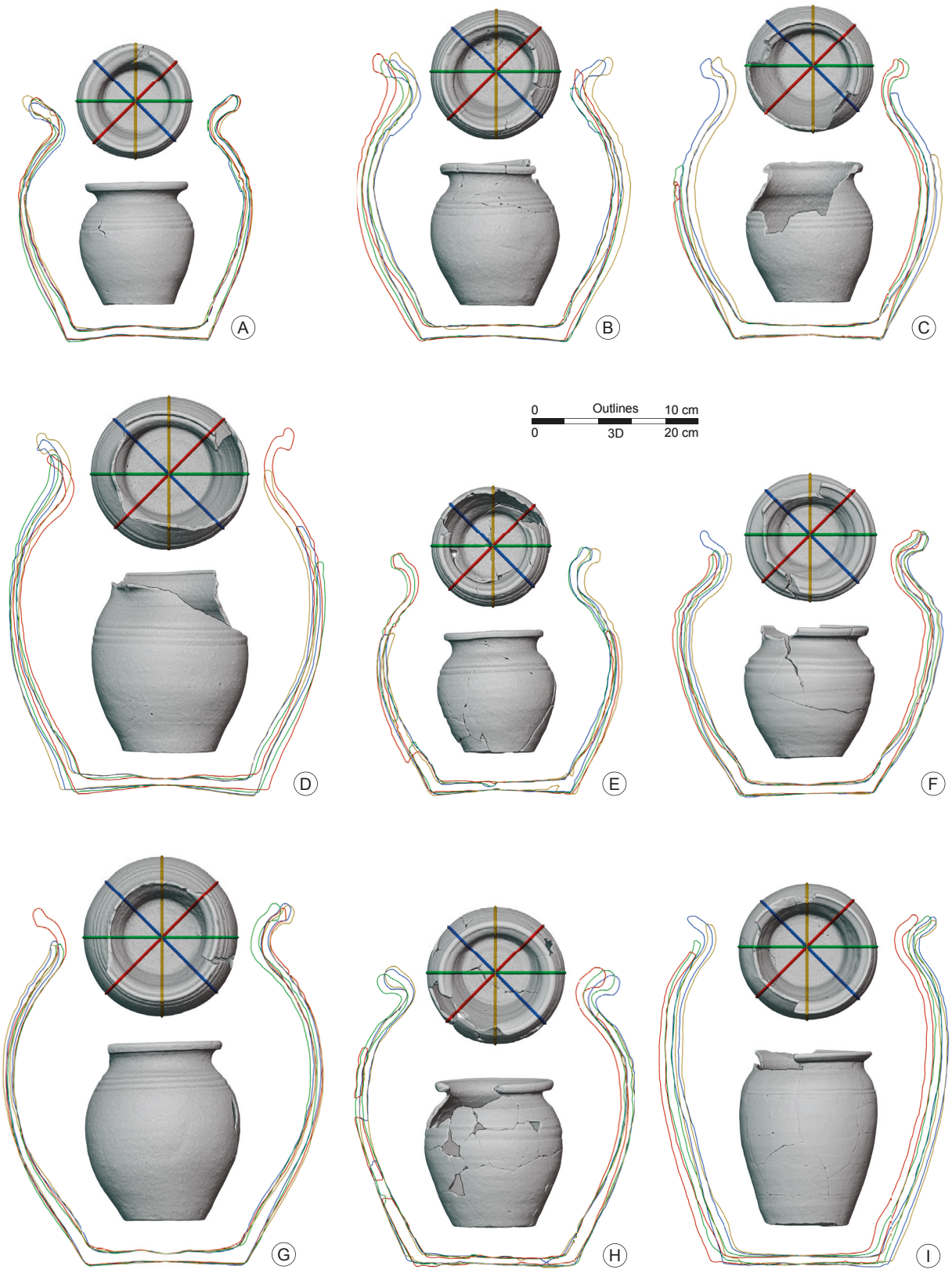


Fig. 56. Jihlava – U Skály Street. 3D models and vertical cross-sections showing degree of vessel symmetry, inv. No.: I A – JiA40_2020-003; B – JiA40_2020-004; CO– JiA40_2020-012; D – JiA40_2020-013; E – JiA40_2020-015; F – JiA40_2020-016; G – JiA40_2020-018; H – JiA40_2020-022; I – JiA40_2020-023. Author M. Košťál.

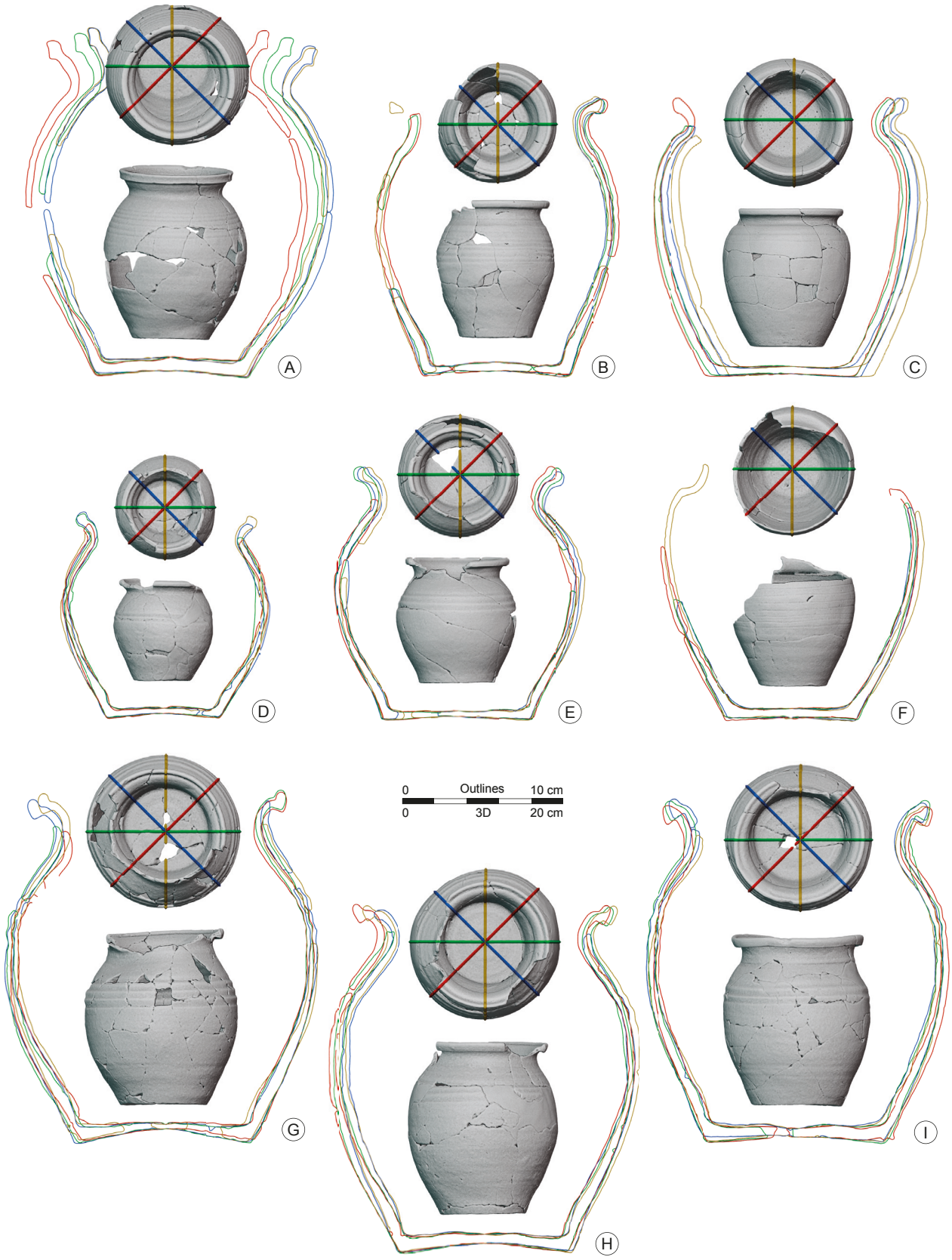


Fig. 57. Jihlava – U Skály Street. 3D models and vertical cross-sections showing degree of vessel symmetry, inv. No.: A – JiA40_2020-025; B – JiA40_2020-026; C – JiA40_2020-030; D – JiA40_2020-033; E – JiA40_2020-034; F – JiA40_2020-045; G – JiA40_2020-047; H – JiA40_2020-048; I – JiA40_2020-049. Author M. Košťál.

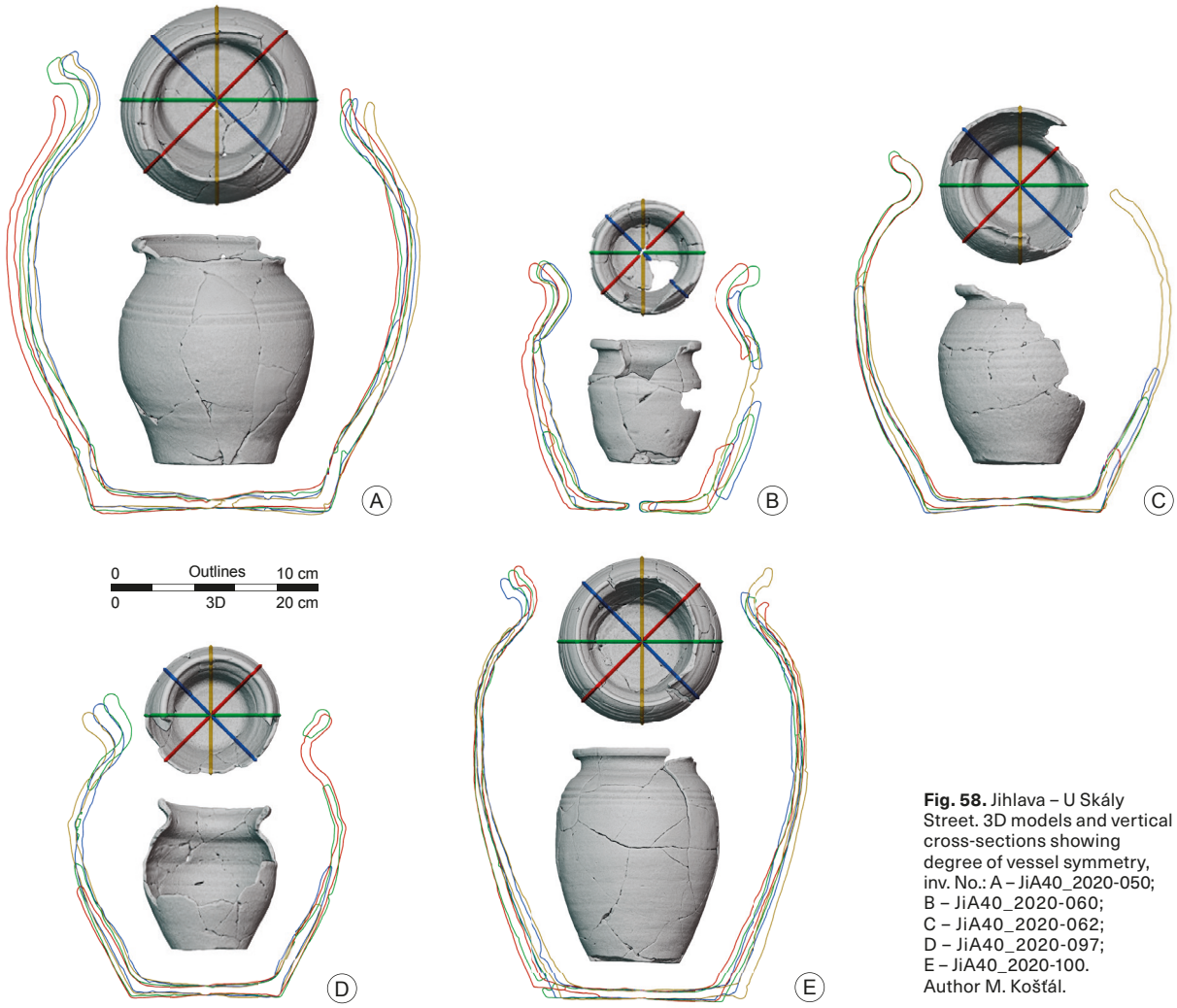
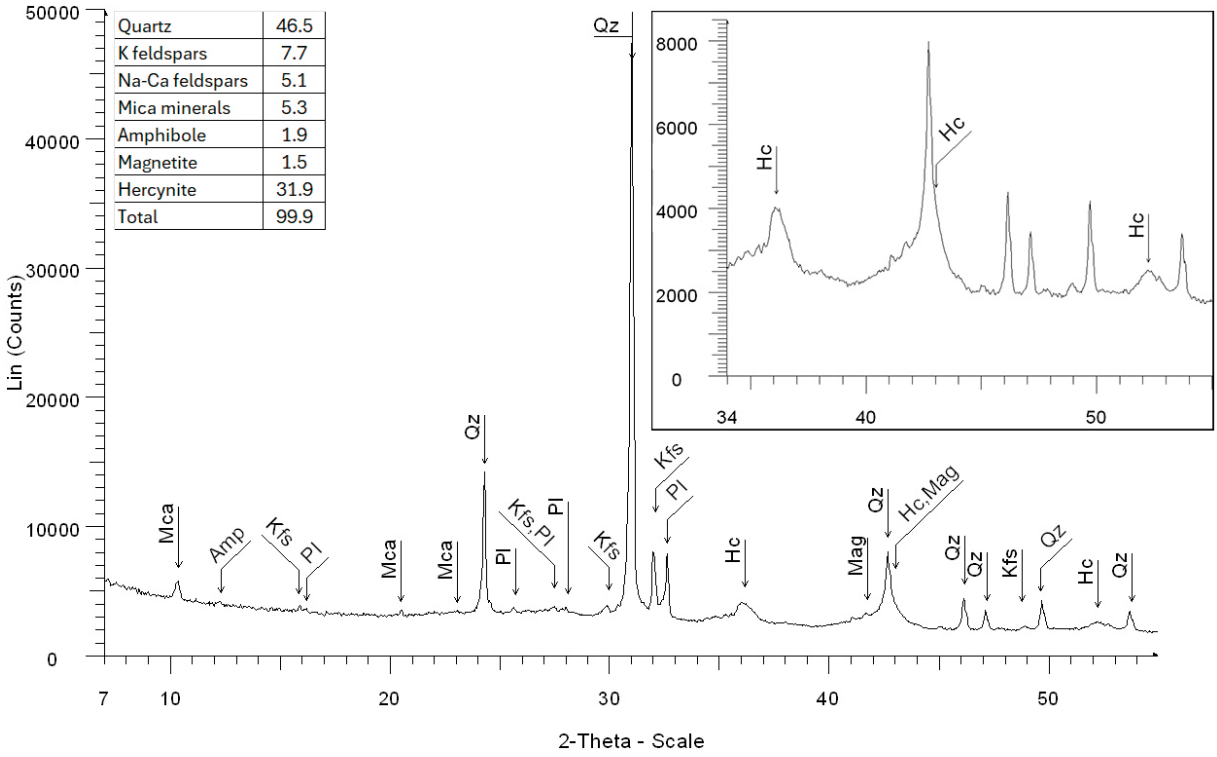


Fig. 58. Jihlava – U Skály Street. 3D models and vertical cross-sections showing degree of vessel symmetry, inv. No.: A – JiA40_2020-050; B – JiA40_2020-060; C – JiA40_2020-062; D – JiA40_2020-097; E – JiA40_2020-100. Author M. Košťál.

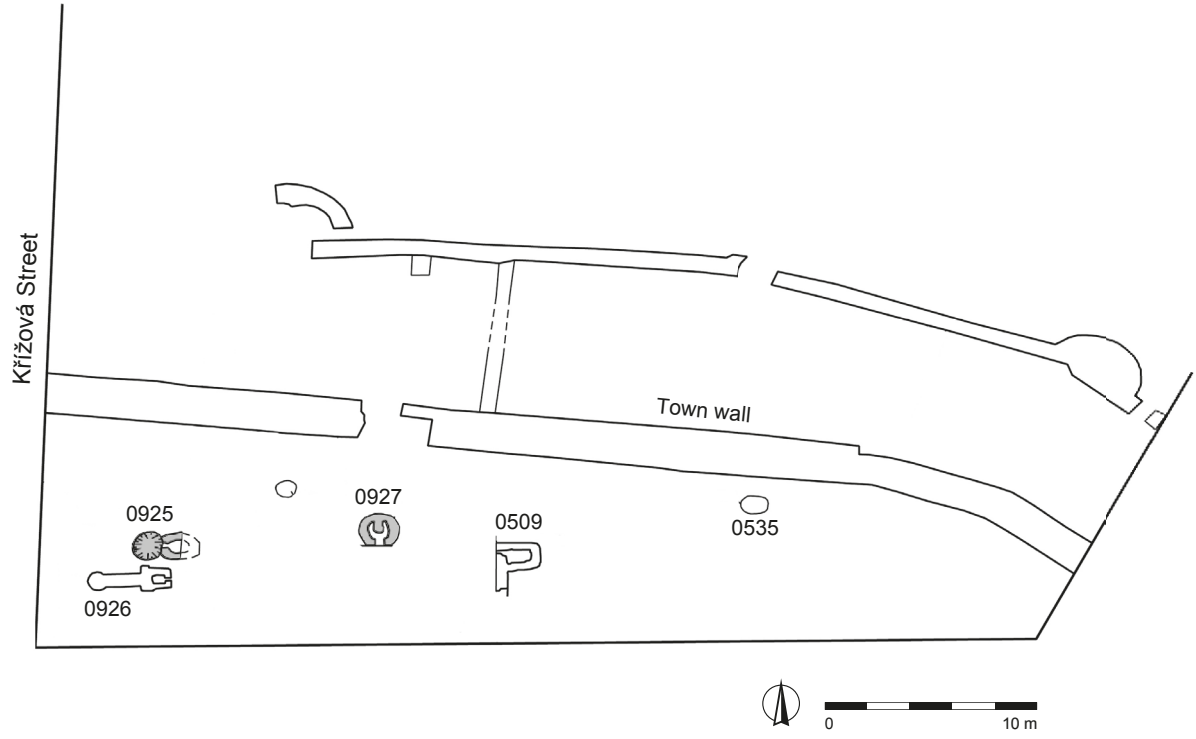
the thin section. Firing temperatures were generally low; based on the strong pleochroism of biotite and high optical activity of the matrix, temperatures were predominantly estimated at around 700°C, occasionally reaching up to 750°C. In four cases, where only slight optical activity of the matrix was noted, temperatures of 800–850°C are considered possible. One sample from fabric A2 shows a vitrified matrix, indicating firing temperatures in the range of 950–1050 °C (Fig. 53). The temperature assessment is based on XRD results, where spinel (with structure close to hercynite) takes up to 32% of the crystalline phase. Its presence proves that at least a part of the firing took place in a reducing atmosphere (Graph 4). Given the preservation of mica mineral residues, it can be assumed that the temperature did not exceed 950–1050°C for a long period.

4.2 Jihlava – Křížová Street

The site is located in the northeastern part of the historic core of the former royal town, in close proximity to the town walls (Fig. 43). A rescue excavation was conducted on plot No. 188 (formerly house No. 14) in 1993, directed by O. Šedo and R. Zatloukal of the Institute for Archaeological Heritage, Brno. Further investigation took place in 2008 under the direction of D. Zimola from the Vysočina Museum in Jihlava. This research focused on previously unexplored parts of the plot and included a re-examination of the kiln (feature 927). The plot has remained undeveloped to the present day (Šedo, Zatloukal 1993, 2–3; Zimola 2004). The ceramic assemblages are housed in the Vysočina Museum in Jihlava. The most significant find at the site is a pottery kiln with a preserved misfired batch



Graph 4. Jihlava –U Skály Street. Diffractogram of sample 15 (angular range 7–55 °2θ) and results of quantitative phase analysis of its crystalline fraction. The inset at the top right shows an enlarged area of the record containing well-defined reflections of spinel (close to hercynite), which indicates firing conditions (Amp = amphibole, Hc = spinel close to hercynite, Kfs = K-feldspars, Mag = magnetite, Mca = mica minerals, Pl = Na-Ca feldspars, Qz = quartz). Author D. Všianský.



StreetFig. 59. Jihlava – Křížová Street. Excavation context. Modified after Zatloukal 1998, 34, No. 2.

(feature 927; Fig. 59). After the mid-14th century, the area was covered by levelling layers and stone paving associated with the construction of stone houses. In the Early Modern period, a stove-making workshop was located here, probably until the first half of the 17th century (Zatloukal 1998, 28–30; 2000a, 63–64).

Another pottery kiln (feature 925) was discovered approximately 10 m south of the previous one (Fig. 59). Kiln 925 was empty and investigated only partially, as its remains were overlain by a wall and the space beneath could not be excavated. Remains of several other kilns or similar installations were also examined, but these cannot be interpreted unambiguously, because their fills contained only fragmentary material (Šedo, Zatloukal 1993, 5–6). Both kilns can be dated, based on the material, to the late 13th century (advanced second half) up to the first half of the 14th century.

Above the backfill of kiln 925, stone-built drying kiln was discovered. It consisted of a stoking pit measuring 1 × 1 m, a 2 m long horizontal flue, and a circular chimney with an internal diameter of 0.45 m. The structure can be dated to the late 14th and early 15th centuries. Its possible connection with pottery production remains only hypothetical (Šedo, Zatloukal 1993, 7; Zatloukal 1998, 28–30). A potential analogy may be provided by a structure investigated at Sezimovo Ústí (Richter, Krajíc 2001, 72–74).

A semi-subterranean timber-and-clay dwelling, dated to the last third of the 13th century and the first third of the 14th century, was most likely connected with the pottery production at the site. The structure extended into the street line, and its remains were intersected by the adjoining stoking pit of kiln 925. It must therefore have been in use prior to the kiln's construction. This was probably a feature from the time of the town's foundation, which may have gone out of use in connection with the building ordinance issued by Přemysl Otakar II around 1270 (Zatloukal 1998, 29).

4.2.1 Kiln relic

Kiln 927 was preserved almost in its entirety; only the front part of the kiln with the stoking pit was destroyed by the construction of a cellar (Fig. 60). The rear part of the kiln was damaged by a trench. The kiln has been preserved up to a height of 0.8 m (Šedo, Zatloukal 1993, 6; Zatloukal 1998, 28). It represents a horizontal (updraft) single-chamber kiln with a central spoon (Procházka 2015, 217).

The kiln was cut into the subsoil of weathered granite and built of quarry granite, amphibolite gneiss, and, occasionally, Cretaceous sedimentary rocks from the Kutná Hora area, bonded with clay. These imported rocks were also used in the construction of the nearby Church of the Exaltation of the Holy Cross, so it can be assumed that stone waste from the workshop building the Dominican monastery was employed in the kiln construction as well. The walls and floor were coated with clay The base of the kiln had an oval shape measuring 1.8 × 1.2 m and was oriented north–south. The floor was divided by a stone block structure (further referred to as the 'spoon') with dimensions of 0.85 × 0.4 m and height of 0.25 m, which separated the kiln floor into two firing channels. The northern end of the spoon was probably bonded to the wall masonry but was unfortunately removed by mechanical excavation. Along the perimeter of the kiln, there was a stone ledge of the same height as the spoon, 0.1–0.18 m wide. No evidence of a grate was found. The preserved stoking pit opening measured 0.35 m in width, 0.43 m in height, and 0.4 m in length.

Kiln 927 contained a batch mixed with the remains of the dome and fuel. Charred wood remains were identified by E. Opravil as silver fir (*Abies alba*). The fill also preserved medium and small fragments of daub with impressions of plant fibres. The preserved, heat-deformed batch can be dated to the turn of the 13th and 14th centuries. In the lower part of the kiln, vessels were placed upside down. At the bottom of the kiln, five bowls were found, which may have served to bridge the firing channels. The bowls had a diameter of 16 cm, while the channels were about 30 cm wide (Zatloukal 1998, 28).

The second kiln (feature 925) was built mainly of gneiss, with a smaller proportion of granite, and probably represents the same type of kiln as kiln 927 (Fig. 61). The structure has been preserved up to a height of 1.2 m. The flat floor consisted of clay daub coatings. A central spoon can also be assumed here, but the situation was disturbed by a later wall. The stoking pit, measuring 1.6 × 1 m in plan and cut 0.5 m into the subsoil, was also investigated. The fill of the kiln itself was examined only to a limited extent, as the circumstances allowed, and yielded rather small fragments. The kiln itself was probably cleared after the last firing. However, pottery dating to the turn of the 13th and 14th centuries was found in large quantities in the adjoining stoking pit (Zatloukal 1998, 29).

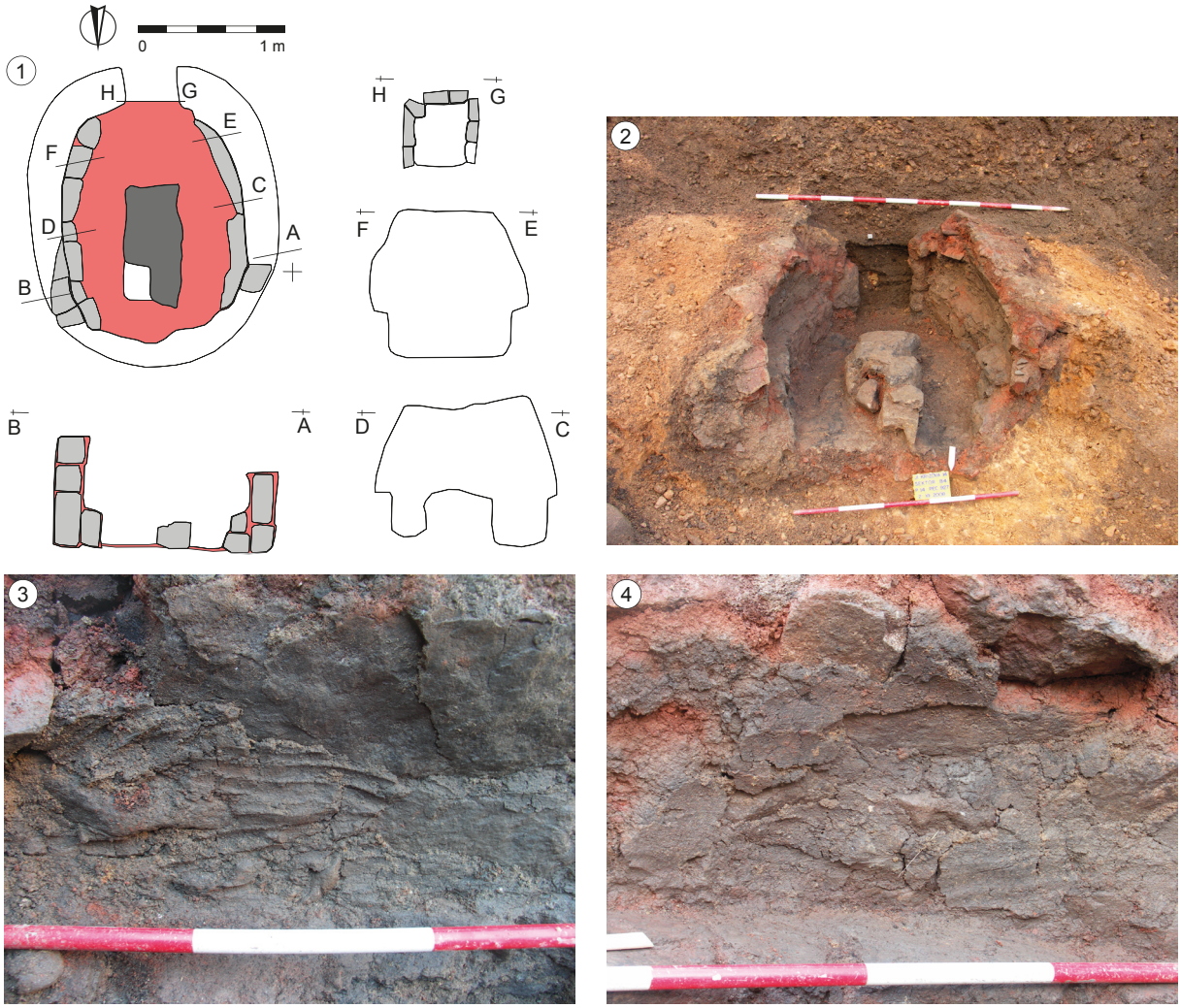


Fig. 60. Jihlava – Křížová Street. Pottery kiln 927. 1 – plan and sections; 2 – the feature after excavation; 3 – clay coating on the kiln wall with fingerprints; 4 – fired clay coating on the kiln wall. Modified after Zatloukal 1998, 35, No. 3.

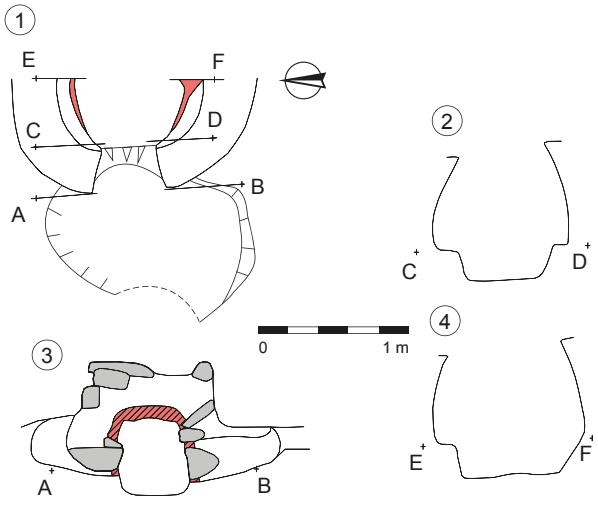


Fig. 61. Jihlava – Křížová Street. Pottery kiln 925. 1 – plan, 2–4 sections. Modified after Zatloukal 1998, 37, No. 5.

4.2.2 Kiln 927 – morphology, typology and metric properties of pottery

The ceramic analysis focused on the batch from kiln 927. At least 108 vessels were identified in the kiln fill. Most of them survived only in fragments, while some were complete or could be fully reconstructed. The restoration of the vessels was complicated by heat damage to the batch, which caused deformation of vessel shapes as well as deterioration of the fabric, leading it to crumble. The ceramics had already been briefly described by R. Zatloukal (1998, 28–29).

In terms of morphology, pots predominated (85 specimens; Fig. 62: 1–6), followed by lids (13 pieces), shallow bowls (sometimes referred to as plates; 7 pieces; Fig. 62: 8), fragments of two stirrup-handled ewers, one cup (Fig. 62: 7) and one lamp



Fig. 62. Jihlava – Křížová Street. Vessels from pottery kiln 927, inv. No.: 1 – pot, 7/93-233/1; 2 – pot, 7/93-233/5; 3 – pot, 7/93-233/925; 4 – pot, 7/93-233/6; 5 – pot, 7/93-233/7; 6 – pot, 7/93-233/9; 7 – cup, 382/7; 8 – shallow bowl, 7/93-233/8. Photo by M. Košťál.

	No. of pots	W	H	D	Z
Index range	7	0.37–0.45	0.95–1.17	0.41–1.02	1.61–1.83
Mean	7	0.42	1.04	0.83	1.76
Median	7	0.44	1.01	0.95	1.81

Tab. 7. Jihlava – Křížová Street, kiln 927. Pot index values.

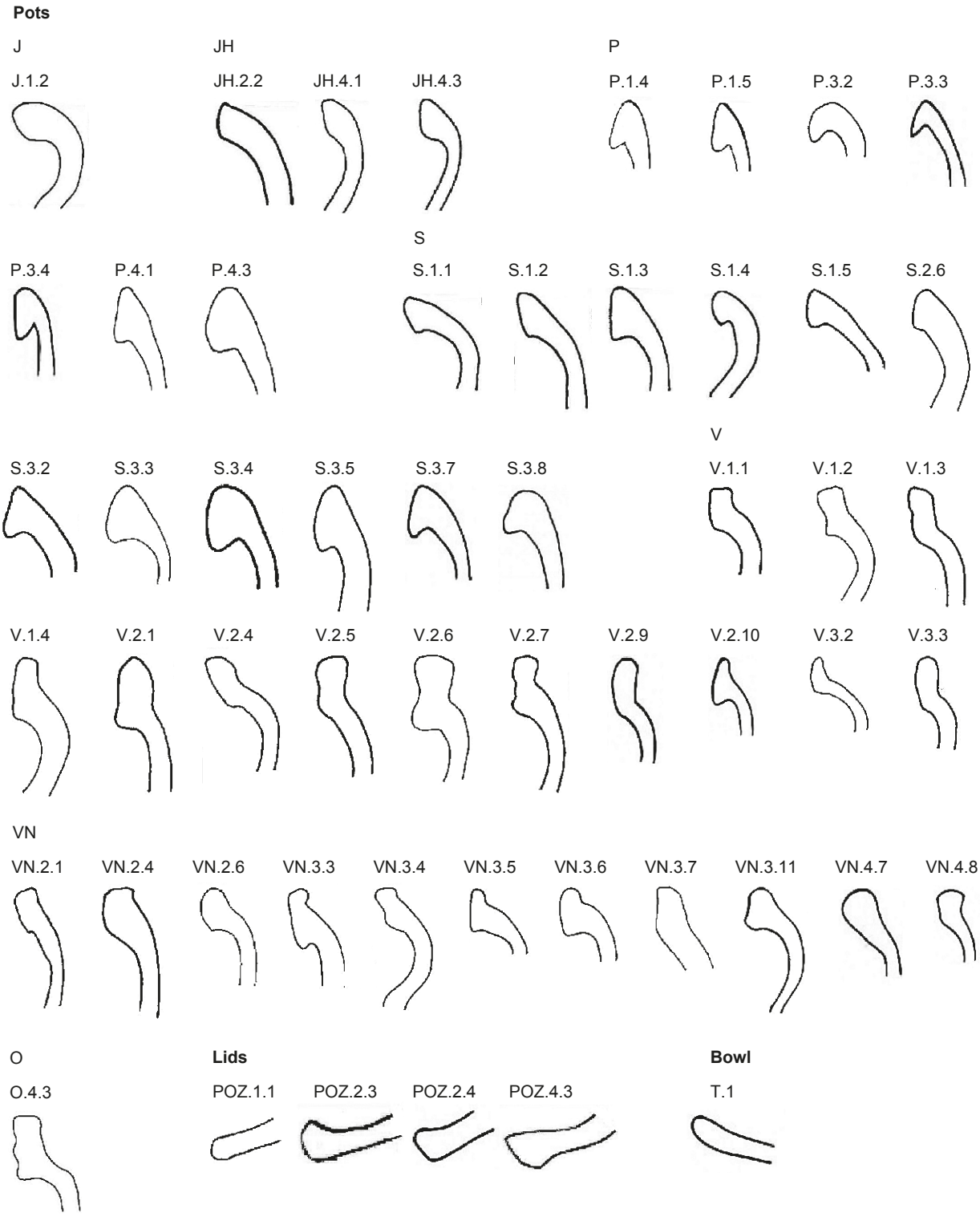


Fig. 63. Jihlava – Křížová Street. Rim types represented among the pottery from kiln 927. Drawings by K. Těsnohlídková.

(Fig. 62: 1, 2). They were accompanied by fragments of at least two storage vessels and one fragment of a chamber stove tile.

Indices W, H, D, and Z were calculated for seven pots (Tab. 7). Both the mean and median values of the W index fall within the 'low' category, with only two vessels classified as 'medium'. The H index, by both mean and median, belongs to the 'high' category, close to the threshold of 'very high', into which three vessels fall. The mean and median values of the D index correspond to moderate body's convexity near the 'high' category; however, the two largest pots show only weak swelling (inv. No. 233-1 and 233-5). The mean and median values of the Z index fall within the 'medium' category, while one vessel (inv. No. 233-5) is positioned close to the 'low' category.

Volumes could be determined for the same seven pots. The volume of the smallest two was 1.2 l and 1.5 l (heights 14–15 cm), one vessel had a capacity of 2.1 l (height 16.5 cm), and four pots ranged between 3–3.4 l (heights 16–19 cm).

Rim types were identified on 244 pot fragments (Fig. 63). More than half of the assemblage consisted of type S rims (54%), with additional significant proportions of types V (15%), VN (13%), and P (12%). Less common were types J (4%), JH (2%), and O (1 specimen). Several VN rims were decorated with grooves: in two cases four grooves, in one case three grooves, and in one case a single groove. Another raised low VN rim bore a wavy line, and another V rim carried two parallel wavy lines.

The decoration of pot bodies is dominated by circumferential horizontal grooves or incised lines, sometimes combined with simple wavy lines. On the bodies of two vessels, most likely pots, marks were incised in the form of a crutch-shaped cross in variable variants (Fig. 64: 5, 6). A relief mark of a cross within a circle was recorded on a single base, probably belonging to a vessel of the same type (Fig. 64: 11).

Among other vessel forms, rim types were identified on hollow lids: four fragments of type POZ.4.3, two rims of type POZ.2.4, and one each of types POZ.1.1 and POZ.2.3. The cup had a capacity of 0.8 l, a rim of type PO.1, and was decorated with three to four grooves on the body. The lamp had rim type KA.1. The rims of stirrup-handled ewers correspond to types KON.3 and KON.6. The shallow bowls were fitted with rims of type T.1 (Fig. 63).

4.2.3 Kiln 927 – ceramic technology

Ceramic paste

The approximate representation of the main ceramic paste types was determined on the basis of rim paste composition, though the results are distorted by extensive overfiring of part of the assemblage. Roughly one quarter of the fragments were heavily overfired and excluded from the statistics, as it was not possible to determine effectively whether the paste had originally contained graphite or mica temper. Among the remaining rim fragments, 98% were made of sandy paste, while graphite-tempered and mica-tempered pottery each accounted for only 1%. The representation of graphite- and mica-tempered pottery is thus highly marginal. Both types were present mostly in fragmentary form.

Ten sherds selected for analysis represent the range of wares present in both fragmentary and torsional states (Tab. 8; Fig. 65): four fragments of sandy paste pottery (two of them heavily overfired), two fragments with a higher mica content, three fragments with graphite temper, and one glazed sherd, which may have entered the kiln fill from stratigraphically higher, later layers. Three fragments of daub were also analysed, one of them bearing an impression of a vessel wall.

Archaeometric analysis confirmed the macroscopic classification of the assemblage into four main fabrics (Tab. 9): fabric A – sandy, fabric B – graphite-tempered, fabric C – micaceous, and fabric D – glazed. Despite differences in tempering materials (Appendix 1-B), these fabrics share several technological characteristics (Appendix 2-B). Most notably, all samples exhibit a weakly parallel microstructure, with the exception of one micaceous sherd (sample 3) and one ceramic fragment embedded in daub (sample 12), both of which show a distinctly parallel fabric. Additional shared features include very poor sorting of aplastic inclusions and predominantly sub-angular to sub-rounded grain shapes. A key unifying trait is the clayey matrix with a relatively low content of silt-sized mineral particles and a mostly frequent occurrence of iron-rich clay pellets, which are present in all samples. Similarly, the general petrographic character of fabrics A–C – disregarding the temper – shows a consistently high content of quartz grains (common to abundant) and alkali feldspars (mostly occasional to common). Micas within the matrix are mostly present in trace to rare quantities for muscovite, and rare to occasional for biotite. Amphibole (samples 2, 6, 8), sillimanite (2, 5, 7, 8),

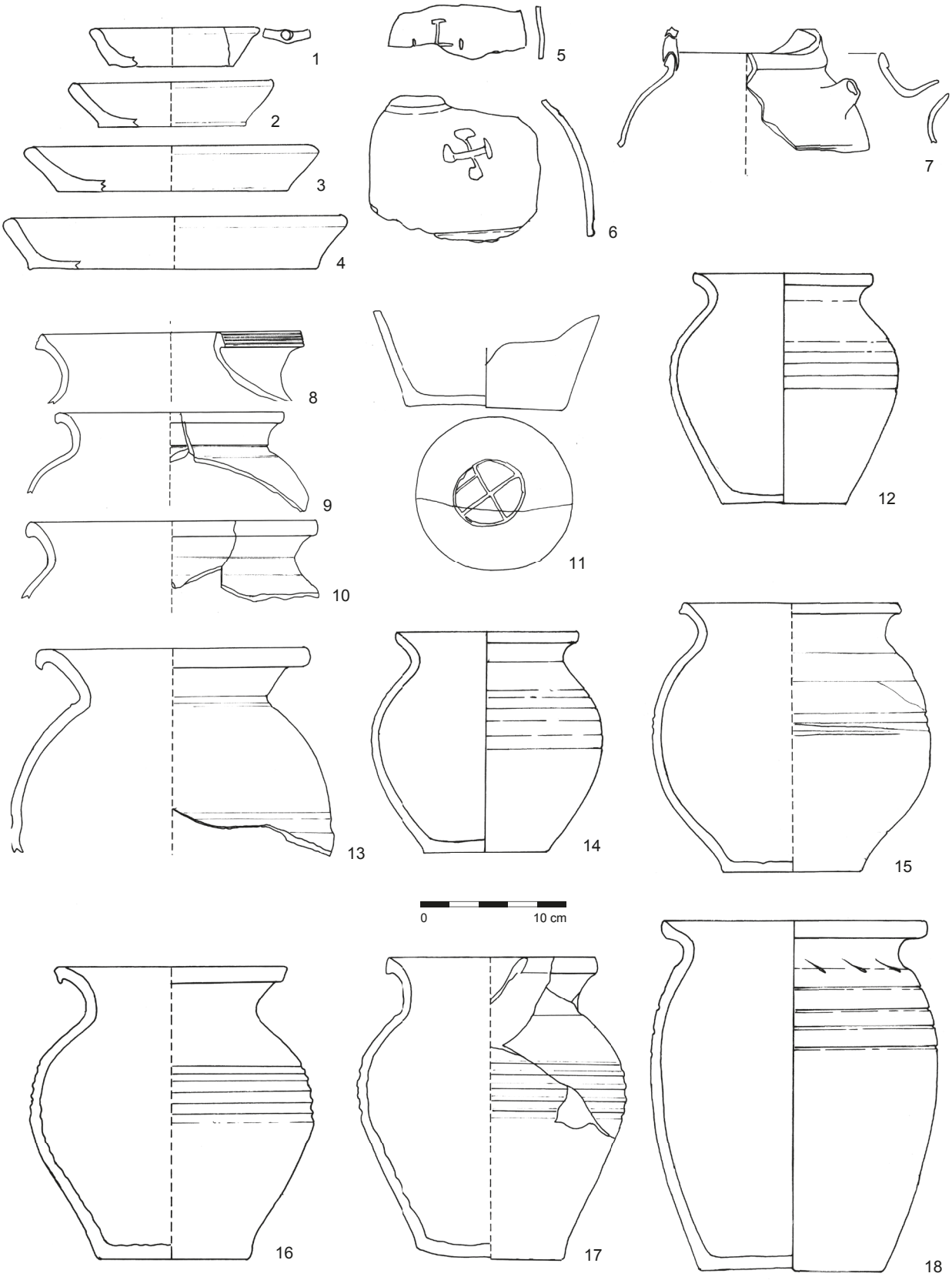


Fig. 64. Jihlava – Křížová Street. Vessels from kiln 927, inv. No.: 1 – lamp, 7/93-233/29; 2 – lamp/shallow bowl, 7/93-233/27; 3 – shallow bowl, 7/93-233/36; 4 – shallow bowl, 7/93-233/23; 5 – belly with incised decoration, 7/93-233/35; 6 – belly with incised decoration, 7/93-233/28; 7 – stirrup handle ewer, 7/93-233/2; 8 – pot, 7/93-233/39/11; 9 – pot, 7/93-233/39/35; 10 – pot, 7/93-233/39/1; 11 – vessel bottom with potter's mark, 7/93-233/20; 12 – pot, 7/93-233/6; 13 – pot, 7/93-233/24; 14 – pot, 7/93-233/9; 15 – pot, 7/93-233/12; 16 – pot, 7/93-233/6; 17 – pot, 7/93-233/11; 18 – pot, 7/93-233/5. Drawings by L. Dvořáková after Zatloukal 1998, 39-41, No.7: 2; 8: 3–5; 9: 6–11.

ID	Context ID	Vessel type	Ceramic class
1	Feature 7/93, context 233	Daub	-
2		Pot	Glazed
3		Pot	Micaceous
4		Pot	Micaceous
5		Pot	Sandy
6		Pot	Sandy
7		Pot	Over-fired
8		Pot	Over-fired
9		Pot	Graphite pottery
10		Pot	Graphite pottery
11		Pot	Graphite pottery
12		Daub	-
13		Daub	-

Tab. 8. Jihlava – Křížová Street, kiln 927. Samples selected for analyses.

spinel (2), and titanite (9) were identified only in a few samples. Other accessory minerals, such as garnet – specifically associated with fabrics B and C – are likely related to temper and do not reflect the original composition of the potter's clay. Fabric D is naturally distinguished by a higher content of plagioclase, micas, and fragments of granitoid rocks.

A comparison of the chemical composition of the individual fabrics, using three samples of kiln wall coating (daub) as reference material, shows that fabrics A and D are very similar and represent compositionally 'average' ceramics for the site (Tab. 10). The daub samples contain a higher concentration of silicon, attributed to its greater content of silty and fine sandy quartz. Fabric B is characterised by

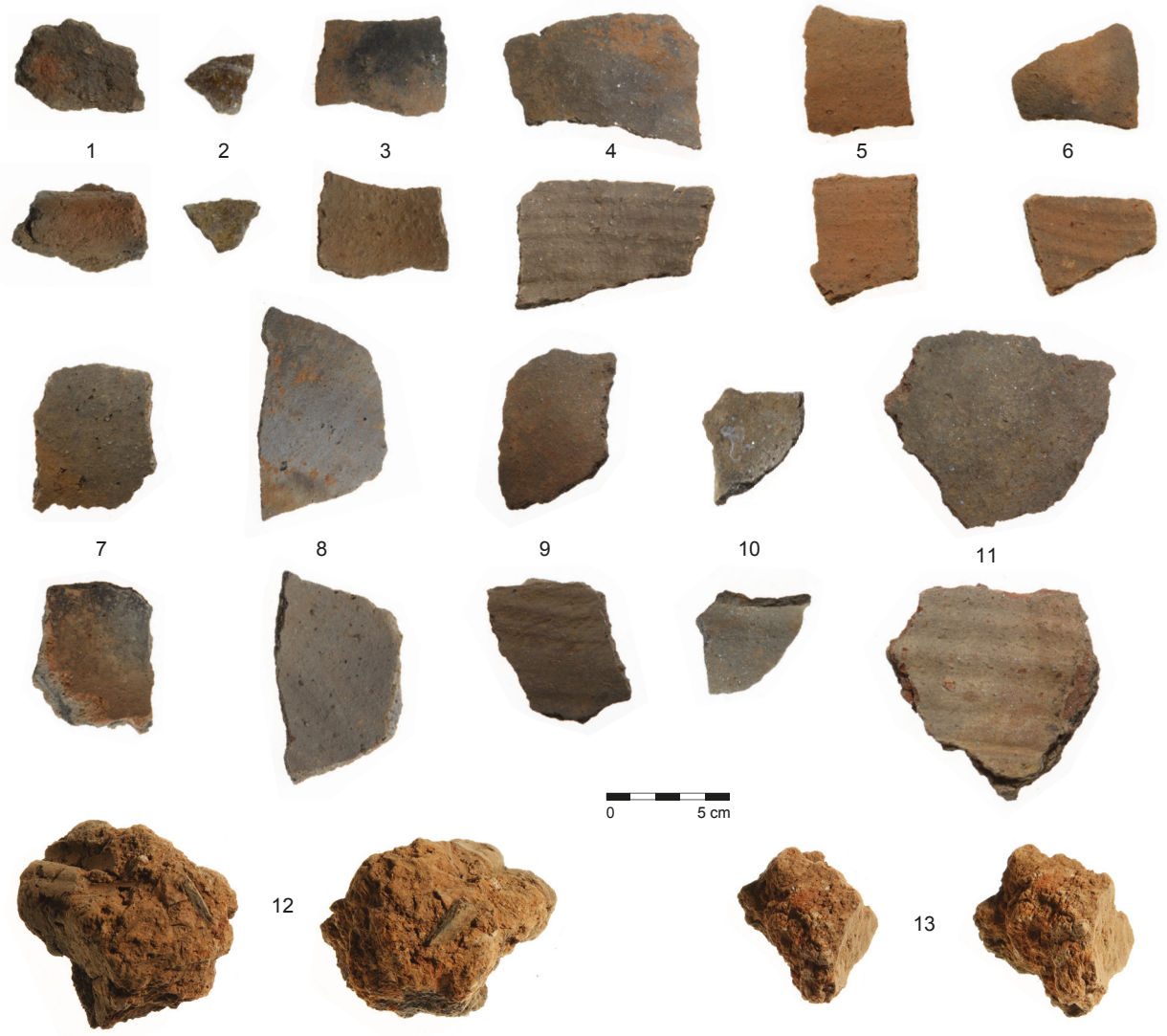


Fig. 65. Jihlava – Křížová Street. Photodocumentation of analysed pottery samples. Photo by K. Slavíček.

Fabric	Sample IDs	Fabric description	Fabric features	Petrographic markers	Chemical markers	Possible sources
A	5, 6, 7, 8	Sandy, non tempered, clayey matrix low in silt particles	Weakly parallel microstructure, unimodal grain size distribution, matrix heterogeneous, iron-rich clay pellets	Quartz, alkali feldspar, granitoid, plagioclase, biotite, muscovite, gneiss, sillimanite, amphibole	Representation of 'average' for the site	Freshwater Tertiary clays, Quaternary alluvial clays, or limonitized tectonic clays all within close vicinity of the site
B	9, 10, 11	Graphite-tempered, silty clay	Weakly parallel microstructure, unimodal grain size distribution, matrix heterogeneous, iron-rich clay pellets	Graphite, graphitic metaquartzite and gneiss, quartz, alkali feldspar, garnet, biotite, muscovite, granitoid, titanite	Compared to A and D: elevated Ca, Mn, Fe and Cu; depleted in Si	Clay – probably the same as fabric A; Temper – Tectonic deposit naturally rich in graphite within Jihlava ore district
C	3, 4	Mica tempered clayey matrix	Parallel microstructure, bimodal grain size distribution, matrix heterogeneous, iron-rich clay pellets	Muscovite, biotite, gneiss, quartz, garnet, alkali feldspar, granitoid	Compared to A and D: elevated K, Ti, Ni, Sr	Clay – probably the same origin as fabric A; Temper – weathered migmatites or granites in the vicinity of the site
D	2	Glazed, non tempered	Weakly parallel microstructure, unimodal grain size distribution, matrix heterogeneous, iron-rich clay pellets	Granitoid, quartz, alkali feldspar, plagioclase, biotite, muscovite, gneiss, spinel, amphibole, sillimanite	Representation of 'average' for the site	Probably the same as fabric A

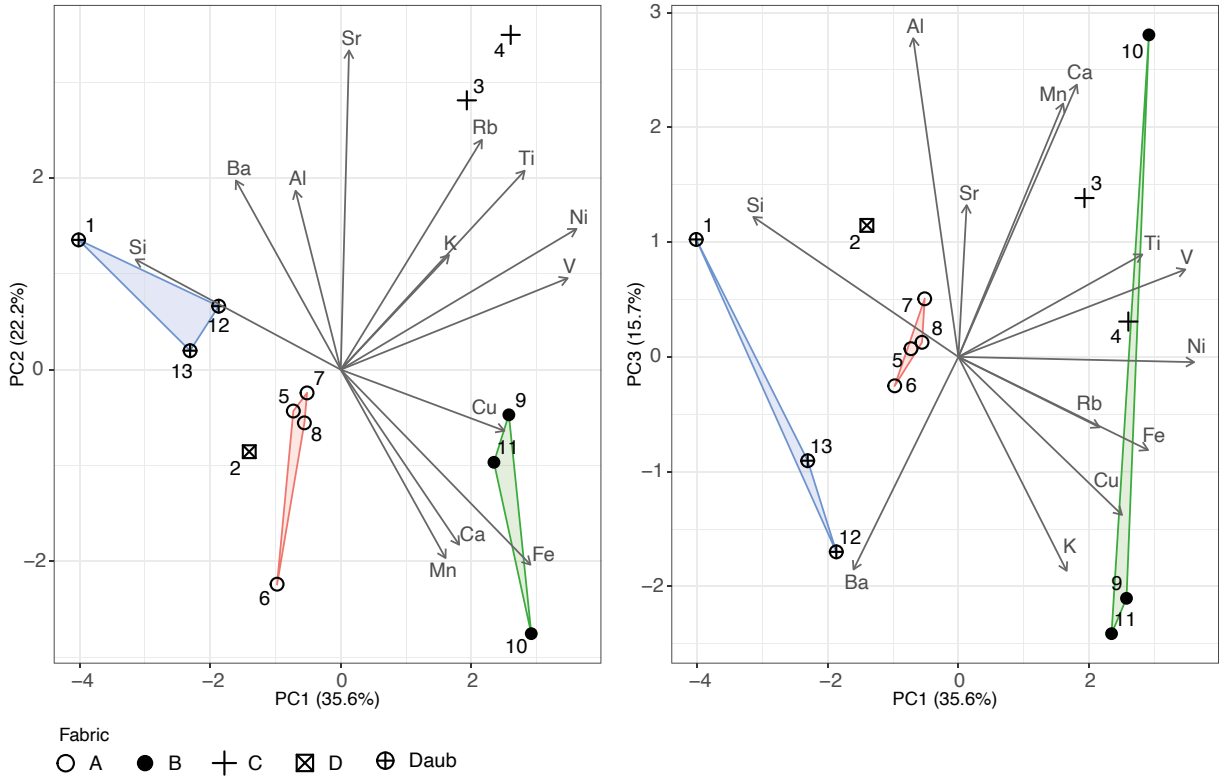
Tab. 9. Jihlava – Křížová Street, kiln 927. General description of fabrics (petrographic markers are listed in order of relative abundance).

	Fabric A				Fabric B				Fabric C				Fabric D	Daub			
	mean	sd	min	max	mean	sd	min	max	mean	sd	min	max	-	mean	sd	min	max
SiO_2	68.4	1.6	66.8	70.7	63.7	1.6	61.9	65	66	1.1	65.2	66.7	71.3	73.5	1	72.7	74.5
Al_2O_3	19.8	2	17	21.6	19.8	2	17.8	21.9	22.4	0.6	22	22.8	19.3	17.4	1.2	16.7	18.8
Fe_2O_3	7.7	0.4	7.4	8.2	10	1.2	9.1	11.3	6.6	0.3	6.5	6.8	5.7	4.8	1.3	3.3	5.7
K_2O	2.4	0.1	2.3	2.5	3.8	0.6	3.2	4.4	3	0.2	2.9	3.2	2.2	2.8	0.5	2.3	3.2
CaO	0.8	0	0.7	0.8	1.4	0.7	0.9	2.2	0.8	0	0.8	0.8	0.8	0.7	0.1	0.5	0.8
TiO_2	0.8	0	0.8	0.8	0.9	0	0.9	1	1	0	1	1.1	0.6	0.7	0.2	0.5	0.8
V	127	3	124	130	138	9	130	148	168	6	164	172	93	92	11	80	99
Mn	444	93	360	543	2659	3717	410	6950	330	25	312	347	453	348	15	335	364
Ni	36	2	33	38	42	2	40	44	47	1	46	48	34	31	1	30	33
Cu	32	2	30	34	43	7	36	50	36	6	32	40	43	30	3	26	32
Rb	154	17	128	165	183	6	177	188	194	18	181	206	153	173	8	166	181
Sr	54	4	48	58	52	3	49	56	84	2	82	85	70	65	2	64	68
Ba	493	123	333	634	363	127	217	451	517	112	438	596	158	740	143	612	894

Tab. 10. Jihlava – Křížová Street, kiln 927. Summary of the chemical composition of fabrics (major oxides in wt %, trace elements in ppm).

elevated levels of Ca, Mn, Fe, and Cu, along with a markedly lower Si content. Fabric C, influenced by tempering with mica, exhibits increased concentrations of K, Ti, Ni, and Rb (Graph 5).

Sandy ceramics were designated as fabric A, serving as the baseline for comparison, as they represent the predominant ceramic paste within the analysed assemblage (Fig. 66: A, B). Although the clay matrix appears broadly similar – if not identical – across all samples, fabric A is distinguished by a unimodal grain-size distribution of non-plastic inclusions. While the character of the clay and silt fractions is comparable across the various fabrics, fabric A additionally contains sand-sized grains of average size of 300 µm (the largest inclusions reaching up to 1900 µm). The size distribution of these coarser particles, including the silty fraction, does not indicate intentional tempering. Although deliberate addition cannot be ruled out entirely, it is more plausible that the raw material was a naturally coarse-grained clay that did not require further tempering. The sandy inclusions consist primarily of quartz and alkali feldspars, with plagioclase occurring only rarely to occasionally. Lithic fragments are mostly



Graph 5. Jihlava – Křížová Street, kiln 927. Principal component analysis of chemical composition – scatter plots of the first component against the second and third. The diagram shows compositional differences among fabrics A, B, and daub, while fabric D is chemically closely related to fabric A. Author K. Slavíček.

granitoid in composition (rare to occasional), and a single fragment of gneiss was identified in sample 7.

Graphite-tempered ceramics (fabric B) possess a slightly more silty clay matrix compared to the other fabrics (Fig. 66: C, D). The average diameter of naturally contained sand-sized fraction is 150 µm (the biggest one as large as 650 µm). Tempering material consists of individual graphite flakes and rounded fragments of graphite-bearing rocks, primarily metaquartzite (Fig. 67: A). The average temper size is 300 µm and it spans up to 1500 µm in diameter. Other rock types containing graphite could not be conclusively identified; however, sample 9 includes a graphite-rich lithic fragment with titanite inclusions, while sample 11 contains graphite-bearing rocks with garnet (Fig. 67: B) and, in another case, with gypsum. The consistent presence of garnet suggests a genetic link to the source of the graphite.

Micaceous ceramics (fabric C) are characterised by a slightly more clay-rich matrix. The temper consists of fragments of two-mica gneiss as well as individual flakes of muscovite and biotite, all occurring predominantly at frequent abundance (Fig. 66: E, F). The micaceous temper size spans between 100–2700 µm with an average of 400 and 800 µm for sample 3 and 4 respectively. Sample 4 additionally contains occasional fragments of granitoid rock. Among the mineral inclusions, the imbalance in the abundance of alkali feldspars is noteworthy – common in sample 3, but rare in sample 4. Garnet is also present, appearing rarely in sample 3 and commonly in sample 4 (Fig. 67: C).

Glazed ceramics (fabric D) are untempered and contain naturally occurring frequent quartz, common alkali feldspars, plagioclase, and biotite (Fig. 66: G, H). Muscovite flakes are present occasionally. Amphibole and spinel appear rarely, while sillimanite occurs only in trace amounts. The lithic component is dominated by frequent granitoid fragments and occasional pieces of gneiss. The rock and mineral grain dimensions are similar to those contained in fabric A.

The reference ceramic sherd that was baked into the kiln wall coating could not be analysed for chemical composition, but its petrographic features closely resemble fabric A, albeit with a slightly finer grain size (Fig. 67: D). The presence of iron-rich clay pellets could not be determined due to extensive alteration of the sample caused by high firing

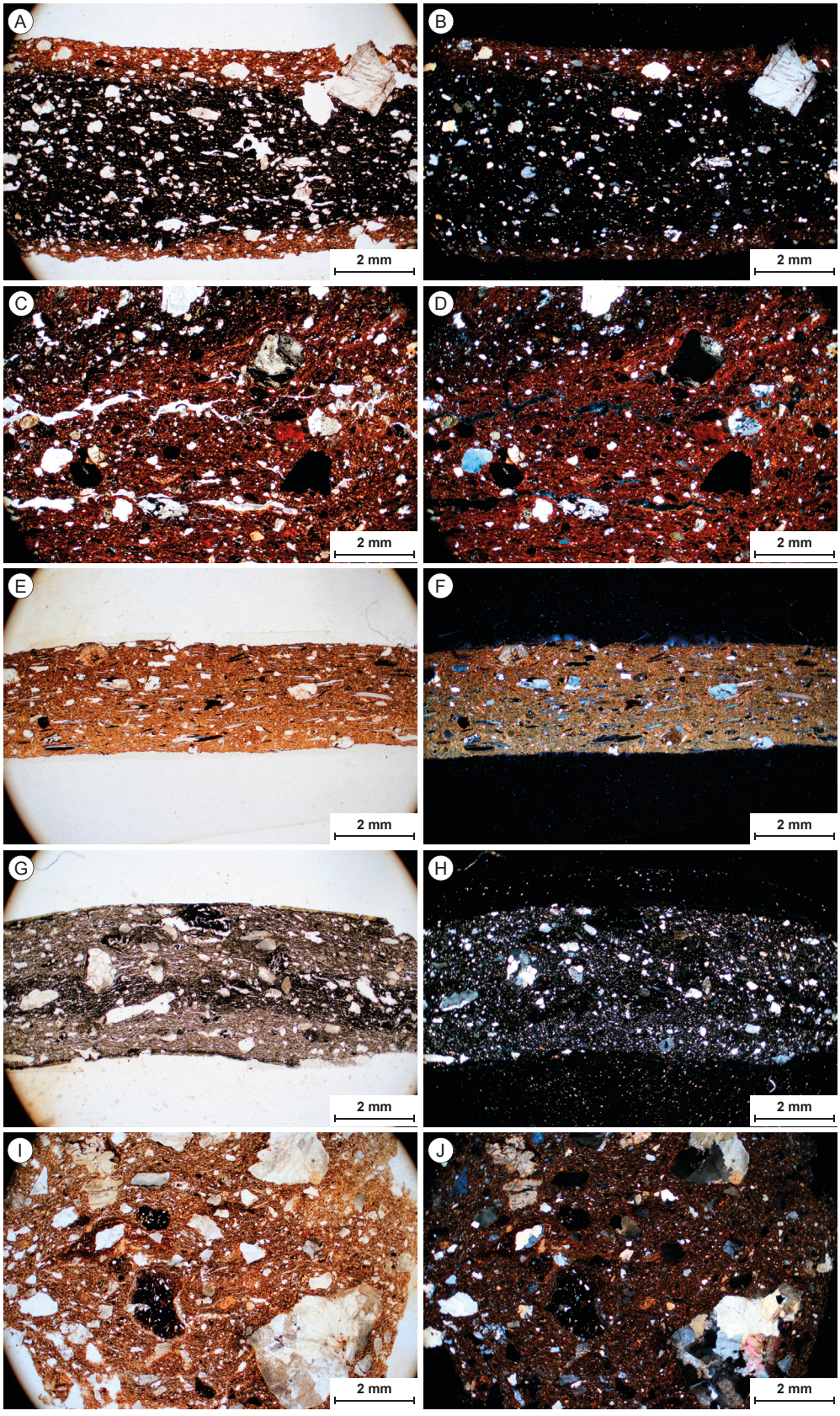


Fig. 66. Jihlava – Křížová Street. Overview of the microstructure of each fabric in PPL (left) and XPL (right): A, B – sand fabric A, sample 5; C, D – graphitic fabric B, sample 11; E, F – micaceous fabric C, sample 3; G, H – glazed fabric D, sample 2; I, J – kiln wall coating, sample 1. Author K. Slavíček.

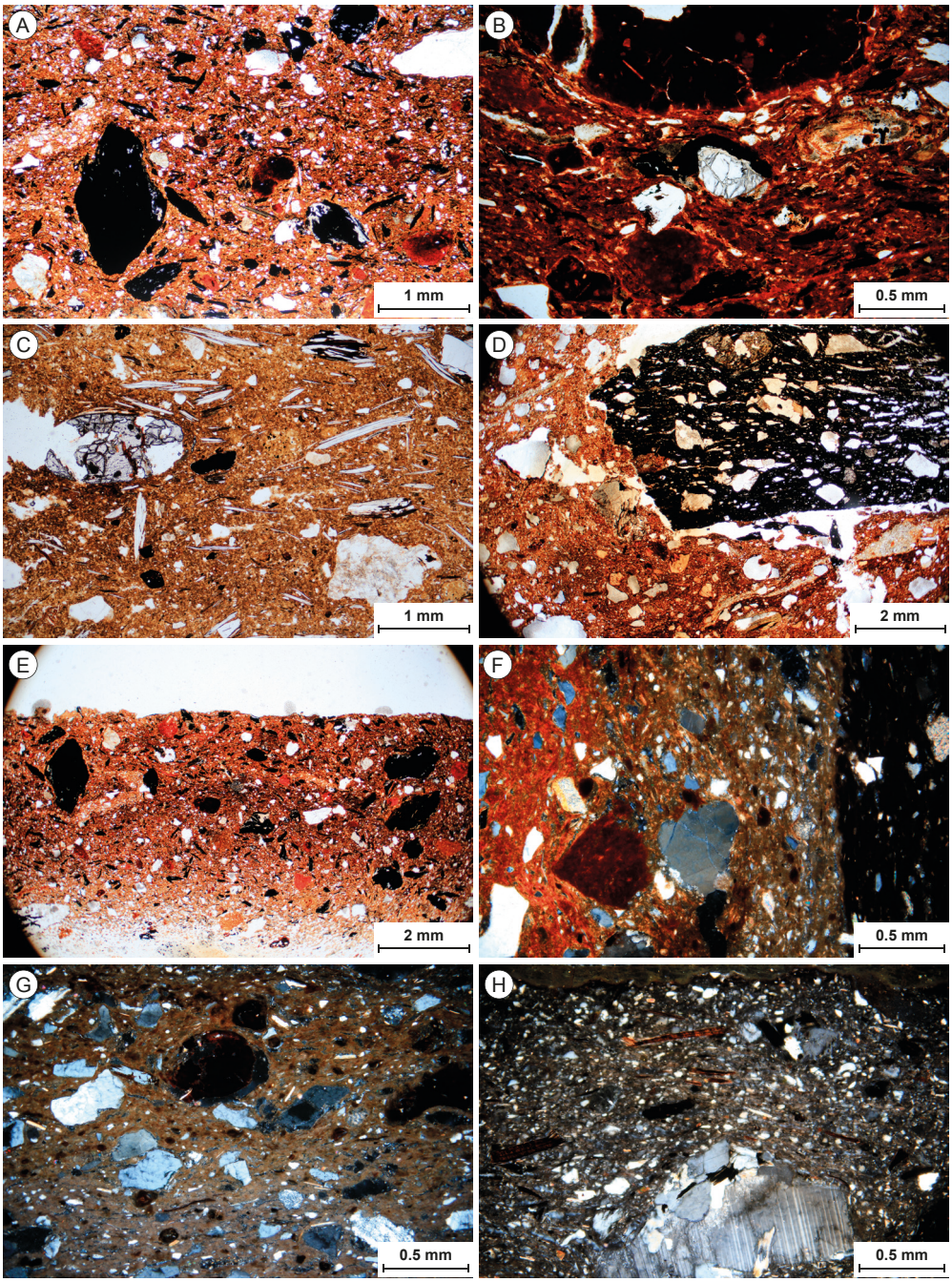


Fig. 67. Jihlava – Křížová Street. Photomicrographs highlighting key features in detail: A – graphitic fabric B with isolated graphite flakes and fine graphitic metaquartzite grains in an oxidised, relatively silty matrix containing numerous iron-rich clay pellets (sample 9, PPL); B – graphitic rock fragment with garnet and a large iron-rich clay pellet at the top (fabric B, sample 11, PPL); C – micaceous fabric C with abundant flakes and stacks of muscovite and frequent flakes biotite; to the left, a rounded and weathered garnet grain (sample 4, PPL); D – ceramic fragment 'baked' into the kiln coating (sample 12, PPL); E – orientation and distribution of graphite flakes perpendicular to the vessel's vertical axis – seen on the left and right—suggest coil-built technique (fabric B, sample 9, PPL); F – vertically oriented section (aligned with vessel axis) showing the transition from an oxidised zone on the left, through a weakly reduced and optically inactive matrix in the centre, to a dark reduced core on the right (fabric A, sample 7, XPL); G – optically inactive matrix due to high firing temperature in the core of sample 8 (fabric A, XPL); H – glazed fabric D (glaze layer at top), optically inactive matrix, numerous weakly pleochroic biotite flakes, and a granitoid fragment at the bottom (sample 2, XPL). Author K. Slavíček.

temperatures and strongly reducing conditions. The petrography of the reference kiln wall coating samples is also similar to fabric A, though with some notable differences – namely, a higher proportion of fine particles, increased plagioclase content, and a greater abundance of granitoid rock fragments (Fig. 66: I, J). In these respects, the composition more closely resembles the matrix of fabric D.

The bedrock of the town of Jihlava consists of the variegated series of the Moldanubian Zone, predominantly migmatites containing accessory minerals such as cordierite, biotite, garnet, sillimanite, and muscovite. In some areas, the bedrock is composed of granites with biotite prevailing over muscovite. To the west of Jihlava, granulites outcrop along the contact with the central Moldanubian pluton. Within the city itself, and especially in its surroundings, sandy and gravelly sediments with lenses of clay represent the sedimentary fill of the Jihlava Furrow. The youngest geological cover consists of Quaternary eluvial and alluvial deposits and loessic clays (Mísař 1983; Francírek, Nehyba 2019; ČGS 2025). The most probable source for fabric A is clay of eluvial or alluvial origin, given its overall similarity with kiln daub – a material for which physical properties were less demanding than for ceramic vessels. Due to the large quantity required for kiln construction, a source located as close to the site as possible can be reasonably assumed. However, in addition to freshwater Tertiary clays and Quaternary alluvial clays, potters' clay may also have been obtained from limonitised tectonic clays filling dislocation zones of the Jihlava ore district. These tectonic fills contain crushed, graphitised rock material, which could have been collected for use as temper (Pluskal, Vosáhlo 1998). Although it is not currently possible to confirm whether the clay used in fabric B originated from a tectonic deposit naturally rich in graphite, the consistent occurrence of iron-rich pellets across all fabrics suggests a shared origin of the base clay. These pellets may represent limonitic concretions or weathered pyrite residues, both characteristic of the Jihlava ore region. If different clay types were used – one with and one without graphite – they must have been selected separately. Garnet, being highly resistant to weathering, may have concentrated in the weathered material and likely entered the ceramic paste of fabrics B and C as part of the temper. The mica used as temper in fabric C may have been collected from weathered migmatites or local granites.

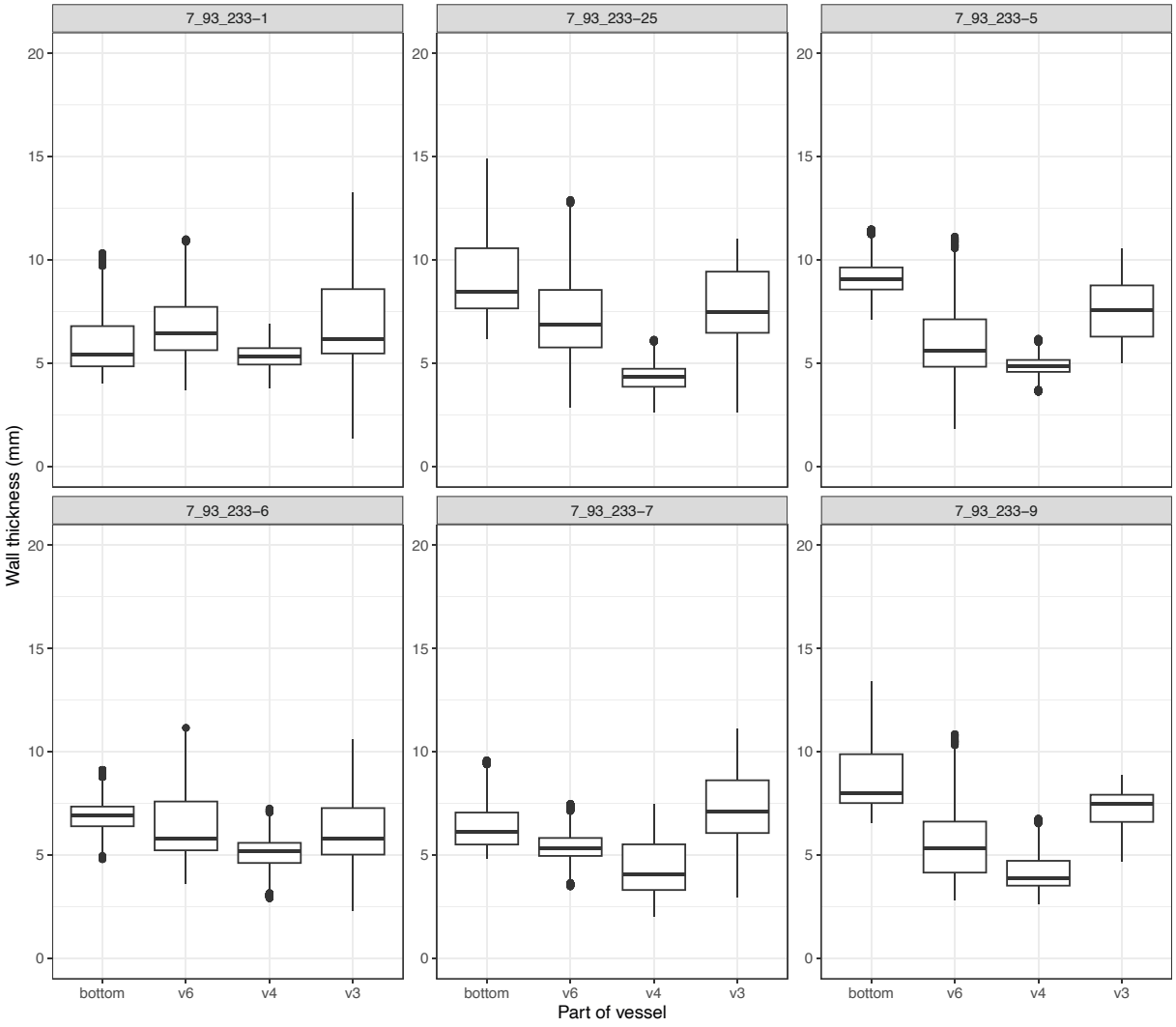
Forming

On the inner walls of the pots, traces of depressions left by coils are visible, often forming ring-like patterns. Together with marks of tool use or finger impressions in the form of grooves, these features attest to the use of rotational kinetic energy during manufacture (Fig. 68). Coils can be documented on some vessels in the area below the neck (Fig. 68: 3, 4), but they are most commonly observed above the base, where the wall undulation can be quite pronounced (Fig. 68: 9). In two cases, thin-section analysis revealed non-plastic inclusion orientation patterns that follow the contour of an original coil (sample 7 – fabric A; sample 9 – fabric B). On part of the vessels, the paste surface is damaged by overfiring. The vessel bases bear traces of sand dusting, including marginal marks left by attachment to or removal from the wheel (Fig. 68: 9). Occasionally, potters' marks occur on the bases, taking the form of circular impressions or a cross on the bottoms of lamps (Fig. 68: 5, 7).

A total of six vessels were 3D scanned. The average wall thickness varied considerably between vessels (Graph 6; Appendix 3-B). In the lower part of the body (v6), it ranged from 5.4 to 7.1 mm; in the section between the point of maximum diameter and the neck (v4), from 4.2 to 5.3 mm; and at the rim (v3), from 6.1 to 7.6 mm. The notably greater thickness at the rim reflects specific rim types. The coefficient of variation was highest for the lower body (v6), ranging from 13.4% to 30.9%; lowest for the upper-body section (v4), at 9.3% to 28.5%; and elevated again at the rim (v3), between 11.3% and 30.7%. The standard deviation of the distance from the vessel surface to the rotational axis (expressing vessel asymmetry) was variable (Graph 7; Fig. 69). In two vessels (7_93_233-6, 7), it remained relatively consistent from the base to the neck, around 2.5 mm or less. In two vessels (7_93_233-1, 5), the asymmetry progressively increased from the base towards the rim, reaching values of approximately 6 and 9 mm. In two vessels (7_93_233-9, 25), the standard deviation increased towards the point of maximum diameter (6–7 mm), then slightly decreased towards the neck (4–5 mm), before increasing sharply again at the rim, exceeding 10 mm. The coefficient of variation was relatively consistent across vessel parts: 2.0–6.1% for v6, 1.5–7.2% for v4, and 1.9–6.2% for v3, with one outlier at 10.4% (vessel 7_93_233-9). In several cases, asymmetry around the point of maximum diameter and rim was visible to the naked eye. This is unlikely to reflect primary imperfection during vessel forming, but is more plausibly attributed to



Fig. 68. Jihlava – Křížová Street. Technological traces observed on vessel fragments from kiln 927, inv. No.: 1 – tool grooves indicating the use of fast rotation, 7/93-233/14; 2 – depressions/rings, Ji8/B-378/387; 3 – depressions below the neck indicating coil presence and rings indicating fast rotation, Ji8/B-378/387; 4 – depressions below the neck indicating coil presence and rings indicating fast rotation, 7/93-233/17; 5 – bottom with remnants of potter's mark, traces of sand dusting and peripheral attachment forming a so-called 'inserted bottom' effect, inner wall showing coil traces and lightly reworked clay, 7/93-233/19; 6 – fine sand dusting and inner wall with rings, then smooth uniform wall, A767; 7 – bottom with remnants of potter's mark, traces of sand dusting, inner wall showing coil traces and evidence of rapid uneven rotation, Ji8/B-378/387; 8 – sand dusting on the bottom and coil traces on the inner wall, thinning of the lower vessel wall visible, 7/93-233/22; 9 – sand dusting on the bottom and peripheral trimming traces, inner wall showing depressions/rings, 7/93-233/15. Photo by M. Košťál.



Graph 6. Jihlava – Křížová Street, kiln 927. Boxplots showing variability in wall thickness visualising data obtained by 3D scanning (indices of vessel parts: v6 – bottom to maximum belly diameter; v4 – maximum belly to the narrowest part of the neck; v3 – between the neck and the rim's edge). Author K. Slavíček.

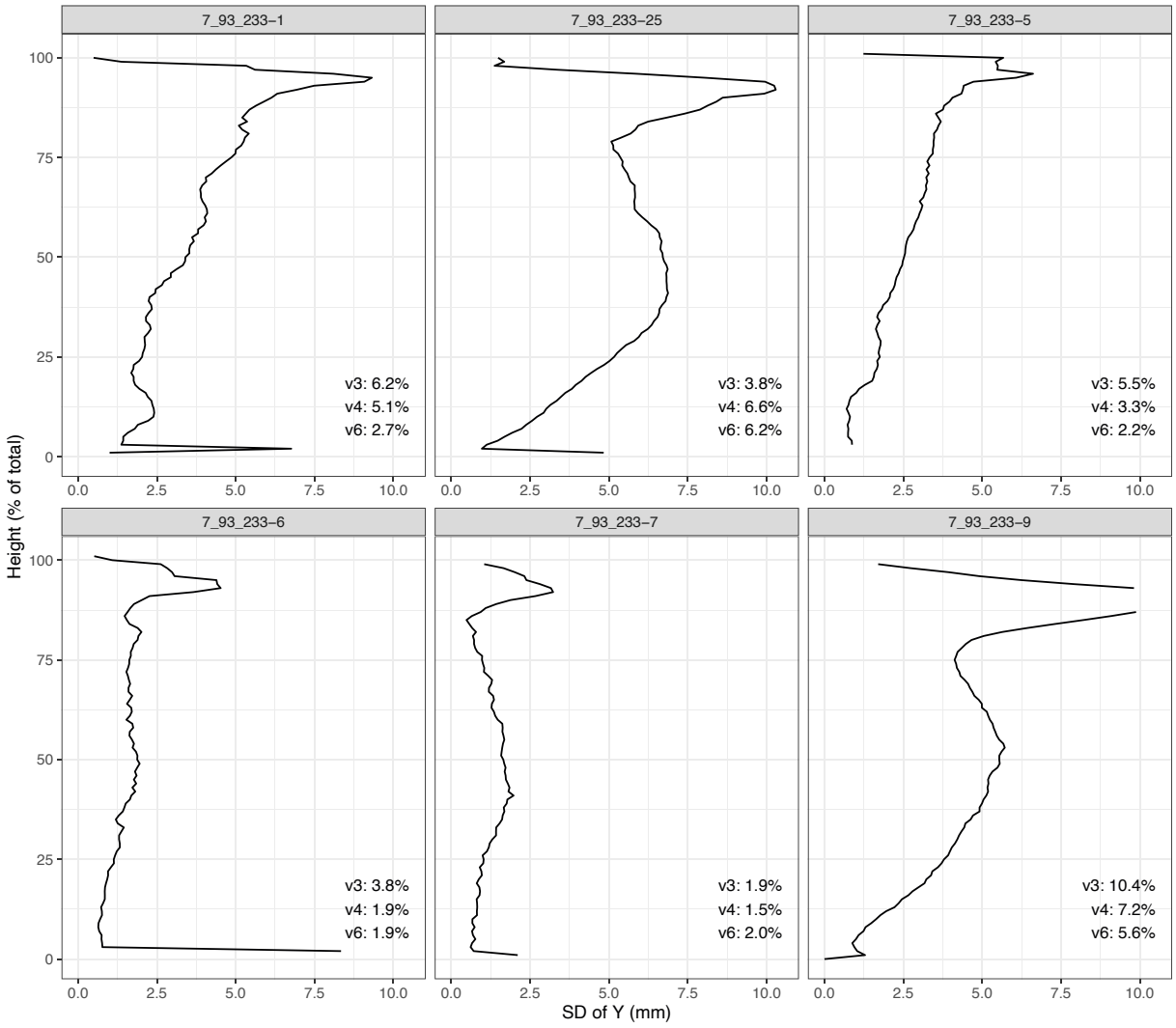
post-forming processes – such as removal of the vessel from the wheel or other handling – while the clay was still moist and structurally unstable.

Firing

The firing technology cannot be objectively evaluated, as the batch was severely affected by overfiring. This resulted in shape deformations of several vessels as well as in the overfiring of the paste itself. Numerous cracks around large quartz grains in the vessel walls and bases indicate rapid temperature fluctuations during firing.

Firing characteristics were assessed approximately on the basis of firing types observed on rim fragments. Mixed or black-core firing predominated (40%), followed by strongly overfired pottery (27%), reduced fragments (19%), and oxidised ones (14%). The heterogeneity of firing features may indicate that the kiln was destroyed during the peak stage of firing, before it was completely sealed. Due to thermal deformation of the vessels in the front part of the kiln – where the highest temperatures can be expected – the batch may have collapsed under conditions of maximum heat and rapid firing.

The firing characteristics observed in selected samples indicate a generally mixed firing atmosphere. Most samples of fabric A exhibit a reduced or weakly reduced core, while the sub-surface matrix is oxidised (Fig. 67: F). The presence of reduction features is likely linked to relatively high



Graph 7. Jihlava – Křížová Street, kiln 927. Diagram showing the standard deviation of the outer surface from the rotational axis across vessel height. Vessel part indices (v3, v4, and v6) are indicated, along with the corresponding coefficients of variation for each respective vessel part. Author K. Slavíček.

firing temperatures, which in samples 5 and 8 may have approached 950°C. This estimate is based on the extent of the optically inactive matrix and the low or absent pleochroism of biotite (Fig. 67: G). Additional evidence is provided by the presence of neoformed spinel (close to hercynite) identified through XRD analysis (Graph 8). Other samples from this fabric were fired at lower temperatures, estimated at <850–900°C based on low optical activity of matrix and biotite pleochroism. Samples of fabric B were predominantly oxidised, with the exception of sample 10, which shows a reduced core. The matrix optical activity varies and can be slight or moderate, as well as none especially in the core. While firing temperatures for this group are estimated below 850°C, sample 10 was fired up to 900°C. The temperature estimate was based on the presence of neoformed spinel and magnesium aluminosilicate identified by XRD. Both analysed samples of fabric C are fully oxidised and their matrix optical activity is relatively high, while biotite pleochroism is medium. The firing temperature estimate is <800°C. The glazed sherd of fabric D (sample 2) was fired at a temperature below 1000°C (Fig. 67: H), as indicated by very low matrix optical activity and the presence of newly formed spinel and the absence of mullite. The reference sherd from the kiln coating (sample 12) displays an optically inactive matrix, likely due to repeated exposure to elevated temperatures (<950°C).

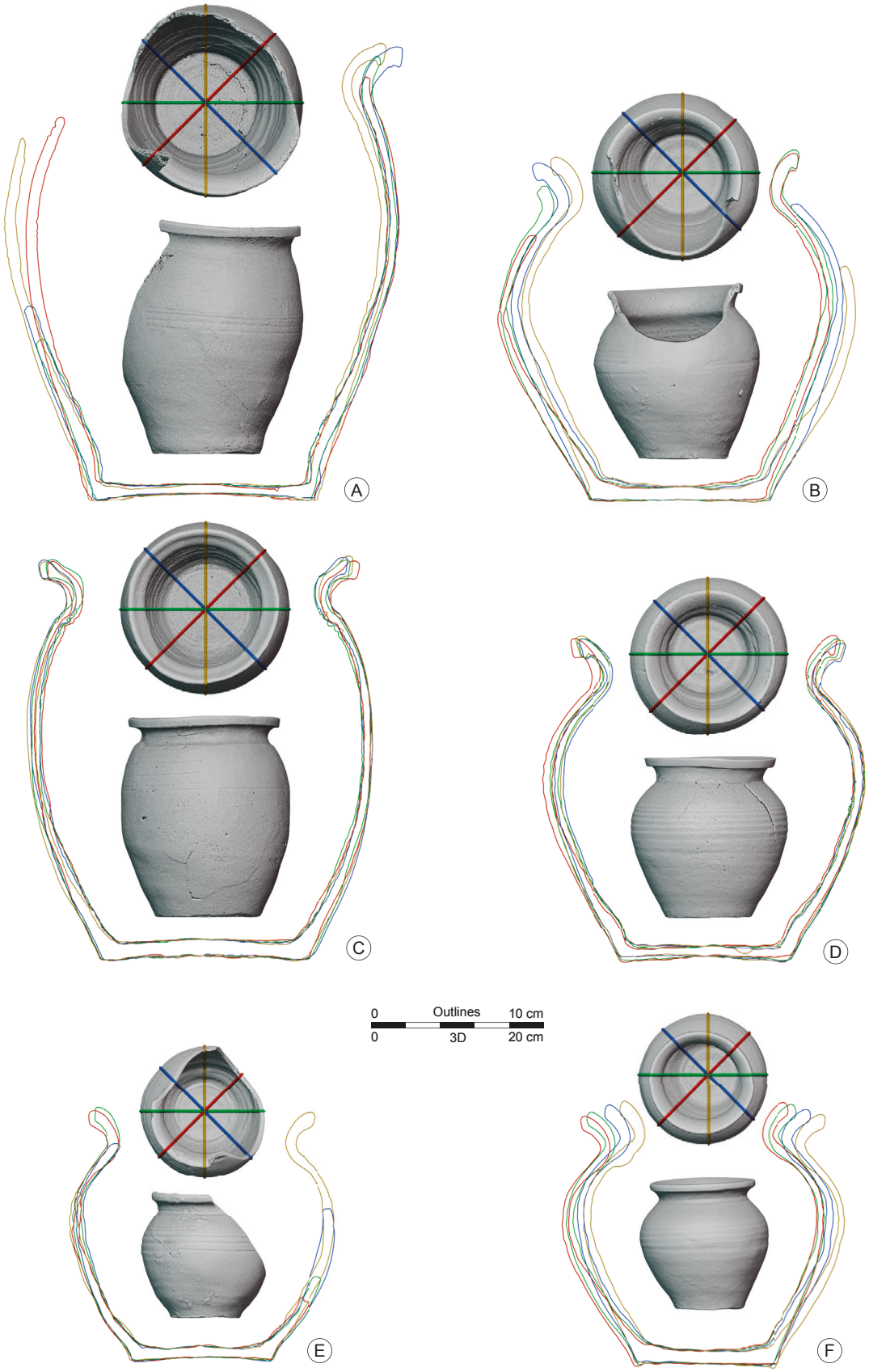
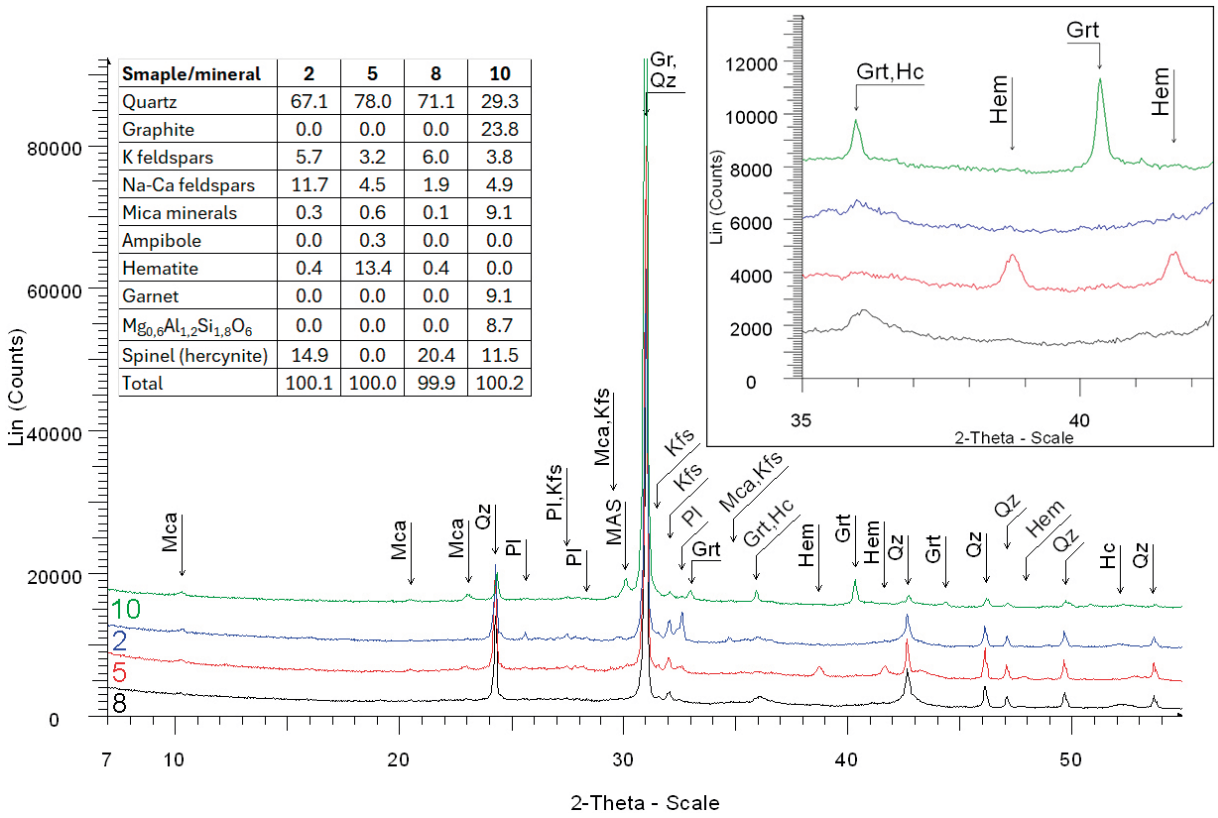


Fig. 69. Jihlava – Křížová Street. 3D models and vertical cross-sections showing degree of vessel symmetry, inv. No.: A – 7/93-233/1; B – 7/93-233/25; C -7/93/-233/5; D – 7-93/233/6; E – 7-93/233-7; F – 7-93-233/9. Author M. Košťál.



Smaple/mineral	2	5	8	10
Quartz	67.1	78.0	71.1	29.3
Graphite	0.0	0.0	0.0	23.8
K feldspars	5.7	3.2	6.0	3.8
Na-Ca feldspars	11.7	4.5	1.9	4.9
Mica minerals	0.3	0.6	0.1	9.1
Ampibole	0.0	0.3	0.0	0.0
Hematite	0.4	13.4	0.4	0.0
Garnet	0.0	0.0	0.0	9.1
$Mg_{0,6}Al_{1,2}Si_{1,8}O_6$	0.0	0.0	0.0	8.7
Spinel (hercynite)	14.9	0.0	20.4	11.5
Total	100.1	100.0	99.9	100.2

Graph 8. Jihlava – Křížová Street, kiln 927. Diffractograms of samples 2, 5, 8, and 10 (angular range 7–55 °2θ) and results of quantitative phase analysis of crystalline fractions of the samples. The inset in the upper right corner shows an enlarged area of the record containing well-defined reflections of phases indicating firing conditions. Hematite forms under oxidizing conditions. Neoformed spinel (close to hercynite) forms during the firing of ceramics under reducing conditions at temperatures around 950°C. The simultaneous presence of hematite and a relatively large amount of spinel in samples 2 and 8 corresponds to initial oxidizing conditions, which changed to reducing ones. The absence of spinel and a high hematite content in sample 5 is the evidence of only oxidizing firing conditions. Another neoformed phase present only in the sample 10 is magnesium aluminosilicate with hexagonal symmetry corresponding to μ-cordierite; Gr = graphite, Grt = garnet, Hc = spinel close to hercynite, Hem = hematite, Kfs = K-feldspars, MAS = phase close to Mg0,6Al1,2Si1,8O6 (μ-cordierite), Mca = mica minerals, Pl = Na–Ca feldspars, Qz = quartz. Author D. Všianský.

4.2.4 Pottery from kiln 925 and its stoking pit

The finds from kiln k 925 were fragmentary. They included small sherds obtained from limited excavation within the kiln fill and larger pottery pieces from the stoking pit. In their properties, the material roughly corresponds to the analysed batch from kiln 927. From the kiln bottom came fragments of pots: a rim of type S.3.8 and a body fragment decorated with grooves. These are heavily overfired fragments, with red lumps visible in the paste alongside quartz grains. In addition, five rim fragments of type P.1.4 were found, containing apparent graphite temper and a higher proportion of mica, fired reductively to a dark grey colour. Four small body fragments were also recovered – two made of sandy paste with oxidising firing, and two with higher mica content fired in a reducing atmosphere (Fig. 70).

The stoking pit contained larger fragments and vessel torsos. It remains uncertain whether they derived from the kiln to which the pit belonged – after its abandonment – or whether they were deposited secondarily, for example from another nearby kiln. Sandy paste pottery predominates, with some fragments showing a higher content of fine mica or red inclusions within the paste (iron-rich clay pellets). Graphite temper or coarse mica inclusions appear only sporadically. Four body fragments of fine, light beige pottery were also identified; this paste type has no analogy in the other kiln. On vessel walls, traces of coiling are visible in the form of wall undulations or linear cracks along coil junctions, while some fragments have smooth interior surfaces. Two base fragments preserve traces of sand dusting. Part of the assemblage bears signs of overfiring, typically in the form of an oxidised surface or a dark core (Fig. 70).

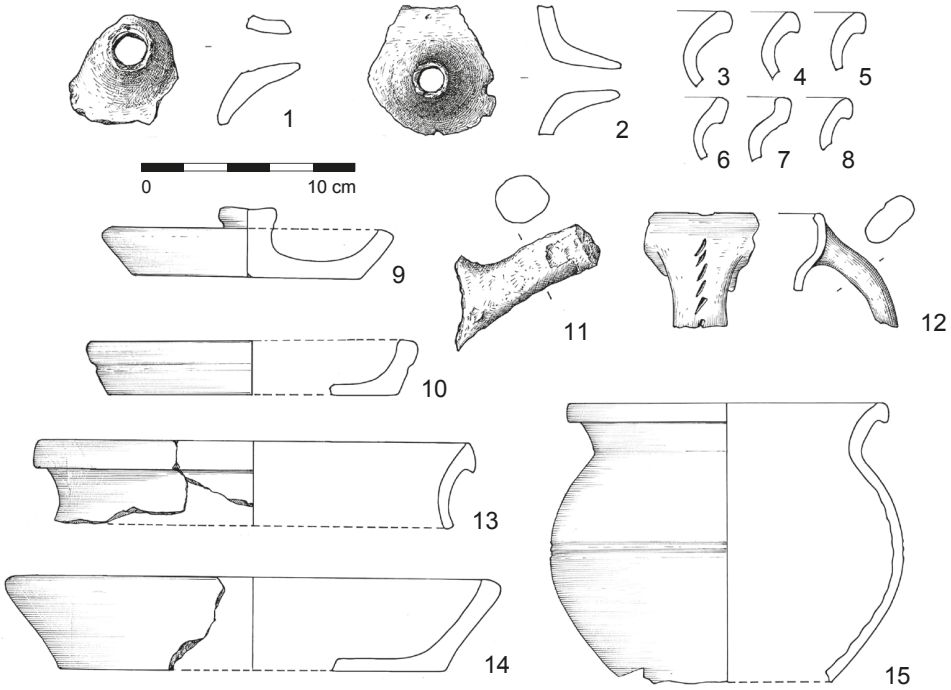


Fig. 70. Jihlava – Křížová Street. Vessels from kiln 925, inv. No.: 1 – lamp, 7/93-233/29; 2 – tangard spout, 7/93-237/2; 3 – tangard spout, 7/93-237/2; 4 – pot rim, 7/93-237/6; 5 – pot rim, 7/93-237/1; 6 – pot rim, 7/93-237/5; 7 – pot rim, 7/93-237/8; 8 – pot rim, 7/93-237/13; 9 – pot rim, 7/93-237/9; 10 – lid, 7/93-237/2; 11 – handle fragment, 7/93-237/2; 12 – jug handle, 7/93-237/2; 13 – pot, 7/93-925/1; 14 – shallow bowl, 7/93-237/2; 15 – pot, 7/93-237/2. Drawings by L. Dvořáková.

The assemblage is dominated by pot fragments, including one larger torso with a rim of type S.2.1 and thirteen additional pot rims: six of type S, four of type V, two of type VN, and one of type P. The vessel bodies were decorated with grooves, in one case with a wavy line, and in another with a roulette pattern. A smoked sherd with rouletted decoration may represent a later intrusion, given both the character of the roulette and the technological features.

Approximately twenty fragments of storage vessels were also recovered. Two flat lids with central knobs were preserved in a nearly intact state, along with two additional lid fragments. Two sherds belong to a form that can be described as a low bowl or a deep plate (two fragments preserving both rim and base). Stirrup-handled ewers are represented by four handle fragments, two spout fragments, and one rim fragment. A jug is represented by a single handle fragment with scratches. Two glazed pottery fragments and one stove-tile fragment may represent later intrusions.

4.3 Kostelec near Jihlava

Kostelec near Jihlava is located in the Vysočina Region, 8.5 km southwest of Jihlava and 8 km north of Třešť (Fig. 71). The first written mention of the village dates to 1288. Recent archaeological excavations have confirmed a pre-foundation settlement dated to the first half of the 13th century, with a battery of bread ovens situated north of the present-day village (Těsnohlídek, Hejhal 2019, 18). The site with the pottery workshop was located near road II/406, on the southern edge of the modern village. It lay outside the medieval core of the settlement, which was concentrated around the Church of St Kunhuta. The area was built over only in the 19th and 20th centuries (Zimola, Vokáč 2011, 437–442, Zimola 2021, 104).

At the end of 1953, a pottery workshop was discovered in Kostelec near Jihlava, indicated by a large quantity of pottery fragments. In September 1954, the pottery kiln itself was disturbed during the construction of foundations for a residential house for employees of the former state enterprise Masna (today plot No. 1954/3). Thanks to the efforts of L. Meduna, then an archaeologist at the Krajské muzeum v Jihlavě (today Muesum Vysočiny Jihlava), a rescue excavation was carried out. This represents the earliest known pottery workshop in the region (Meduna 1954; Zimola 2021, 102–103).

The excavation report dated 15 October 1954 includes a basic field drawing of the kiln, a hypothetical reconstruction, and a written description. The drawing reconstruction was prepared at least partly afterwards at the museum rather than directly on site. Unfortunately, the photographs taken during the excavation did not adequately capture the ground plan of the feature and therefore cannot assist in refining the drawings. The finds are stored in the depository of the Vysočina Museum in Jihlava.

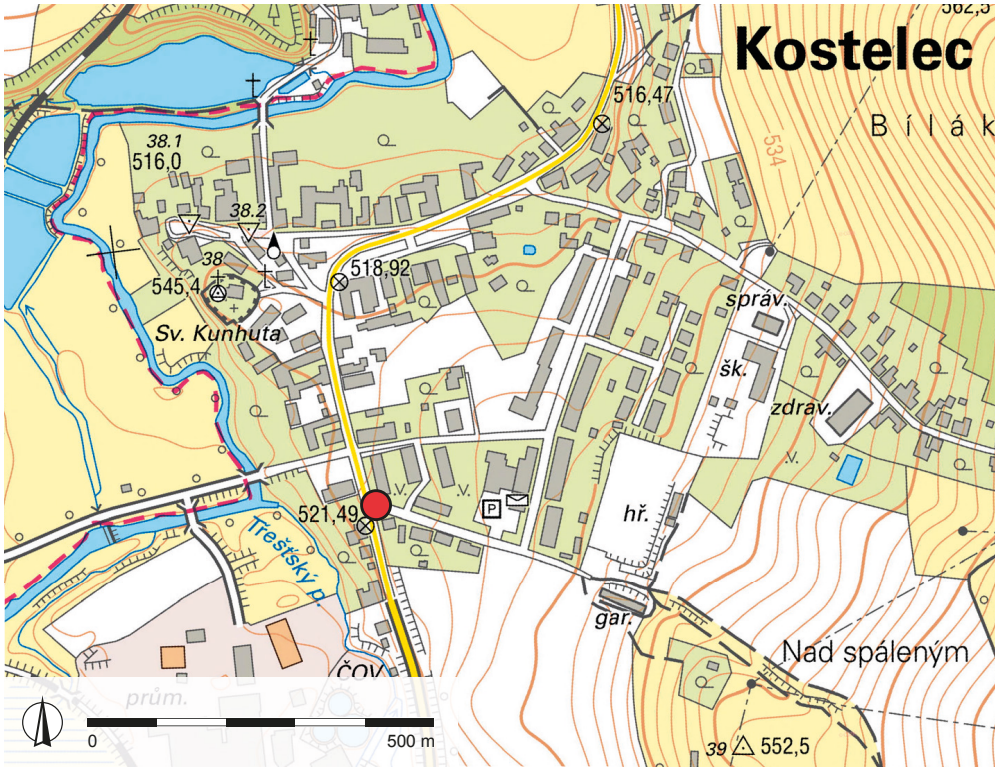


Fig. 71. Kostelec near Jihlava. Location of the kiln on the current map. Source: mapy.cz, author M. Filip.

The kiln was first published in 1955 in the journal Naše vlast, which featured a brief summary of the find on its back page (Meduna 1955). A concise evaluation of the material was later carried out by J. Bláha as part of his doctoral thesis, and subsequently by R. Zatloukal in a study focused on pottery kilns from Jihlava and its surroundings (Bláha 1968, 148; Zatloukal 1998, 30–31). The kiln was originally dated to the 15th century, later to the turn of the 13th and 14th centuries (Meduna 1954; Bláha 1968, 148; Zatloukal 1998, 30–31). The pottery assemblage from the kiln was recently reanalysed by D. Zimola and attributed to the first half of the 14th century (2021, 102–117).

4.3.1 Kiln relic

The kiln floor was almost circular in shape (Fig. 72). Its perimeter was defined by a layer of clay and daub fired to a reddish colour. The walls were preserved to a height of about 1 m. Along the walls and in the rear part of the kiln were large, flat, overfired stones, some of which may have formed a paving at the base of the kiln. Additional stones found in the central part may have belonged to the former central spoon. Large lumps of clay were also recovered, probably originating from the collapsed dome or the grate of the kiln. The walls were coated with clay and fired to red. The firing chamber measured 190 cm along its longer axis and 180 cm along the shorter one; the stoking pit measured 70 × 70 cm.

The stoking pit contained a layer of ash and charcoal. The kiln can most likely be classified as horizontal single-chamber kilns with a central spoon (Meduna 1954; Zatloukal 1998, 35; Procházka 2015, 217; Zimola 2021, 105).

A number of complete vessels were found inside the kiln, accompanied by numerous fragments. Photographs indicate that some of the vessels were discovered in an inverted position, probably in their original placement, representing the remains of the kiln's last batch (Fig. 72). The archaeologist also noted that smaller vessels had been inserted into larger ones. This interpretation is questionable, as the pottery corresponds to already smoked ware, which could have been damaged by such handling. Part of the assemblage is heat-deformed, and some sherds are underfired (Meduna 1954). A total of 4,211 fragments were recorded from the kiln fill, from which at least 204 individual vessels could be reconstructed (Zimola 2021, 107). This number is probably too high for a single batch, suggesting that the assemblage may also include production waste from the surrounding area or material found in the close vicinity of the kiln that was later attributed to the kiln fill during excavation.

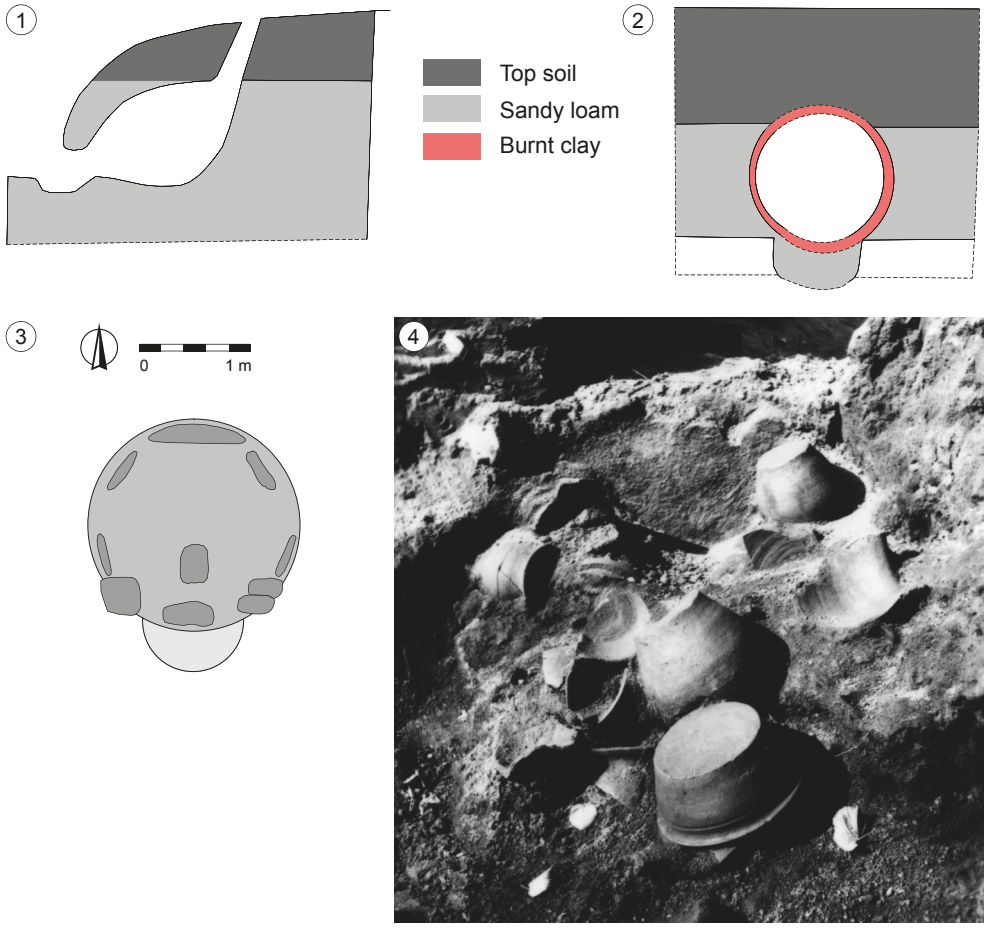


Fig. 72. Kostelec near Jihlava. Excavation context of the kiln, after the original field drawing. 1, 2 – sections; 3 – plan of the kiln with large stones on the surface of the firing chamber floor; 4 – photo of complete and fragmented vessels in the firing chamber of the kiln. Modified after Meduna 1954 and Zimola 2021,105, obr. 8, 9. Graphics by M. Filip.

4.3.2 Morphology, typology and metric properties of pottery

Only a small portion of the assemblage was preserved in large fragments, yet a substantial number of vessels could be reconstructed. Photographs of the complete vessels from the kiln batch show approximately 27 complete or partially preserved pots with full profiles. Apart from pots without handles, one jug and one bowl with a spout in the rim can be identified (Fig. 73). Pots dominated the assemblage (87%). Other vessel types were represented by jugs (6%), bowls (3%), lids (3%), and storage vessels which were represented by several fragments (2%) (Fig. 74, 75). The rim of the storage vessel (three fragments) corresponds to Brno type 15.2, indicating connections with the Austrian



Fig. 73. Kostelec near Jihlava. Original photographic documentation of complete vessels and fragments. After Meduna 1954.



Fig. 74. Kostelec near Jihlava. Complete pots, inv. No.: 1 – JiFS-39/967 (2391); 2 – JiFS-39/925; 3 – JiFS-40/355 (2392); 4 – JiFS-39/919; 5 – JiFS-39/950 (2393); 6 – A739; 7 – JiFS-39/969; 8 – JiFS-40/283 (2415). Photo by M. Košťál.

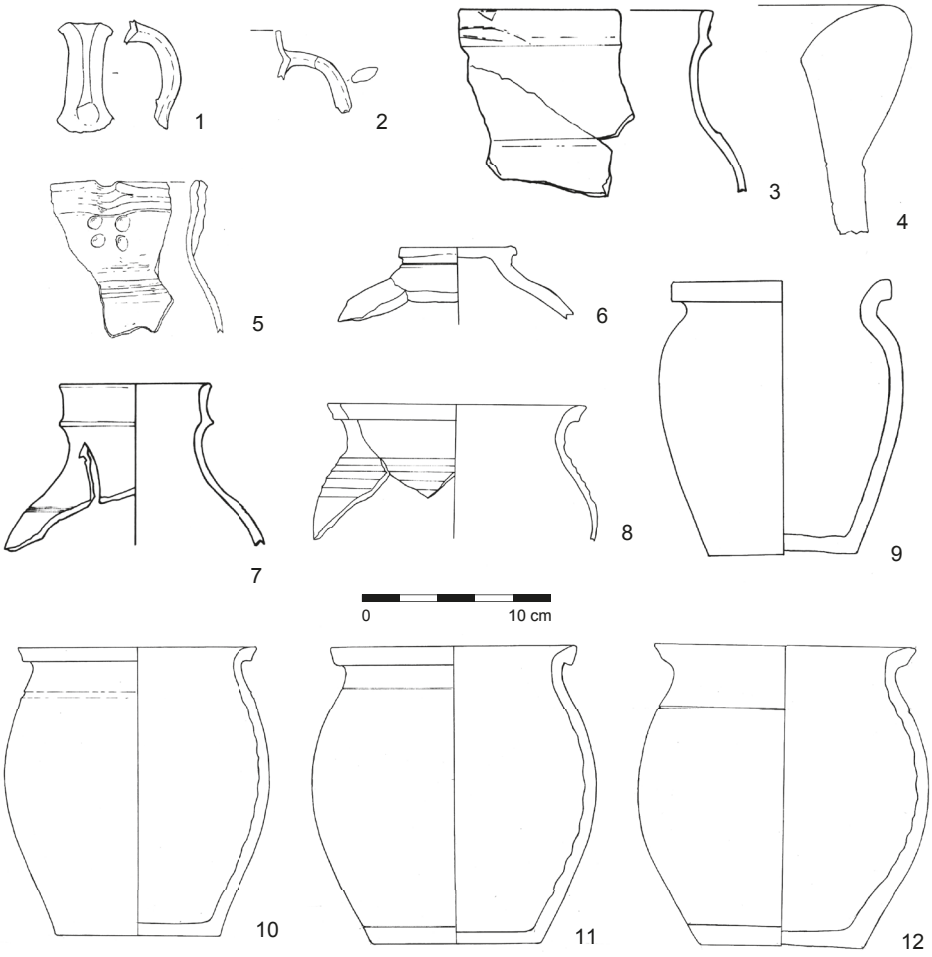


Fig. 75. Kostelec near Jihlava. Selected vessels and fragments, inv. No.: 1 – A 732/45; 2 – A 732/36; 3 – A 732/3; 4 – A 717/1; 5 – A 732/1; 6 – A 733/3; 7 – A 732/4; 8 – A 793/1; 9 – without inv. No. (after Bláha 1968, pl. 43/1); 10 – JiFS-39919; 11 – JiFS-40355; 12 – JiFS-39969. Drawings by L. Dvořáková after Zimola 2021,110–113, obr. 14: 1; 15: 4; 16: 8, 10; 17: 7.

ceramic tradition of the 14th century (Unger 1984, 294; Scharrer-Liška 2007, 41–42).

At present, only eight complete vessel forms are preserved. The pots have relatively low, smoothly profiled necks. The maximum body diameter is located between the midsection and the upper third of the vessel (Fig. 74, 75). The heights of the eight measured pots range from 14 to 22.4 cm (mean 19 cm); rim diameters range between 13.8 and 18.2 cm (mean 13.08 cm); maximum body diameters between 13.7 and 19.9 cm (mean 17.9 cm); and base diameters between 10.5 and 12.6 cm (mean 10.9 cm). The volumes of these vessels range from 1.8 to 5.2 l (mean 3.6 l).

Five of the vessels have a low-set maximum diameter, and three a moderately placed one (W index), corresponding to barrel-shaped to globular forms. The vessel bodies are strongly swollen, with one pot classified as moderately swollen but positioned close to the boundary between the two categories (D index). The degree of bulbosity is also high (H index). Both the mean and median values of the Z index fall within the medium category, approaching the 'low' level, into which only a single vessel falls (Tab. 11).

Among the pot rims, nearly half belong to type V (47%), about one quarter to type P (24%), and another quarter to type S (27%), with distinctly

	No. of pots	W	H	D	Z
Index range	8	0.39–0.47	1.01–1.13	0.49–0.71	1.58–1.88
Mean	8	0.44	1.06	0.62	1.7
Median	8	0.45	1.06	0.63	1.675

Tab. 11. Kostelec near Jihlava. Pot index values.

thickened rims prevailing within the latter group. Rim type OV occurred only once. Jug rims were represented by ten specimens: seven jugs with rim type DZ.3, two fragments with rim type DZ.5, and one fragment with rim type DZ.4. The bowl had a rim of type M.1 (Fig. 76).

The vessel bodies are generally undecorated, with decoration appearing only in a few cases. The shoulders of some pots bear grooved or incised decoration (rarely a single groove, more often around five) similar to examples from Mstěnice. However, in Kostelec these grooves often form a fully developed spiral of broad incised lines. One or two grooves also occur on the necks of jugs. Three body fragments display a simple wavy line. At the base of the jug spouts, pairs of impressed pits were used as decoration, and a similar motif appears on the upper parts of the handles (Zimola 2021, 111, obr. 15: 1, 4).

4.3.3 Ceramic technology

Ceramic paste

The pottery was made from clay with a natural addition of sand and mica. Only a small amount of mica is visible in the paste, which is relatively fine in texture. Graphite-tempered pottery is absent, while a higher content of mica appears only sporadically on some fragments. Macroscopically, the pottery thus appears fairly homogeneous, with the observed differences primarily related to the firing atmosphere.

Although 20 samples were analysed (Tab. 12; Fig. 77), the results did not reveal any significant compositional differences that would justify the definition of multiple ceramic fabrics (Tab. 13). Some variability was present but can be interpreted as natural variation within a local clay source (for a summary of elemental concentrations, see Tab. 14). The raw material used was a clay with a relatively

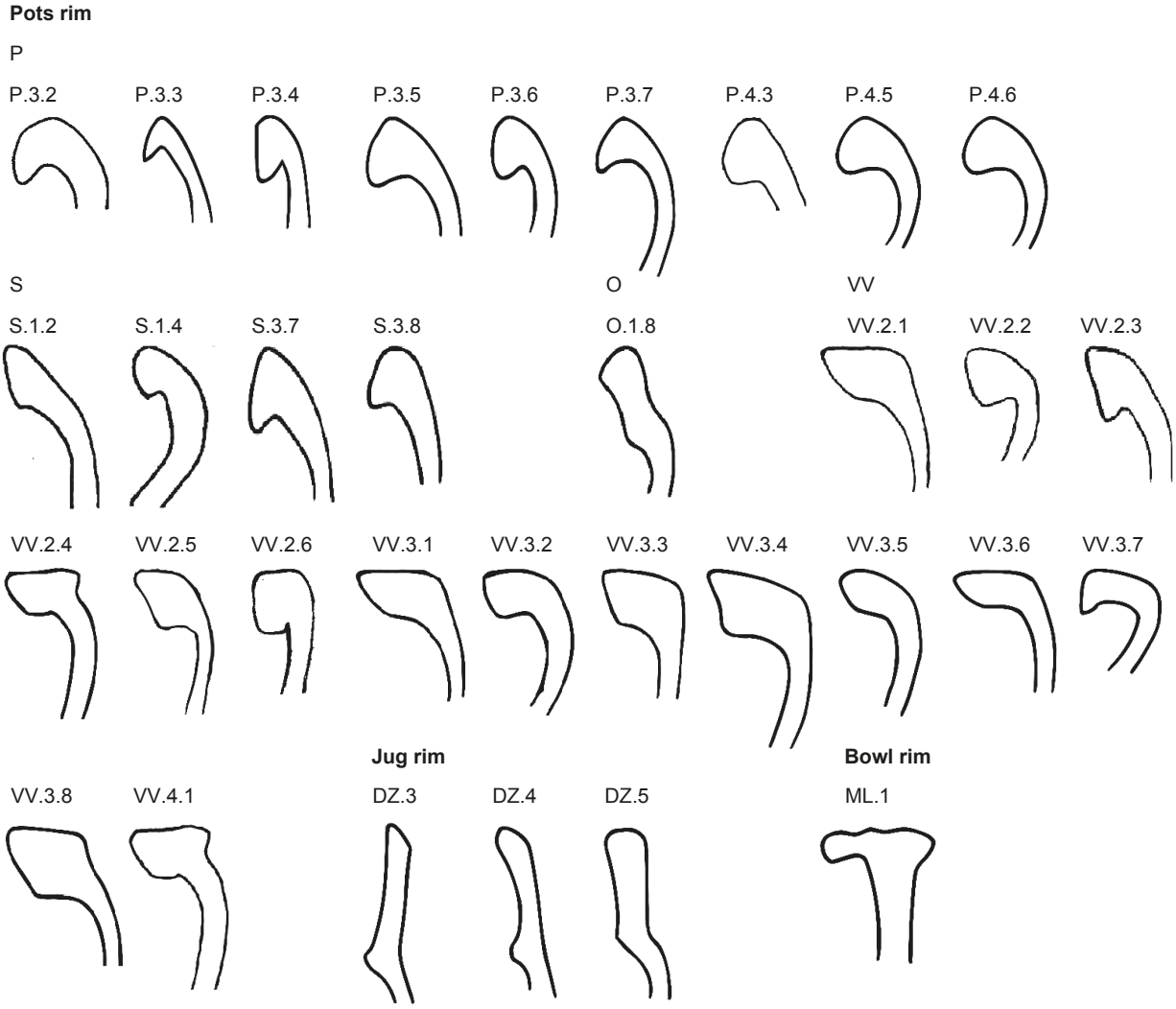


Fig. 76. Kostelec near Jihlava. Rim types. Drawings by K. Těsnohlídková.

ID	Accession number	Vessel type	Ceramic class
1	A783/8	Pot	Sandy
2	A783/7	Pot	Sandy
3	A783/28	Pot	Sandy
4	A796/4	Pot	Sandy
5	A793/3	Pot	Sandy
6	A786/1	Pot	Sandy
7	A786/6	Pot	Sandy
8	A779/18	Pot	Sandy
9	A779/14	Pot	Sandy
10	A779/6	Pot	Sandy
11	A778/21	Pot	Sandy
12	A780/10	Pot	Sandy
13	A780/21	Pot	Sandy
14	A781/19	Pot	Sandy
15	A781/5	Pot	Sandy
16	A782/11	Pot	Sandy
17	A782/15	Pot	Sandy
18	A776/36	Pot	Sandy
19	A776/39	Pot	Sandy
20	A776/23	Pot	Sandy

Tab. 12. Kostelec near Jihlava. Samples selected for analyses.

	Mean	Sd	Min	Max
SiO_2	69	1.1	67.2	70.9
Al_2O_3	21	1	18.3	22.1
Fe_2O_3	5.2	0.6	4.4	6.4
K_2O	2.8	0.3	2.3	3.4
CaO	1	0.1	0.9	1.3
TiO_2	0.9	0.1	0.8	1
V	110	10	92	128
Mn	283	44	222	376
Ni	42	3	39	46
Cu	43	5	34	54
As	11	1	10	13
Rb	159	26	123	206
Sr	82	12	67	110
Ba	283	133	119	602
Pb	26	2	23	32

Tab. 14. Kostelec near Jihlava. Summary of the chemical composition (major oxides in wt %, trace elements in ppm).

Sample IDs	Fabric description	Fabric features	Petrographic markers	Possible sources
All samples	Sandy, non tempered, clayey matrix low in silt particles, rich in biotite	Weakly parallel microstructure, particles alinged on the surface of former coils in some samples, unimodal grain size distribution, iron-rich clay pellets, plant tissue	Quartz, biotite, gneiss, alkali feldspar, plagioclase, granitoid, muscovite, amphibole, sillimanite, serpentinite, metaquartzite, pyroxene, garnet, tourmaline, chlorite	Eluvial or alluvial deposits derived from eroded crystalline Moldanubian rocks

Tab. 13. Kostelec near Jihlava. General description of fabrics (petrographic markers are listed in order of relative abundance).

low proportion of silt-sized particles (Appendix 2-C). The total content of non-plastic inclusions (silt and sand fractions of average size 150–280 µm) ranged from 10 to 20 vol.%. Sand grains of up to 2 mm were predominantly sub-angular to sub-rounded and mainly equant in shape. The inclusions were generally very poorly sorted. The microstructure was weakly parallel, and grain-size distribution was mostly unimodal, with two samples showing a weakly bimodal character (samples 8 and 11). In several samples (3, 8, 9, 17), the orientation of sand particles followed the original shape of the coil (Fig. 78: A), indicating residual forming traces. Voids comprised approximately 5 vol.%, and their morphology included planar forms and vughs.

The potter's clay, which is quite rich in biotite, contained iron oxyhydroxides in about half of the samples, usually in occasional abundance, and clay pellets were also present at similar frequencies. Almost all samples contained preserved remains of plant tissue or voids after its combustion (Fig. 78: B). Based on their preservation, it is unclear whether these represent wood fragments or charcoal; however, their current character resembles charcoal. Their consistent presence suggests a systematic technological practice: either the clay was not cleaned of organic matter during paste preparation, or organic materials entered the clay intentionally (e.g. to reduce weight) or unintentionally during processing or storage.

The sand fraction was mineralogically dominated by frequent to abundant quartz grains (Appendix 1-C). Alkali feldspars and plagioclases were occasional to frequent and showed some variability. Biotite occurred in short lamellar fragments or stacks, ranging from occasional to abundant. Given their morphology, biotite flakes were most likely naturally present in the clay rather than deliberately added as temper (Fig. 78: C). Muscovite was mostly occasional. The most common accessory mineral was amphibole (rare to trace), present in all samples. Sillimanite was found in about half of the specimens, generally in rare

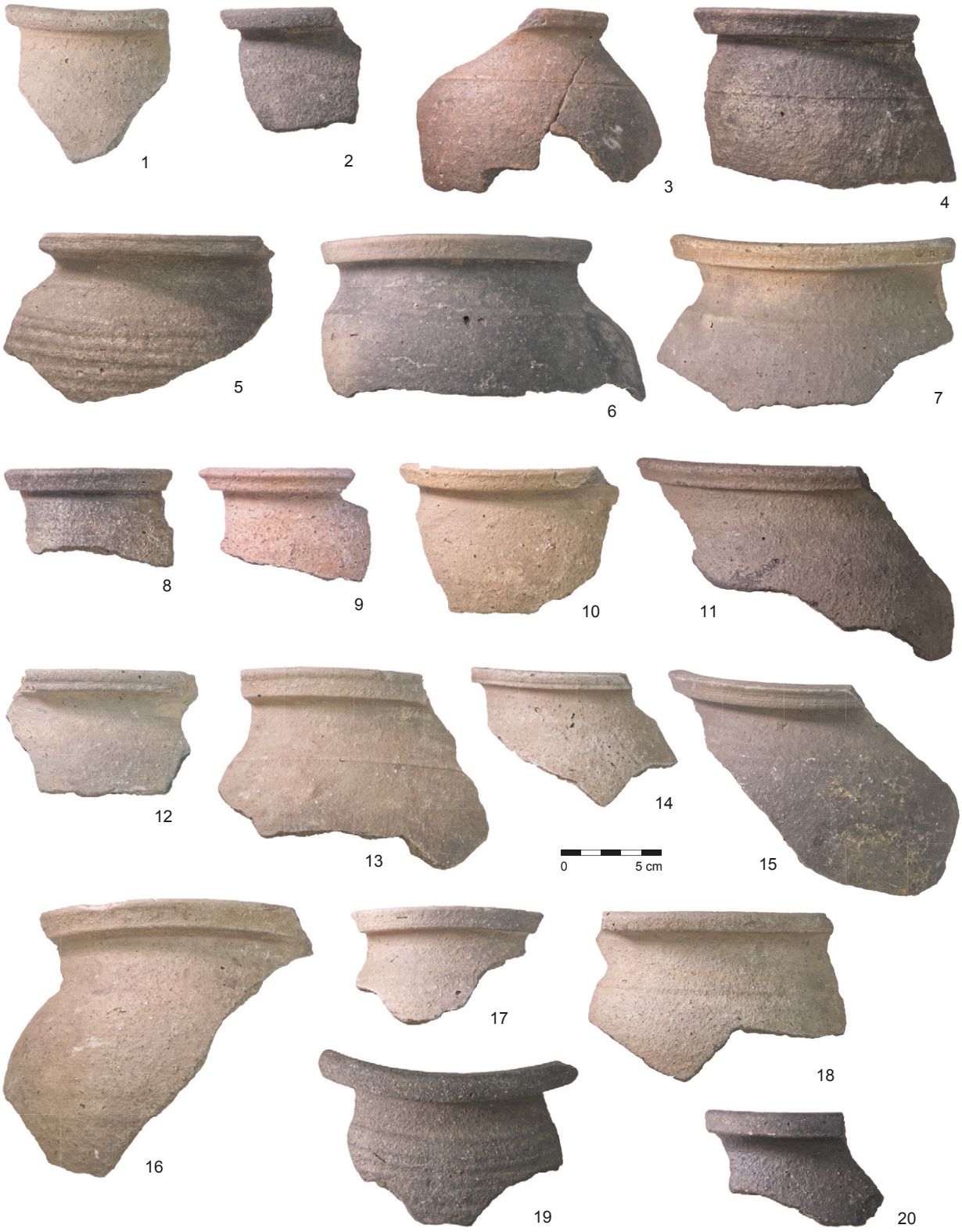


Fig. 77. Kostelec near Jihlava. Photodocumentation of analysed samples. Photo by M. Košťál.

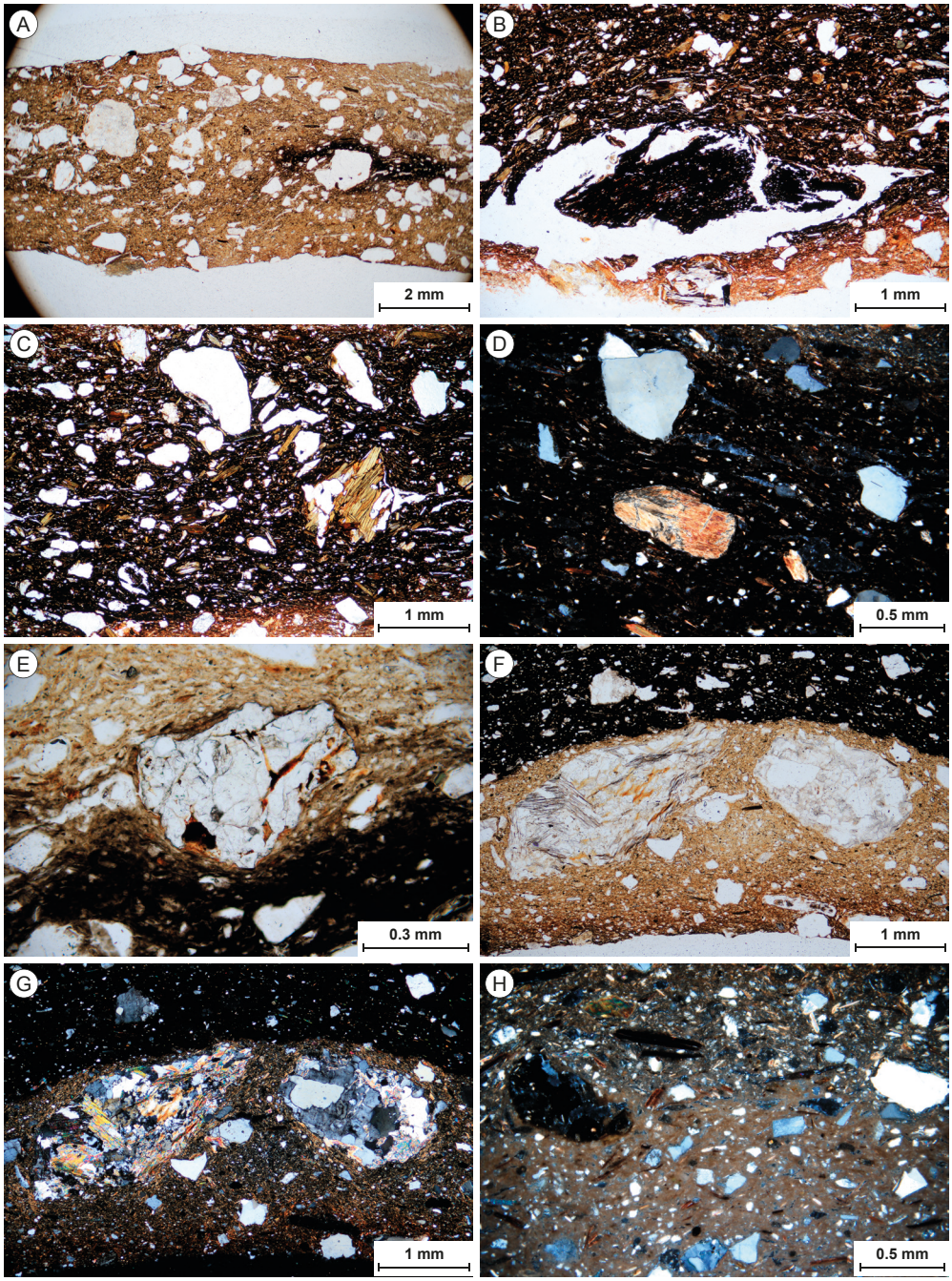


Fig. 78. Kostelec near Jihlava. Photomicrographs: A – overview of the microstructure in sample 9 (PPL). Predominantly weakly oxidised, locally reduced in the core. Unimodal grain size distribution. Non-plastic inclusions aligned along the surface of the original coil; B – plant tissue remains in sample 3 (PPL); oxidised surface layer, reduced core, abundant biotite with strong pleochroism; C – sample 3 (PPL), detail showing biotite abundance and a gneiss fragment, weakly parallel microstructure; D – sample 18 (XPL), detail showing quartz sand grains and sillimanite, weakly parallel microstructure; E – garnet grain at the boundary between oxidised and reduced zones in sample 9 (PPL); F, G – thin dark-smoked surface layer, clearly separated oxidised zone and reduced core; large sub-angular fragments of gneiss and granitoid in sample 6 (F – PPL, G – XPL); H – optically inactive matrix in the core of sample 1 (XPL). Author K. Slavíček.

amounts (Fig. 78: D). Pyroxene, garnet (Fig. 78: E), and tourmaline were only present in trace quantities. Among lithic fragments, gneisses were the most frequent (common to frequent), followed by granitoids (typically common; Fig.78: F, G). Serpentinite and metaquartzite fragments occurred less frequently.

The geological bedrock of Kostelec is composed of paragneisses and migmatites of the Moldanubian Zone. In this area, these units are in contact with granites of the Moldanubian pluton. Locally, serpentinites, limestones, and dolomites can be also found. Amphibolite body occurs south of the village,

while to the east, a north–south trending granulite zone extends along the landscape. The River Jihlava flows into Kostelec from the southwest, joined from the south by the Třešťský Stream. These waterways carry weathered material derived from gneisses, granites, and amphibolites. The petrographic composition of the analysed ceramics corresponds well with the local geological setting. The angular morphology of the grains suggests only short-distance transport. The clay used was naturally coarse-grained, likely derived from either eluvial or alluvial deposits.

Forming

Due to their relatively symmetrical shapes and the undulating profiles of their inner walls, the vessels were initially interpreted as wheel-thrown on a fast potter's wheel (Zimola 2021, 107). However, several features contradict this interpretation: distinct traces of sand dusting are visible on some vessel bases, while typical cut-off marks from removing vessels from the turntable are absent. In addition, coil impressions can be observed in the vessel walls. Although the possible use of sand dusting during wheel-throwing has been experimentally tested, the technique appears to be rather complex and unlikely (Bernhardt 2011). Peripheral traces of attachment to or removal from the turntable are either missing or only faintly visible, and no potters' marks were identified on the bases.

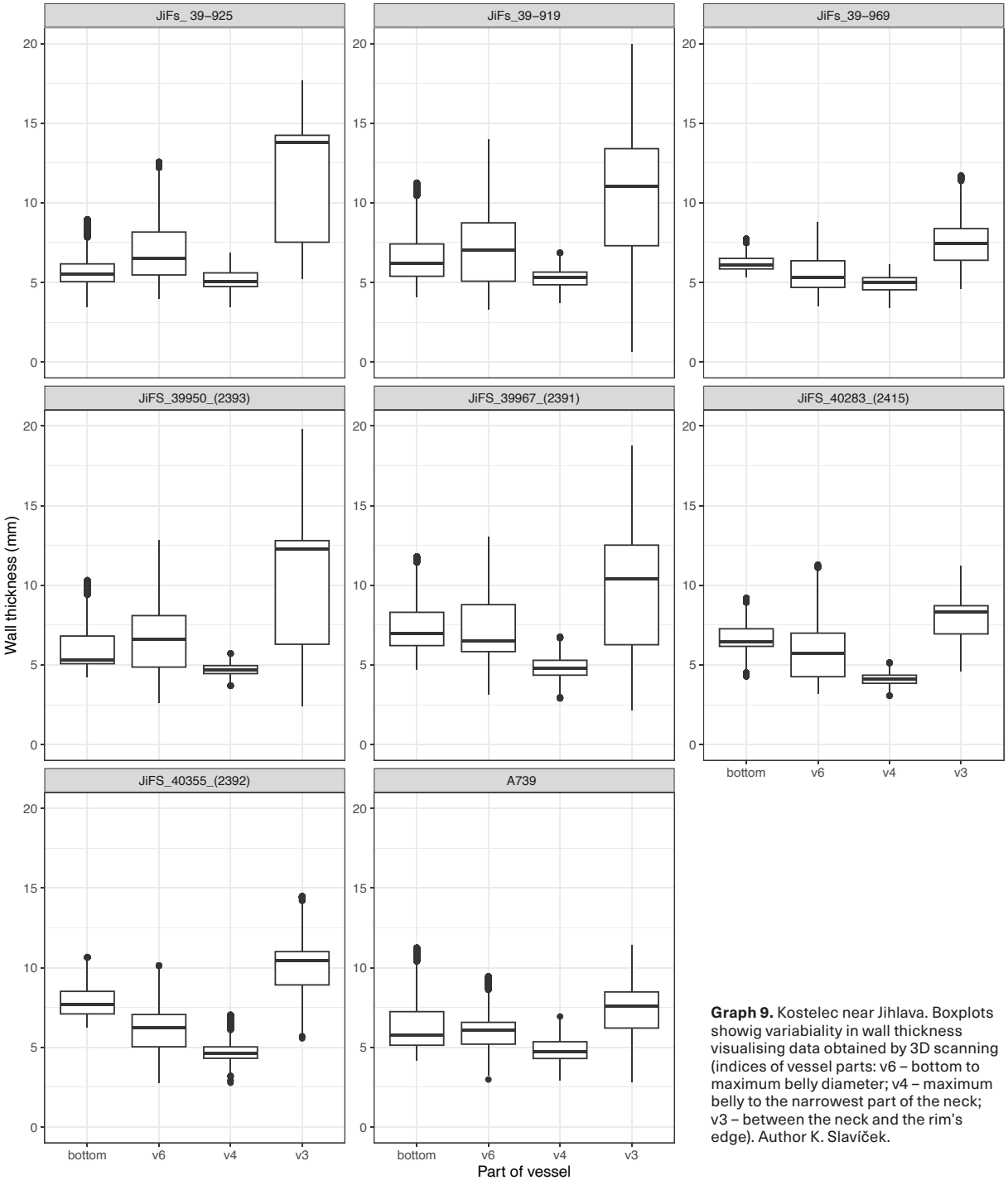
Wall thickness ranges from approximately 5–8 mm in the lower part of the body to 4–5 mm in the upper sections. Pronounced internal horizontal ridges are visible, but macroscopic traces of coiling are generally absent. Where present, they appear primarily in the lower part of the vessel, just above the base. However, thin-section analysis revealed particle orientation indicative of residual coiling in four samples (Fig. 78: A). A 3D scan of eight vessels and subsequent statistical analysis showed that the standard deviation of wall thickness was highest in the lower body (v6) and the rim (v3), at 1.3–2.1 mm and 1.2–3.6 mm, respectively (Graph 9; Appendix 3-C). The coefficient of variation for these zones was 19.3–30% and 15.3–30.4%, respectively. In contrast, the section between the point of maximum diameter and the neck (v4) consistently exhibited lower wall thickness across all vessels, averaging 4.7–5.3 mm, with relatively low variability (coefficient of variation 7.8–16.5%).

The ceramic vessels from the Kostelec kiln thus likely represent advanced techniques of wheel coiling, where the potter made full use of rotational kinetic energy to complete and refine the vessel form (Fig. 79). The high degree of technical control is evidenced by the pronounced axial symmetry of 3D scanned vessels, with a standard deviation in the radial distance from the rotation axis more or less stable and low (around or below 2.5 mm) from the bottom to the part below the rim (Graph 10; Fig. 80). Rims are the least symmetrical part of the vessel (standard deviation reaching up to 7 mm). The coefficient of variation is 1–4.1% and 0.8–4.5% for body sections v6 and v4, and 0.4–6.2% for the rim (v3). Coiling traces in the walls are almost completely smoothed out, only occasionally appearing as minor surface defects. An alternative explanation for the sand impressions on the bases is secondary in nature – potentially resulting from placing vessels on a sandy surface during drying. In this unlikely case, the vessels could still be wheel-thrown despite the absence of typical wheel removal traces.

Firing

Most of the vessels show traces of firing under predominantly reducing conditions, apparently with a relatively rapid course and a final closure of the kiln. Given the size of the assemblage, firing characteristics were quantified only for complete vessels and preserved rim fragments, i.e. a total of 302 specimens. Approximately two-fifths (42%) were fired with a light grey surface and a dark core; another fifth (21%) displayed a sandwich firing pattern with a dark core, light middle zone, and dark surface. Reduced pottery with a uniformly dark fabric and mixed-firing pottery each accounted for 14%. A small proportion consisted of homogeneous light-grey pottery (7%) and smoke-darkened ware with a light fabric (2%). On some vessels, traces indicating their placement within the kiln are visible.

The fact that the assemblage represents a misfired batch is indicated by heat deformation visible on several vessels, most notably the twisting of rims. In some cases, the rims are cracked or split by heat, and in three vessels the cracks extend through the entire body, almost reaching the base. The firing can therefore be regarded as unsuccessful, although the kiln did not collapse during the process; otherwise, the surface layer of the batch would not show oxidation. It is likely that part of the deformation occurred when high temperatures were reached in the final stage of firing, after the kiln had already been sealed. The firing process was thus completed, resulting in the partial smoking of the batch surface. The defects would have become apparent only after the kiln had cooled. It is also possible that only part of



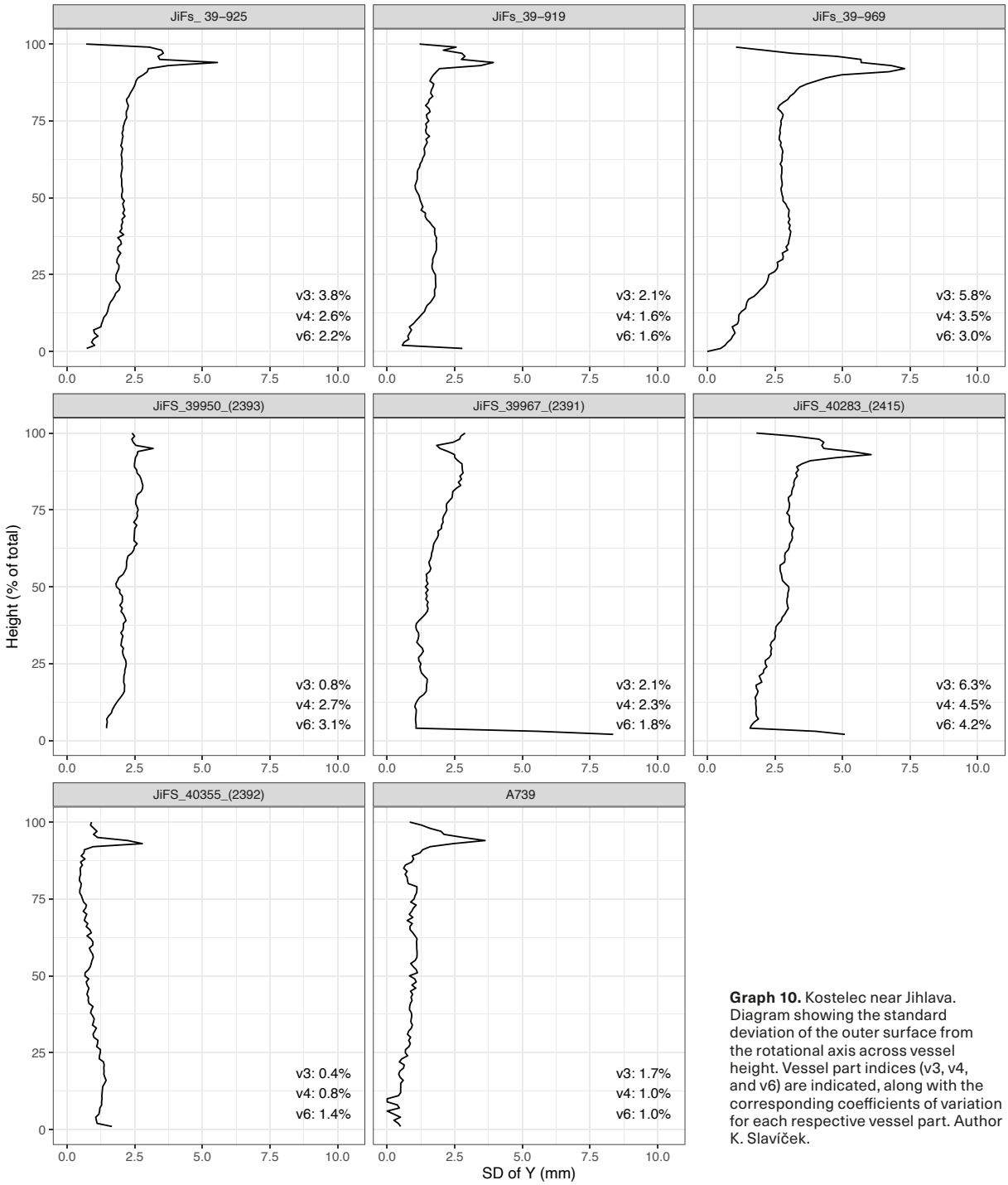
Graph 9. Kostelec near Jihlava. Boxplots showig variabiality in wall thickness visualising data obtained by 3D scanning (indices of vessel parts: v6 – bottom to maximum belly diameter; v4 – maximum belly to the narrowest part of the neck; v3 – between the neck and the rim's edge). Author K. Slavíček.

the batch was damaged and that the defective vessels were left inside the kiln. They were probably left *in situ*, in the same inverted position as during firing.

Firing conditions inferred from the analysed samples suggest a relatively rapid process at moderately low temperatures. Most sherds exhibited smoke-blackening on both the interior and exterior surfaces, while the cores were consistently strongly reduced. A weakly oxidised zone typically formed between the reduced core and the smoked surface (Fig. 78: F). Based on the moderate to strong pleochroism of biotite (Fig. 78: C), the colour transition of green amphibole (from green to colourless), and unburnt plant remains (Fig. 78: B), the firing temperature is estimated to have remained below 800°C, with some samples suggesting firing below 700°C. An optically inactive matrix was observed in only six samples (1, 7, 13, 14, 17, 18), typically forming a narrow layer between the reduced core and the oxidised zone beneath the surface (Fig. 78: H).



Fig. 79. Kostelec near Jihlava. Technological traces, inv. No.: 1 – grooves and rings below the neck (A 796/4); 2 – tool grooves indicating the use of fast rotation (A 783/28); 3 – faint ring traces (A 776/39); 4 – depressions/rings (A 782/11); 5 – faint joining lines of coils preserved below the neck (A 786/6); 6 – pronounced coil above the bottom and depressions/rings on the vessel wall (without inv. No.); 7 – S-shaped crack in the bottom and traces of cutting off with a string; interior of the bottom with rings (without inv. No.); 8 – crack in the wall of the pot caused by a rapid increase in temperature during firing (2392); 9 – sand dusting and cut-off traces along the outer bottom edge, and coil marks on the inner wall (not registered). Photo by M. Košťál.



Graph 10. Kostelec near Jihlava. Diagram showing the standard deviation of the outer surface from the rotational axis across vessel height. Vessel part indices (v3, v4, and v6) are indicated, along with the corresponding coefficients of variation for each respective vessel part. Author K. Slavíček.

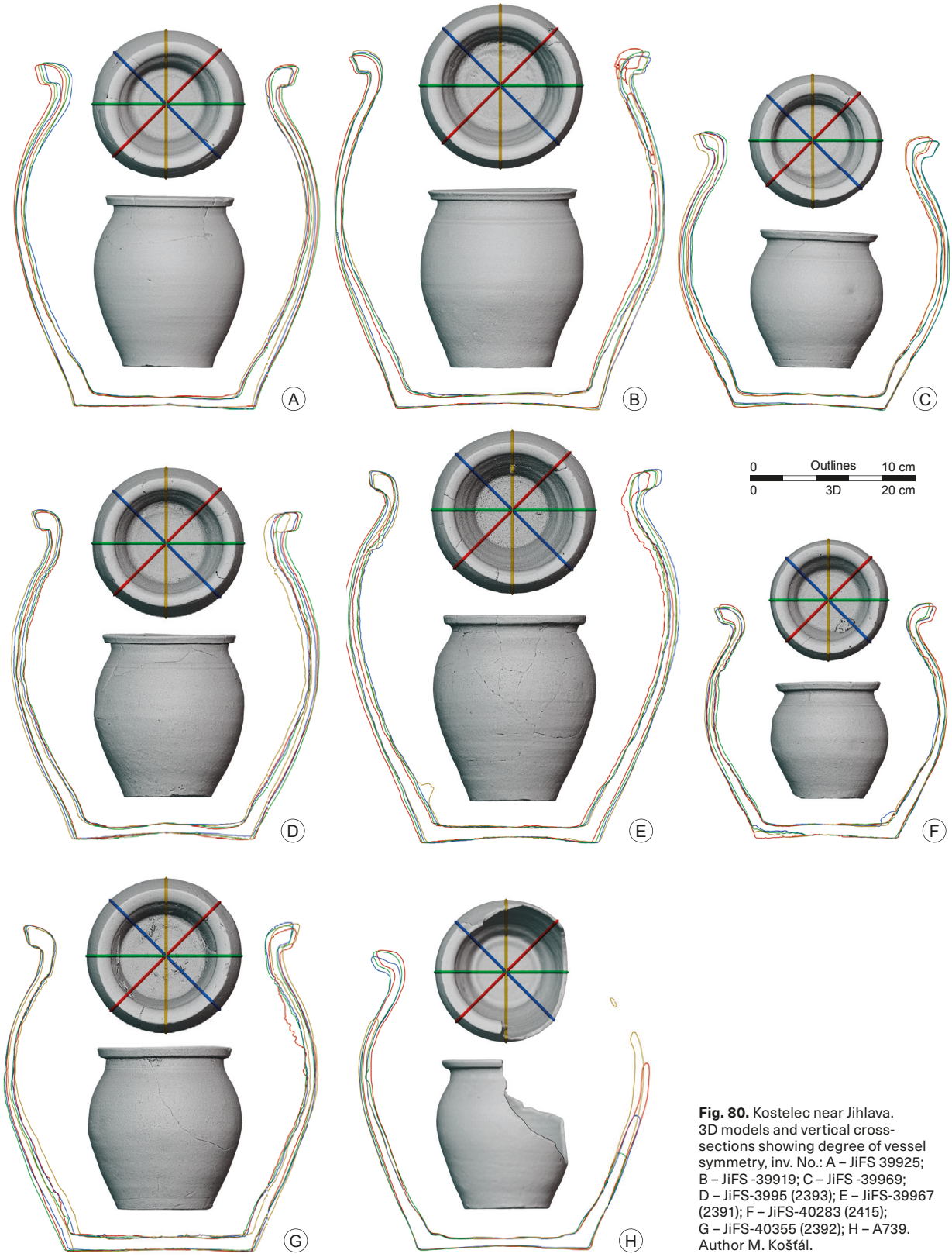


Fig. 80. Kostelec near Jihlava. 3D models and vertical cross-sections showing degree of vessel symmetry, inv. No.: A – JiFS 39925; B – JiFS -39919; C – JiFS -39969; D – JiFS-3995 (2393); E – JiFS-39967 (2391); F – JiFS-40283 (2415); G – JiFS-40355 (2392); H – A739. Author M. Košťál.

4.4 Mstěnice

Mstěnice is located 3 km southeast of the town of Hrotovice (Třebíč District) in the Hrotovice Upland, on the southeastern edge of the Bohemian-Moravian Highlands (Fig. 81). Settlement continuity is documented here from as early as the 8th century, reaching its peak in the 11th and 12th centuries. In the second half of the 13th century, a medieval village developed on the site, featuring a small castle and later a fortified manor. The first written mention dates to 1393. The settlement was abandoned during the Czech–Hungarian wars, probably in 1468, during the campaign of Matthias Corvinus against George of Poděbrady, and was never reoccupied.

Between 1960 and 2010, excavations were carried out at the site by the Moravian Museum under the direction of V. Nekuda and later his son R. Nekuda. Most of the site was uncovered during this long-term research. From the 13th–15th-centuries village, the excavations revealed a fortified manor, a courtyard, seventeen farmsteads surrounding the village green, and a mill (especially Nekuda 1985; 1992; 2000; Nekuda, Nekuda 1997; Nekuda, Přichystal 2008).

Remains of two pottery kilns were later uncovered beneath a three-room residential building of the manor at the southwestern edge of the village (Fig. 82, 83). The excavation director interpreted several nearby sunken features as parts of the potter's homestead: two storage pits and three surface, or more precisely, shallow post-built structures (16/62, 46/62, 57/62). Feature 46/62 contained a hearth in its eastern corner and was therefore interpreted as a dwelling. The partial plan was never published within the overall site plan, but the relevant graphic documentation has been traced (Nekuda 1963, 64–70; 2000, 110–112, 115, 302–304, obr. 173; Nekuda, Reichertová 1968, 41–47).

A review of the available finds housed in the Moravian Museum shows that only part of the material from the surface-built structures 16/62 and 46/62 may be contemporary with the operation of the kilns, while sherds of later pottery also occur. The finds from storage pit 26/62 could not be located, and the ceramics from storage pit 27/62 date no earlier than the second half of the 14th century. According to the field documentation, additional sunken features, postholes, and similar structures were present in the wider area. Before a comprehensive reassessment of the finds and plant documentation, it is not possible to determine unequivocally whether the production facilities were situated within the homestead as suggested by V. Nekuda (2000, 115, obr. 173), or in a separate area outside the residential zone. In any case, the kilns belonged to the early phase of the High Medieval village, which was still built entirely of perishable materials, and they were located on the periphery, perhaps largely beyond the contemporary settlement.

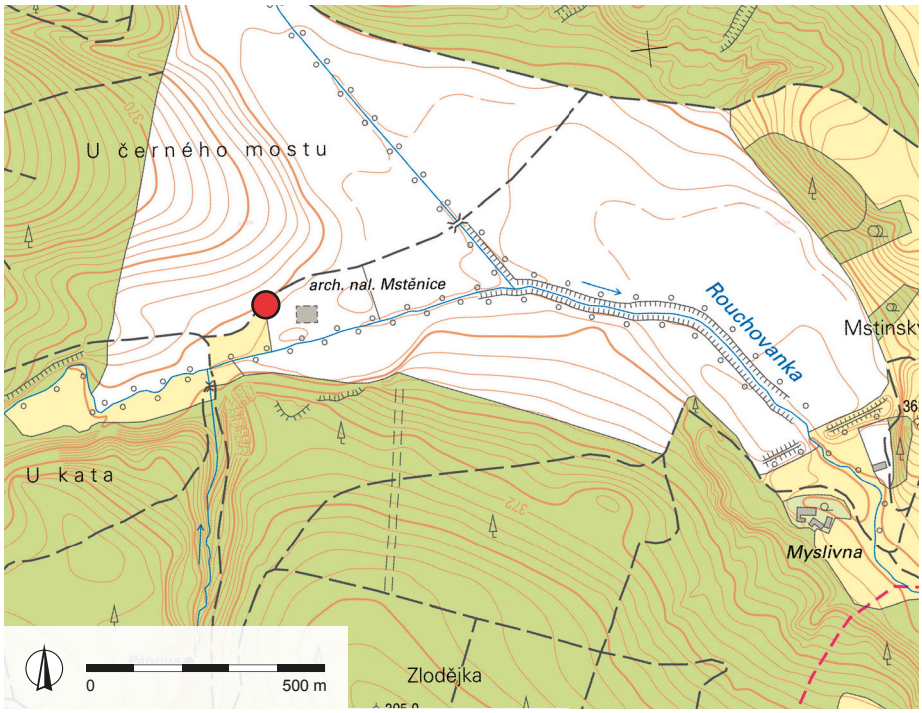


Fig. 81. Mstěnice. Location of the kilns on the current map. Source: mapy.cz. Graphics by M. Filip.

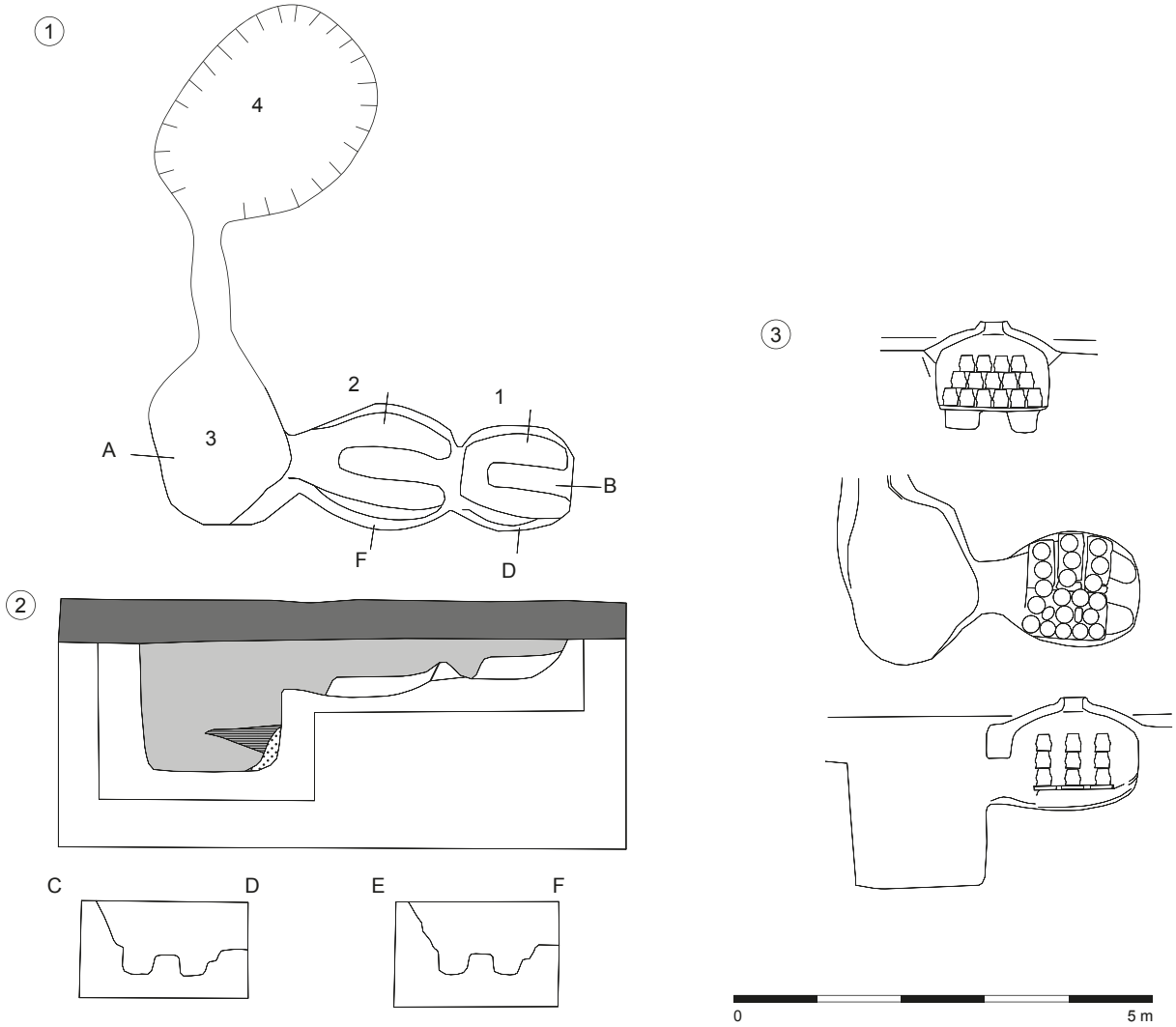


Fig. 82. Mstěnice. Excavation context of pottery kilns: 1 – plan (1, 2 kilns, 3 – stoke pit of the kiln 2 , 4 – clay exploitation pit); 2 – longitudinal and cross-section, 3 – tentative reconstruction of the kiln. After Nekuda 2000, 112, obr. 168.

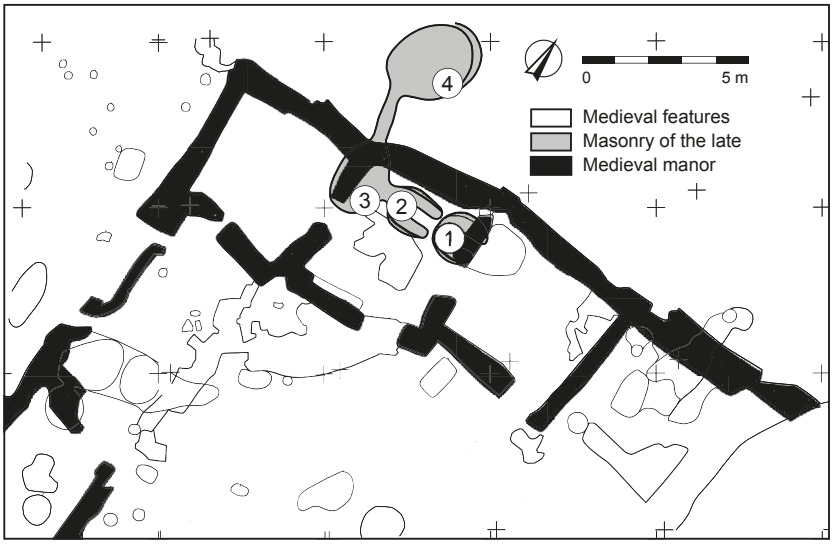


Fig. 83. Mstěnice. Excavation context of the pottery kilns. 1, 2 – kilns; 3 – stoke pit; 4 – clay exploitation pit. Modified according to archaeological field documentation from the excavation, stored in the Moravian Museum.

The pottery assemblage from the kilns was initially dated to the second half of the 13th century, but the structures were later attributed to an early medieval settlement, specifically to its final phase at the beginning of the 13th century (Nekuda 1963, 64; Michna 1966, 1; Nekuda 1972, 13; 2000, 110). This revised dating, however, has not been generally accepted (Procházka 2002; Procházka, Peška 2007, 145). The finds are housed in the Moravian Museum in Brno.

4.4.1 Kiln relics

Both kilns were aligned along a common west–east axis (Fig. 82). On the surface, the features were indicated by concentrations of reddened daub, and fragments of vessels became increasingly frequent within the fill. Unfortunately, a more detailed description of the fill structure is missing from the published reports.

Kiln 1 had the shape of an irregular quadrilateral with rounded corners. The floor and walls were well preserved, coated with clay and fired to a depth of 7–12 cm. The maximum preserved length of the feature was 130 cm and its width 118 cm. The kiln floor lay 140 cm below the present ground surface and was divided by a longitudinal clay spoon measuring 95 cm in length and 30 cm in both width and height (Nekuda 1963, 64).

Kiln 2 was located directly in front of kiln 1 and was probably constructed within the stoking pit of kiln 1 after the latter had gone out of use. It represents the same type of kiln but with a larger ground plan. The preserved length of the feature was 180 cm and its width 130 cm. The central spoon measured 130 cm in length and 30 cm in width. Along the side walls, at the height of the central spoon, a slight ledge was observed forming a narrow shelf, the widest (15 cm) in the central part of the kiln. The stoking pit opening measured approximately 50 cm in diameter and 57 cm in length. The walls and floor were fired in a manner similar to the previous structure. The stoking pit, which allowed for convenient kiln operation, measured 190 × 162 cm and was sunk 95 cm below the subsoil surface. On its northern side, the pit was connected by a corridor about 40 cm wide to a pit of circular plan interpreted by V. Nekuda as a clay exploitation pit, measuring 2.1 × 2.4 m of unknown depth. This feature has not been described in detail in the published reports (Nekuda 1963, 64; field records stored in the Moravian Museum).

According to the excavation director, the complete vessels in kiln 1 were found placed upside down and had subsequently cracked under the pressure of the surrounding clay. Vessels in kiln 2 were reportedly found in the same position. The orientation of both kilns corresponded to the prevailing wind direction at the site (Nekuda 1963, 64; 2000, 110–112). The assemblage from the Mstěnice kilns has been published three times to varying extents, not counting several brief or preliminary mentions. None of these publications, however, provides a complete catalogue of finds. According to the most detailed inventory (Nekuda 1963, 66–68), kiln 1 (A) contained 347 registered items, including seven complete or reconstructed vessels (six pots and one bowl) and an additional nineteen larger parts. Kiln 2 yielded 185 registered items, including five complete pots and fifteen larger reconstructed fragments. Unfortunately, no full catalogue of the finds is available – only typewritten inventory cards have been preserved. The stoking pit has no published inventory list; so far, 167 registered items have been traced out of an estimated total of around 700. The finds from the so-called exploitation pit have not yet been located.

As part of the project, a revision of the current state of the individual assemblages was carried out. In the depository of the Moravian Museum, some of the material, particularly the complete and reconstructed vessels, could not be located. Several of the available reconstructed forms were unsuitable for technological analysis due to the restoration method applied, in which the interiors of the vessels were entirely coated with plaster used to fill the missing parts. This limitation also affected the 3D analysis. The present description of the pottery incorporates information previously published by V. Nekuda and supplements it with new observations based mainly on the fragmentary material preserved in the Moravian Museum depository.

4.4.2 Morphology, typology and metric properties of pottery

In kiln 1, in addition to the eight complete or reconstructed vessels with full profiles, 19 partially preserved lower (12) or upper (7) vessel sections and numerous fragments were recovered. The assemblage consisted of plain pots without handles, one bowl, and the rim of a bell-shaped lid (Fig. 84: 13–19). The pots have oval or barrel-shaped bodies, in some cases asymmetrical (possibly due to the laboratory reconstruction process). The necks are rounded, with a smooth transition between the shoulder and the body. The bases are flat or slightly concave on the interior.

The heights of seven measurable complete or reconstructed pots range from 17 to 29 cm (mean 22.9 cm, median 23.9 cm). Rim diameters vary between 14.5 cm and 21.5 cm (mean and median 17 cm); maximum body diameters range from 16 cm to 23.9 cm (mean 20.7 cm); and base diameters from 10.5 cm to 15.2 cm (mean 12.4 cm). One pot (inv. No. 5060), 17 cm high and with a volume of 2.1 l, deserves particular mention. It was produced by wheel coiling. On its coarse base, traces of a circular potter's mark, probably with a cross at the centre, were observed, along with peripheral marks indicating attachment to the turntable. On the inner walls, depressions, ridges, and fingerprints are visible.

Among the pots and their fragments, six basic rim types were identified (on 76 fragments): type S accounted for 66%, type VZ for 10%, type P for 9%, VV for 8%, P 6% and VN 1% (Fig. 85). The shoulders of the pots were most often decorated with one to five grooves or narrow incised lines arranged in dense sequences; in rare cases, a greater number of grooves was spaced more widely apart. Also rare, and observed only on fragments, are grooves in the corkscrew patterns, or a faint relief cordon (kiln 1). One undecorated pot was also present.

In addition to the pots, the kiln contained a bowl measuring 11 cm in height, with a rim diameter of 34 cm and a base diameter of 22.5 cm. Below the

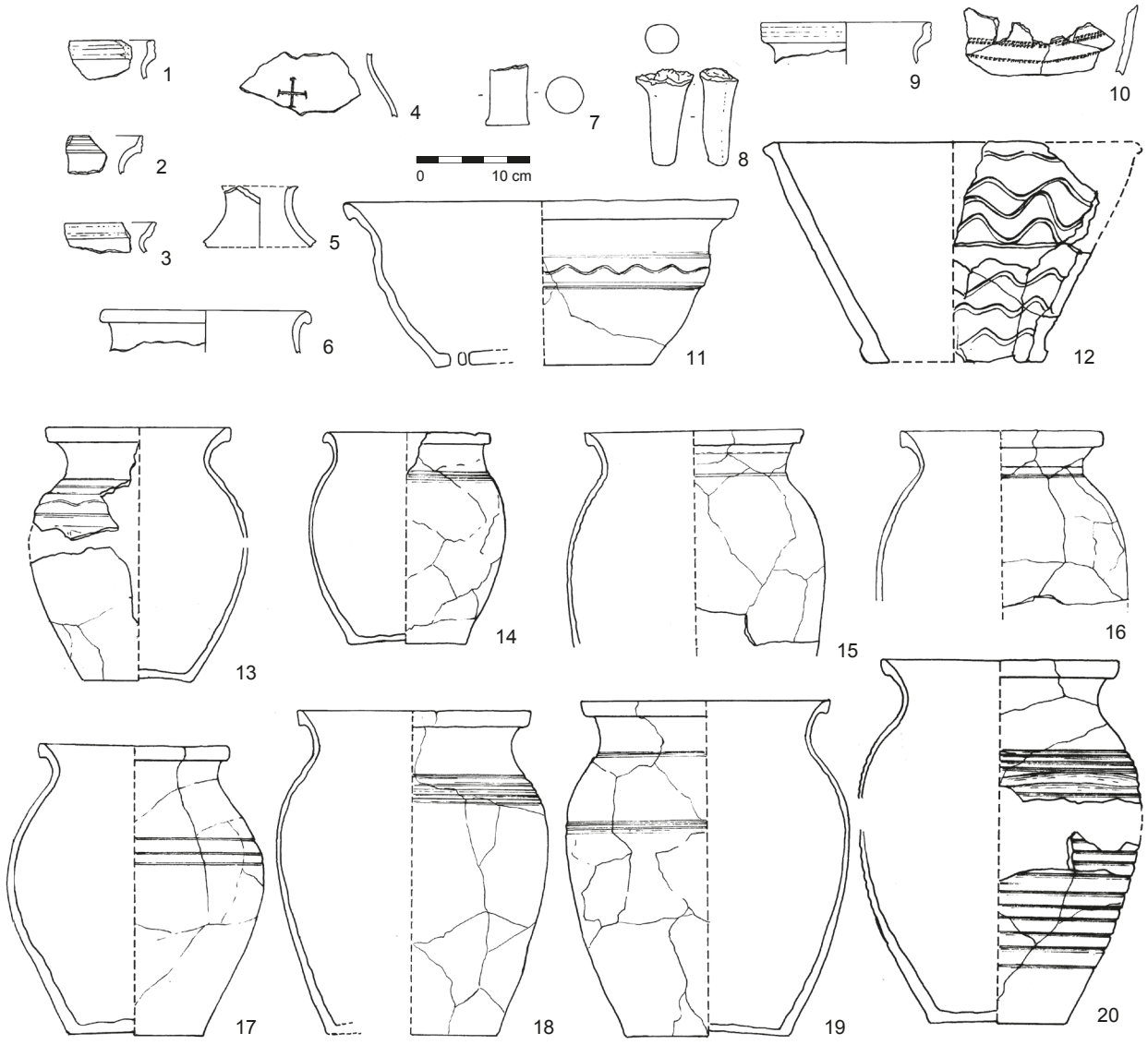


Fig. 84. Mstěnice. Pottery from kilns and stoke-pit, inv. No.: Kiln 2: 1–6, 11; stoke-pit: 7–10, 12, 16, 20; kiln 1: 13–15, 17–19. 1 – rim fragment of a pot, 5423; 2 – rim fragment of a pot, 5422; 3 – rim fragment of a pot, 5420; 4 – belly with incised decoration, 5330; 5 – neck, 5328; 6 – rim of a pot, 5400; 7 – leg, 11061; 8 – leg from a tripod pan, 11060; 9 – rim of a pot, 11240; 10 – belly with roulette decoration, 11572; 11 – bowl, 5318; 12 – hopper (funnel) vessel 11049; 13–20 – pots, 13 – 5061, 14 – 5305, 15 –5602, 16 – 59025, 17 – 5306, 18 – 5658, 19 – 5062, 20 – 59063. Partially adopted from Nekuda 2000, 228, No. 2: 1–5; 229, No. 297: 8, 9; 230, No. 298: 6; 231, No. 299: 10, 11. Drawings by L. Dvořáková after Nekuda 2000, 228–231, obr. 296: 1–5; 297: 8, 9; 299: 6, 10, 11.

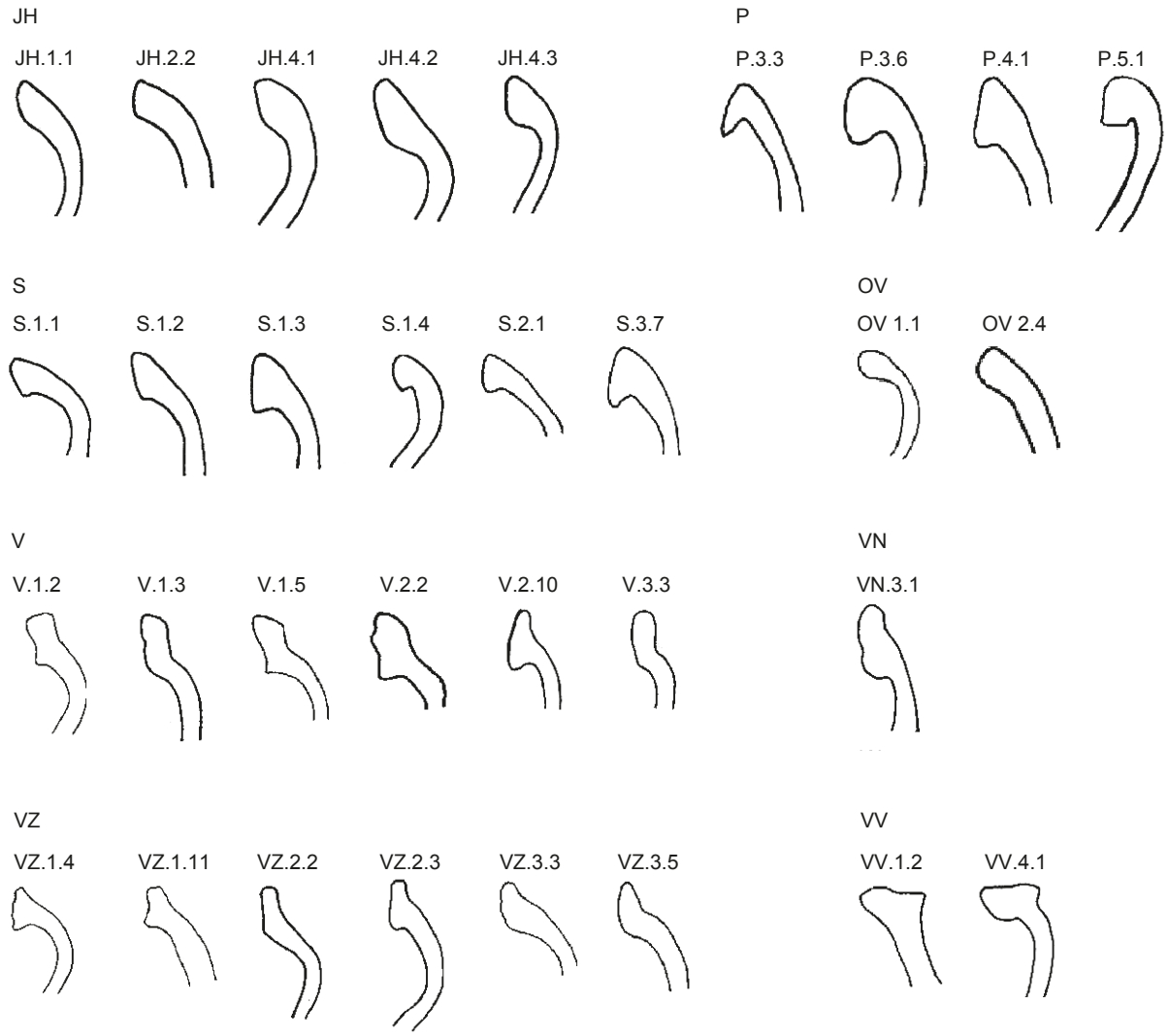


Fig. 85. Mstěnice. Rim types. Drawings by K. Těsnohlídková.

rounded rim, it was decorated with a shallow groove and four horizontal incised lines (Nekuda 1963, 66–68; 2000, 110).

In kiln 2, five pots were reconstructed, along with four large upper and four lower sections of similar vessel forms. Other shapes included the torso of a pot-shaped bowl, two rim fragments of conical bowls, a fragment of a small pot with a handle, and the neck and rim of a vessel probably representing a jug. Bell-shaped lids were represented by one rim fragment and one handle knob (Nekuda 1963, 67–69; Michna 1966, 1; Fig. 84: 1–6, 11).

The pots have globular bodies and usually rounded necks with a smooth transition between the neck and the body. Five complete pots were measured, with heights ranging from 14.4 to 21 cm (among the incompletely preserved forms, larger examples also occur, e.g. inv. No. 5314 without base, slightly over 23.2 cm; Fig. 84; Fig. 86: 1). Rim diameters range from 12.6 to 14.5 cm (mean 13.8 cm); maximum body diameters fall between 14.5 and 19.8 cm (mean 16.1 cm); and base diameters between 9.5 and 13 cm (mean 10.8 cm). Exact volumes were determined for two pots: one with a capacity of 2.4 l (inv. No. 5311; Fig. 86: 3) and another with 1.8 l (inv. No. 5310; Fig. 86: 4). Both vessels were produced using the rotational profiling technique. They have coarse bases bearing traces of sand dusting, and on the inner walls above the base, impressions and circular ridges are visible.

Compared to kiln 1, a wider range of decoration and greater rim variability were observed here. In



Fig. 86. Mstěnice. Technological traceson vessels, inv. No.: 1 – torso of a pot made by profiling wheel-throwing, showing characteristic traces on the inner wall and a weak sand coating on the bottom, 5315, kiln 2; 2 – pot made by profiling wheel-throwing with sand dusting on the bottom, 5060, kiln 1; 3 – pot made by profiling wheel-throwing with sand dusting on the bottom, 5311, kiln 2; 4 – pot made by profiling wheel-throwing with sand dusting on the bottom and probably remains of a potter's mark, 5310, kiln 2. Photo by M. Košťál.

addition to grooves and incised lines, the pot bodies occasionally featured a single wavy line or multiple interlaced wavy lines; in some cases, a wavy motif also appeared on the rim. A total of 108 rims were identified: 62% belong to type S, 18% to type P, 9% to type JH, 9% to type V, and 1% to type VV (Fig. 85; Michna 1966, appendix 1, codes changed). The decoration of the pot shoulders consists of narrow, closely spaced incised lines or grooves, with one wavy line or two opposing wavy lines occurring only rarely. One vessel base bore a fragmentary potter's mark in the form of a circle with a cross (Nekuda 1963, 66–67), and a mark in the shape of a crutch cross was recorded on a neck fragment.

Within the fills of both kilns, later intrusions were identified, for example, a knob from a bell-shaped lid in Kiln 1 and a more undercut brim pot rim from kiln 2.

	No. of pots	W	H	D	Z
Index range	11	0,38-0,49	0,95-1,26	0,63-1,18	1,4–1,92
Mean	11	0,45	1,09	0,82	1,69
Median	11	0,45	1,09	0,8	1,68

Tab. 15. Mstěnice. Pot index values.

The pottery from the stoking pit represents a less homogeneous assemblage than that from the two kilns, and a considerable portion of it has not yet been located (Fig. 84: 7–10, 12, 16, 20). Examination of the available material, particularly the pot rims, indicates that most of the ceramics are similar in character to those from the kilns. A complete funnel and a large part of one pot were successfully reconstructed (Nekuda 2000, 231, obr. 299: 10, 11). Rim types were identified in 117 cases: 55% type S, 20% type V, 13% type P, and 12% type VZ. The higher frequency of type V rims located in the first kiln is interesting. It is therefore possible that the same potter, or his successor, began producing vessels with these rims only in the second kiln, perhaps influenced by pottery from more northerly regions encountered through trade. Among the decorative elements, special attention should be drawn to the rare occurrence of roulette impressions on the vessel body and rim.

Only in the stoking pit were found fragments of three or four funnels, characterised by a distinctly expanded and obliquely bevelled upper rim and a collar-like thickened lower rim, with the inner surface decorated by irregular wavy lines. The rim diameters of these funnels measure 33 cm, 39 cm, and 40 cm, the bases (in two measurable cases) 17 cm, and the only preserved height is 21 cm. Several fragments of flat lids (four pieces), a bell-shaped lid (one rim fragment), and two rim fragments of a stirrup-handled ewers may also be associated with the production in the kilns. A larger sherd of a small handled jug or cup bears two pairs of crossed incisions on the handle. An interesting find is a roughly worked leg, probably from a tripod pipkin, as well as an incomplete cylindrical object of uncertain function. The assemblage contained a significant number of intrusive finds resulting from the construction of the manor's foundations during the later Middle Ages, directly into the fill of the discussed feature, as well as residual material of earlier origin (Nekuda, Reichertová 1968, 298).

Given the small number of complete forms within the individual assemblages and the assumption that both kilns belonged to a single workshop, the W, D, H, and Z indices were calculated for the entire set of complete and reconstructed pots from kilns 1 and 2, i.e. a total of 11 specimens (Tab. 15). The W index (range 0.38–0.49; mean and median 0.45) indicates a predominance of pots with a low-set maximum diameter, barrel-shaped forms with low bellies, while only one vessel falls into the category with a moderately placed bulge. The D index (range 0.63–1.18, mean 0.95, median 0.91) shows a relatively wide variation in the degree of body's convexity: most vessels (7) belong to the medium category, two to the low, and two to the high category. Finally, the H index, expressing the degree of bulbosity (range 0.95–1.26; mean and median 1.09), places two vessels in the very high category, eight – most of the assemblage – in the high category, and one in the medium category. Both the mean and median values of the Z index fall within the medium category, approaching the 'low' level, which includes three vessels.

4.4.3 Ceramic technology

The assemblages from the kilns, as well as most of the finds from the stoking pit associated with kiln 2, share common characteristics and can essentially be attributed to a single ceramic horizon. The production exhibits both technological and typological–morphological features typical of the early phase of high medieval pottery.

Paste

The pottery from both kilns was compositionally rather homogeneous. In kiln 1, the vessel paste was medium-grained and sandy, probably with a natural addition of mica. In kiln 2, a higher proportion of fragments with increased mica content was observed, and the pottery there appeared subjectively finer in texture. The ceramics contained only minimal amounts of graphite. A single fragment that can be considered an intrusion and fragments of a funnel were graphitic (Nekuda 1963, 69; Michna 1966, 1–2)

Local loess deposits have commonly been considered the source of the potting clay. As early as the 1960s, a basic chemical analysis of the ceramic paste was carried out, determining the contents of major oxides and identifying a small amount of graphite (3.63%). However, it remains unclear which

ID	Inventory No.	Kiln	Vessel type	Ceramic class
1	5038	Kiln 2	Pot	Sandy
2	5055	Kiln 2	Daub	-
3	5065	Kiln 1	Pot	Sandy (+ ~mica)
4	5135	Kiln 1	Pot	Sandy (+ ~mica)
5	5151	Kiln 1	Pot	Sandy (+ ~mica)
6	5157	Kiln 1	Pot	Sandy-micaceous
7	5171	Kiln 1	Pot	Sandy (+ ~mica)
8	5172	Kiln 1	Pot	Sandy (+ ~mica)
9	5183	Kiln 1	Pot	Sandy (+ ~mica)
10	5203	Kiln 1	Pot	Sandy (+ ~mica)
11	5206	Kiln 1	Pot	Sandy (+ ~mica)
12	5234	Kiln 1	Pot	Sandy (+ ~mica)
13	5318	Kiln 2	Pot	Sandy (+ ~mica)
14	5319	Kiln 2	Pot	Sandy-micaceous
15	5332	Kiln 2	Pot	Sandy (+ ~mica)
16	5358	Kiln 2	Pot	Sandy
17	5409	Kiln 2	Pot	Sandy (+ ~mica)
18	5435	Kiln 2	Pot	Sandy (+ ~mica)
19	5468	Kiln 2	Pot	Sandy-micaceous
20	5470	Kiln 2	Pot	Sandy (+ ~mica)
21	5488	Kiln 2	Pot	Sandy
22	5703	Kiln 2	Pot	Sandy (+ ~mica)
23	8860	Kiln 2	Pot	Sandy with micaceous surface

Tab. 16. Mstěnice. Samples selected for analyses.

analytical method was used or what specific material was examined, whether the result refers to a single sherd or represents an average of several samples (Nekuda 1972, 35; 2000, 110).

Several macroscopic paste classes were distinguished. The assemblage is dominated by a micaceous class containing a moderate amount of biotite. Less frequent is micaceous pottery with a high content of muscovite. Both types are represented in material from both kilns. In addition, sandy pottery with only sporadic mica grains was identified, occurring in two partially overlapping variants distinguished by the presence of coarser quartz grains (around 1 mm). In the first variant, these grains occur only occasionally, while in the second they are present more frequently. Graphite-tempered pottery was not identified macroscopically during the latest analysis. Kiln 2 also contained a single fragment characterized by fine paste, traces of surface burnishing, and a smoked firing; this specimen may represent a later intrusion.

A total of 22 ceramic samples were selected for archaeometric analyses to represent the full macroscopic variability of the assemblage (Tab. 16; Fig. 87). Ten samples originated from kiln 1 and twelve from kiln 2. Additionally, one sample of the outer kiln wall from Kiln 2 was analysed as a reference.

The results of elemental composition and petrographic analyses revealed that the material was more heterogeneous than previously suggested by macroscopic observations (Appendix 1-D, 2-D). Four primary fabric groups (A–D) were identified (Tab. 17). Fabric A – micaceous sandy ware – is the most common and is divided into subgroups A1 and A2 (14 samples total, present in both kilns). Fabric B, another sandy ware, includes four samples from both kilns and is subdivided into B1–B4. Fabric C – muscovite-rich ware – comprises three samples (C1 and C2 subgroups, from both kilns). Fabric D is represented by a single sample made of calcareous loess-derived clay (from kiln 2).

Subgroups A1 and A2 differ primarily in clay granularity. (Fig. 88: A–D). While A1 includes a lower quantity of aplastic particles (~15–25 vol.%, of avg. size spanning 150–400 µm with max. size of 3200 µm), A2 contains more silt and sand sized particles (~30 vol.%, avg. size ~200–300 µm, max. size up to 3400 µm), and has higher Si and K concentrations (Graph 11; Tab. 18). A1 includes four samples from kiln 1 and six from kiln 2; A2 (4 samples) is exclusive to kiln 2. Both subgroups are made from naturally sandy clays with a sufficient content of non-plastic inclusions which in A1 are mostly sub-angular to sub-rounded, while those in A2 are more rounded, suggesting a difference in raw material genesis. A1 clay likely derives from residual weathering products (eluvial origin), whereas A2 appears to originate from alluvial deposits.

Despite differences, both A1 and A2 share identical petrographic features: weakly parallel microstructure and very poorly sorted inclusions. The aplastic fraction is dominated by serpentinites (serpentinized peridotites; Fig. 89: A–B), frequent to dominant in abundance. These contain variably altered olivine, garnet rimmed with kelyphitic zones, and occasionally micritic or sparitic calcite and talc (Fig. 89: C–G). Serpentinite fragments also include pyroxenes, amphiboles, phlogopite and among serpentine group minerals – antigorite (Fig. 89: H, I). Less common rocks include migmatites (rare to common), metaquartzite (occasional), amphibolite (rare; Fig. 89: J), and gneiss (only one sample). Mineral inclusions include abundant biotite (phlogopite), occasional to frequent clinopyroxene, olivine, and amphibole, occasional orthopyroxene, and rare to common feldspars (both plagioclase and alkali feldspars; Fig. 89: K–N). Garnet and calcite were common but not present in all samples; talc was mostly occasional. Two A2 samples contained common iron-rich clay pellets.



Fig. 87. Mstěnice. Photodocumentation of analysed samples. Photo by M. Košťál.

Fabric group B includes four subgroups based on technological and petrographic differences, each represented by one sample. These differ from fabric A by higher concentrations of Al, Si, K, Ti, V, As, Rb, Ba, and Pb (Graph 11; Tab. 18). Fabric B1 (kiln 1) is marked by abundant clay pellets and a bimodal grain size distribution (Fig. 88: E, F). It contains weakly parallel microstructure and very poorly sorted inclusions. Inclusions which were a natural part of the clay were silt sized (1 vol.%, <20 µm). The clay contains trace microfossils and common glauconite (Fig. 89: O). Rock fragments (25 vol.%, avg. size ~300 µm, max. size 2800 µm) are sub-angular to sub-rounded, dominated by gneiss and migmatite (frequent), and metaquartzite (occasional). Quartz and polycrystalline quartz are frequent; feldspars, biotite, garnet, muscovite, sparite, amphibole, and orthopyroxene occur in varying amounts. Fabric B2

Fabric	Sample IDs	Fabric description	Fabric features	Petrographic markers	Chemical markers	Possible sources
A1	3, 7, 10, 11, 13, 15, 17, 18, 20, 22	Sandy-micaceous, non tempered, clayey matrix with silt and sand	Weakly parallel microstructure, unimodal grain size distribution	Serpentinite, biotite, garnet, clinopyroxene, amphibole, olivine, orthopyroxene, calcite, quartz, alkali feldspar, plagioclase, talc, migmatite, metaquartzite, amphibolite	Representation of 'average' for the site	Eluvial material derived from weathered serpentinite
A2	4, 5, 8, 12	Sandy-micaceous, non tempered, clayey matrix richer in silt particles, and sand	Weakly parallel microstructure, unimodal grain size distribution		Compared to A1: elevated Si and K	Aluvial, short distance transported material derived from weathered serpentinite
B1	9	Sandy-micaceous, tempered, clayey matrix, microfossils (trace amount)	Weakly parallel, bimodal grain size distribution, abundant clay pellets	Migmatite, gneiss, quartz, muscovite, garnet, glauconite, alkali feldspar, plagioclase, biotite, calcite, metaquartzite, tourmaline, orthopyroxene, amphibole	Compared to Fabric Group A: elevated Al, Si, K, Ti, V, As, Rb, Ba, and Pb	Combination of serpentinite and crystalline rocks (gneiss, migmatite) derivates
B2	16	Sandy (less mica), untempered, clayey matrix with silt and sand	Weakly parallel, unimodal grain size distribution	Amphibole, quartz, biotite, alkali feldspar, garnet, serpentinite, plagioclase, clinopyroxene, olivine, migmatite, metaquartzite, orthopyroxene		Eluvial material derived from weathered serpentinite
B3	1	Sandy (less mica), untempered, clayey matrix with silt and sand	Unparallel, unimodal grain size distribution	Quartz, biotite, migmatite, gneiss, glauconite, alkali feldspar, plagioclase, muscovite, garnet, tourmaline		Migmatite and gneiss derived eluvial or short-distance transported alluvial sediment
B4	21	Sandy-micaceous, tempered, clayey matrix	Parallel, bimodal grain size distribution	Quartz, metaquartzite, migmatite, gneiss, alkali feldspar, plagioclase, biotite, glauconite, muscovite, amphibole		Temper: Migmatite and gneiss derived eluvial or short-distance transported alluvial sediment
C1	6, 14	Micaceous (muscovitic), clayey matrix with silt and sand, possibly tempered	Parallel, unimodal grain size distribution	Muscovite, biotite, quartz, migmatite, gneiss, alkali feldspar, plagioclase, orthopyroxene, serpentinite, metaquartzite, garnet, amphibole, talc		Combination of serpentinite and muscovite rich derivates such as gneiss or mica schist
C2	19	Micaceous (muscovitic), clayey matrix richer in silt and sand compared to C1, possibly tempered	Weakly parallel, unimodal grain size distribution	Muscovite, quartz, biotite, gneiss, migmatite, alkali feldspar, orthopyroxene, chert, amphibole, plagioclase, calcite, tourmaline		
D	23	Loess derived, silty matrix with sand, microfossils	Weakly parallel, unimodal grain size distribution	Quartz, gneiss, iron rich clay pellets, plagioclase, alkali feldspar, muscovite, biotite, kalcite, metaquartzite, migmatite, amphibole, garnet	Compared to Fabric Group A: elevated Ca and Sr	Calcareous loess-derived caly

Tab. 17. Mstěnice – both kilns. General description of fabrics (petrographic markers are listed in order of relative abundance).

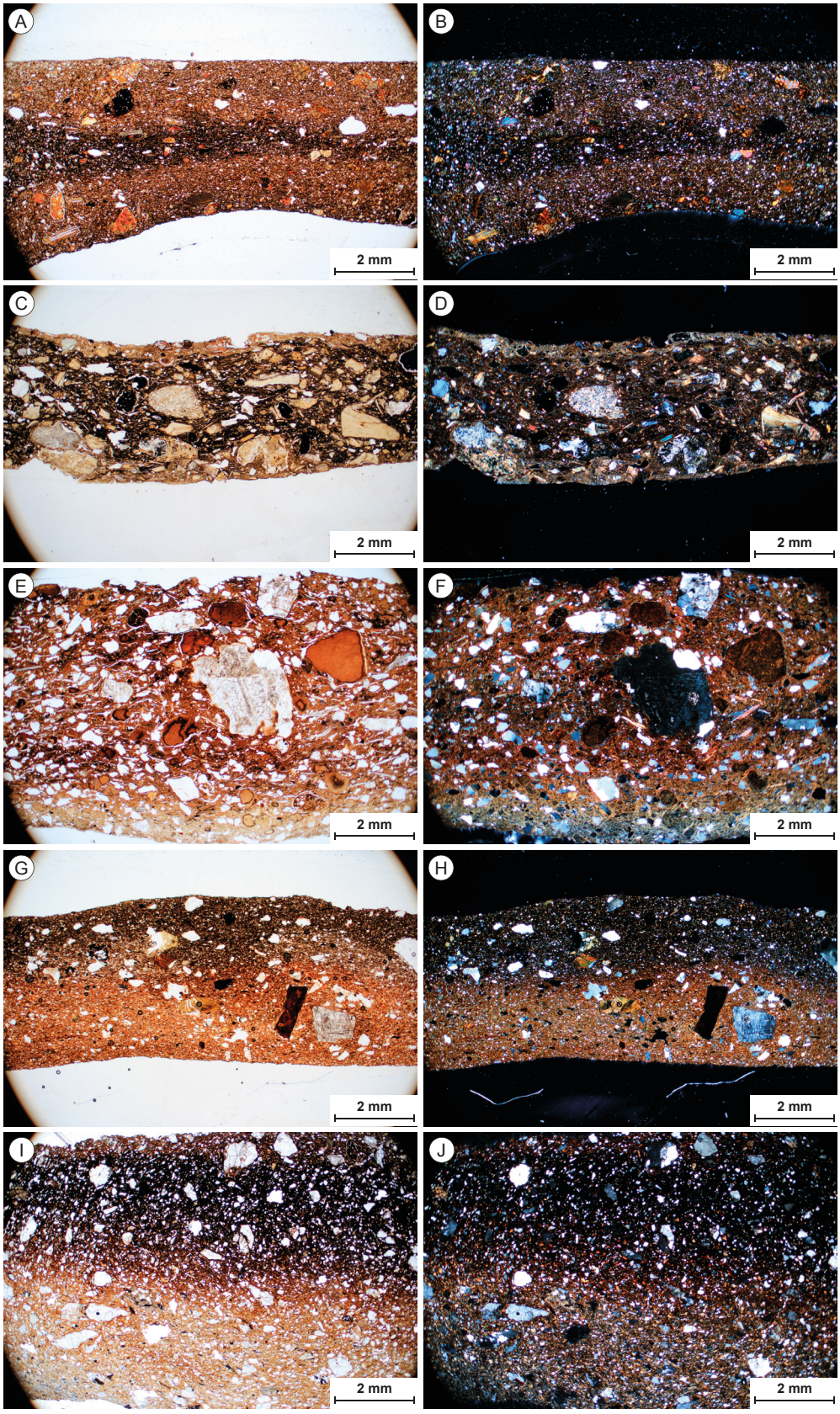
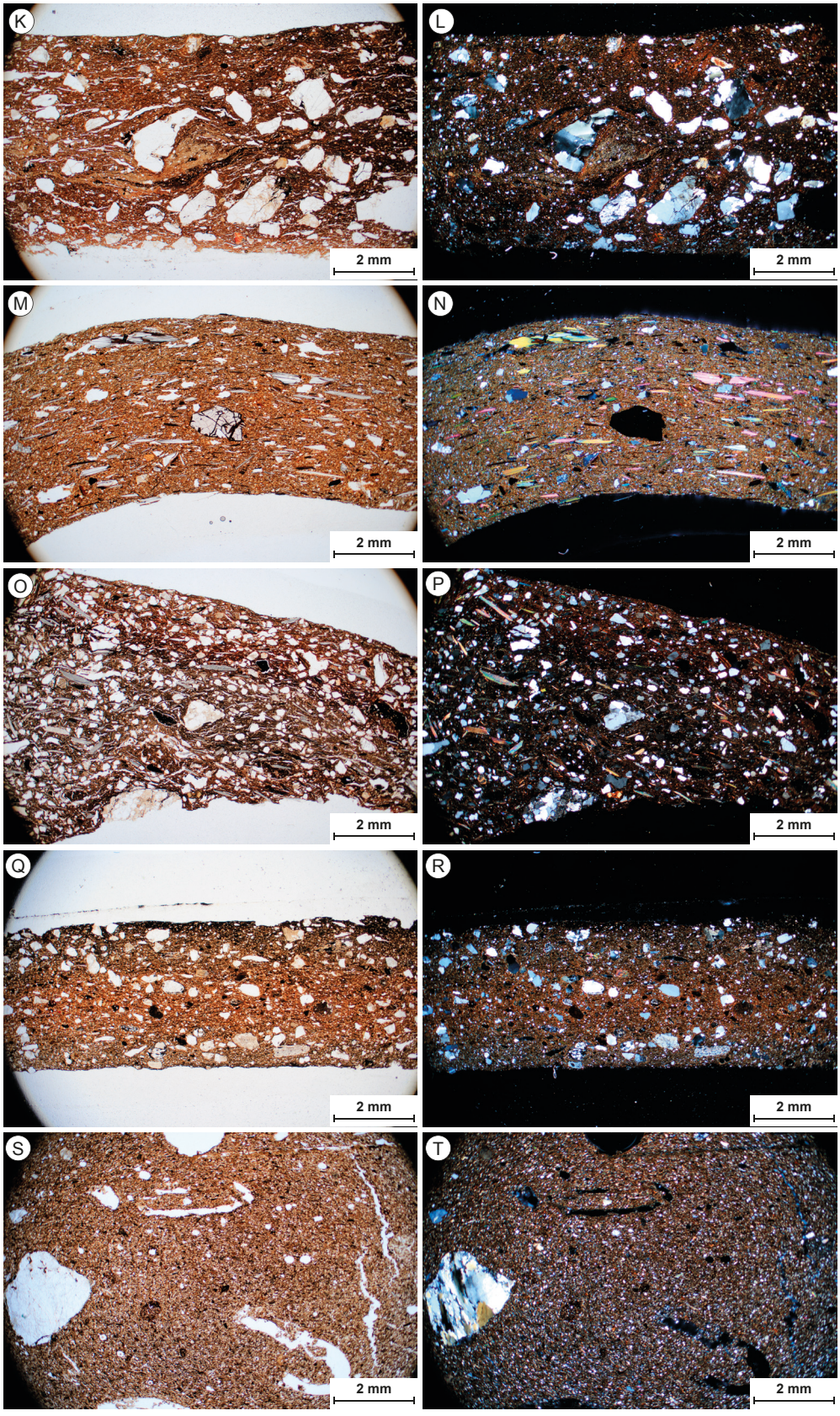


Fig. 88. Mstěnice. Overview of the micructure of each fabric in PPL (left) and XPL (right): A, B – sandy-micaceous fabric A1, sample 13; C, D – sandy-micaceous fabric A2, sample 12; E, F – fabric B1, sample 9; G, H – fabric B2, sample 16; I, J – fabric B3, sample 1; K, L – fabric B4, sample 21; M, N – muscovitic fabric C1, sample 14; O, P – muscovitic fabric C2, sample 19; Q, R – fabric D, sample 23; S, T – daub (kiln 2 coating), sample 2. Author K Slavíček. Fig. 88 continues on the next page.


K
2 mm
L
2 mm
M
2 mm
N
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O
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P
2 mm
Q
2 mm
R
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T
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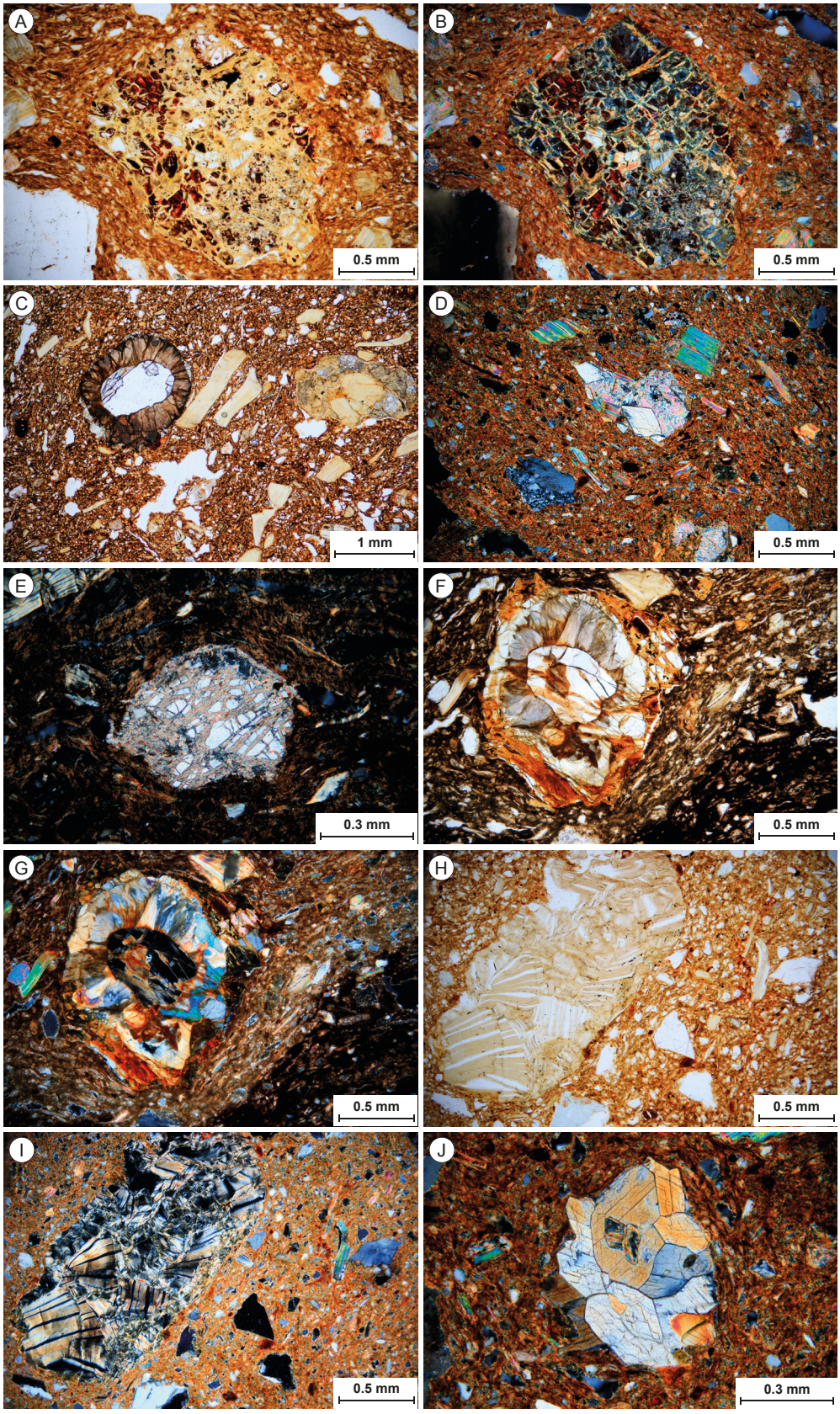
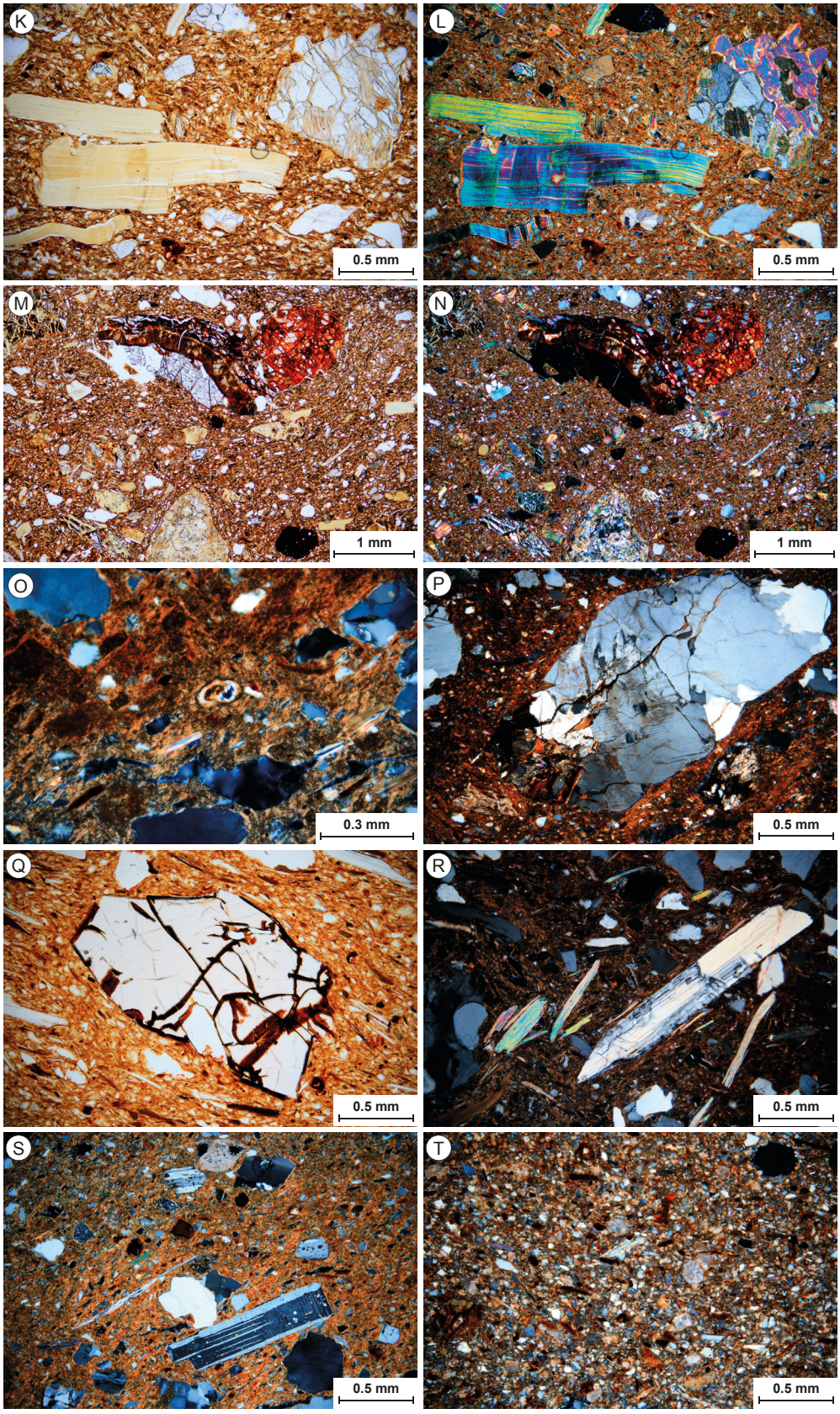
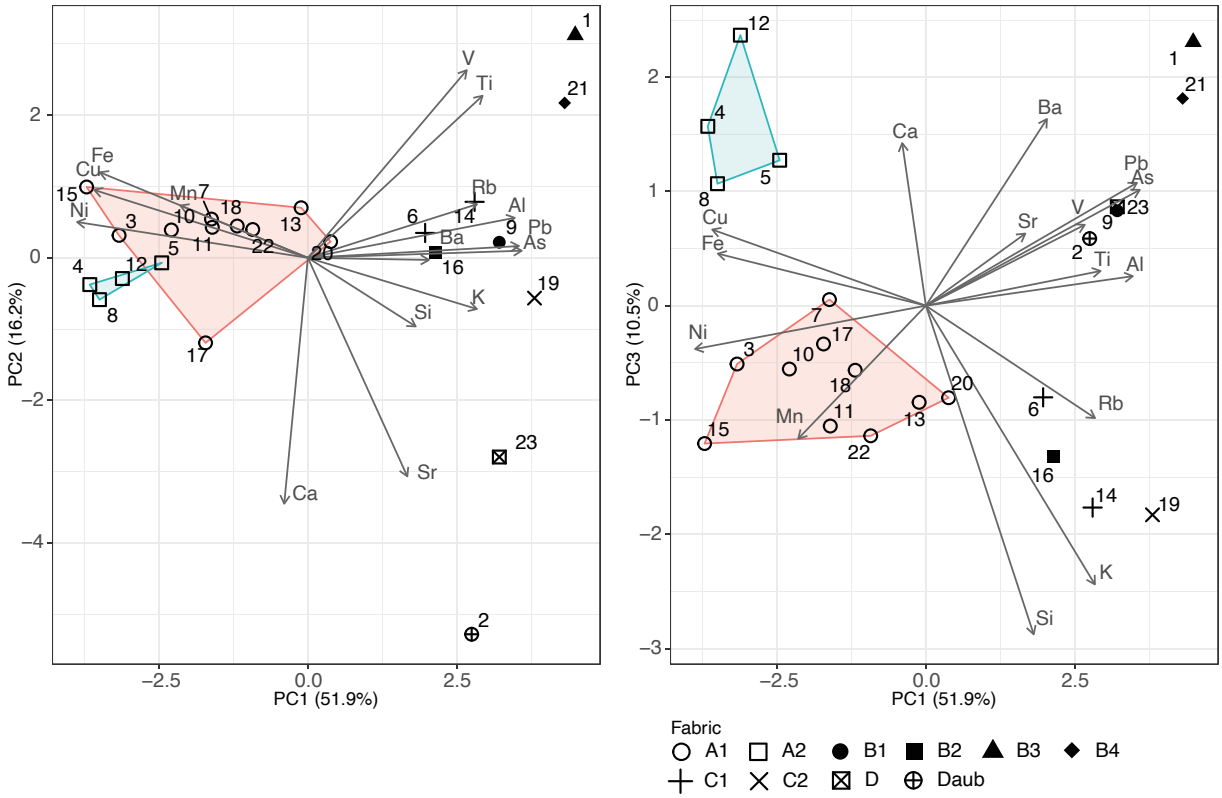


Fig. 89. Mstěnice. Photomicrographs highlighting key features in detail: A, B – serpentinized peridotite fragment in sample 3, fabric A1, PPL and XPL; C – kelyphitic zone formed around garnet (center-left), frequent stacks of biotite, serpentinite grain on the right (sample 3; PPL); D – rock fragment composed of talc, muscovite and amphibole in the center (sample 18; XPL); E – remains of olivine in sample 4, fabric A2 (XPL); F, G – kepliphitic zone which formed around garnet grain within serpentinized peridotite (sample 5; fabric A2; PPL and XPL); H, I – large frament of serpentinite composed of antigorite and smaller angular garnet to the right (sample 3; PPL and XPL); J – amphibolite in sample 3 (XPL);



K, L – stacks of biotite flakes, peridotite (top-right), garnet and amphibole (top-center) in sample 3 (PPL and XPL); M, N – overview of fabric A1 rich in peridotite fragments in various states of serpentinization, biotite is frequent in ceramic paste (sample 3; PPL and XPL); O – microfossil in the matrix of fabric B1 (sample 9; XPL); P – gneiss fragment in sample 21 (fabric B4; XPL); Q – grain of garnet in muscovitic fabric C1 (sample 14; PPL); R – orthopyroxene among muscovite flakes and quartz grains in sample 19 (fabric C2; XPL); S – calcite (top) bearing fabric D containing common plagioclasses, quartz and micas (sample 23; XPL); T – kiln coating sample 2 made of loess has a silty matrix (XPL). Author K. Slavíček.



Graph 11. Mstěnice – both kilns. Principal component analysis of chemical compositions – scatter plots of the first component against the second and third. The diagram shows similar chemical compositions of fabrics A1 and A2, variable compositions among samples belonging to fabrics B1–B4 and C1–C2, and a certain similarity between fabric D and daub. Author K. Slavíček. 21; M, N – muscovitic fabric C1, sample 14; O, P – muscovitic fabric C2, sample 19; Q, R – fabric D, sample 23; S, T – daub (kiln 2 coating), sample 2. Author K Slavíček.

	Fabric A1				Fabric A2				Fabric B1	Fabric B2	Fabric B3	Fabric B4	Fabric C1				Fabric C2	Fabric D	Daub
	mean	sd	min	max	mean	sd	min	max	-	-	-	-	mean	sd	min	max	-	-	-
SiO_2	72.8	0.8	71.7	74.3	69.1	1	68	70.1	66.5	73.8	67	68.9	71.1	0.8	70.5	71.7	69.3	70.3	72.2
Al_2O_3	12.1	0.9	11	14	12	0.5	11.5	12.6	22.1	13.7	20.1	18.1	15.2	1.1	14.4	16	17	16.4	12.5
Fe_2O_3	9.1	1	7.9	10.6	12.1	0.8	11.4	13	5.4	6.6	6.9	7.4	7.4	0.2	7.2	7.5	6	6.4	4.3
K_2O	2.8	0.3	2.3	3.4	2.1	0.1	2	2.3	2.7	3.5	2.8	2.8	3.8	0.1	3.7	3.9	4.8	2.7	3.7
CaO	2.1	0.7	1.4	3.9	3.7	0.6	3	4.5	2.2	1.3	1.7	1.4	1.4	0.1	1.3	1.5	1.9	3.3	6.5
TiO_2	0.9	0.1	0.8	1	0.8	0	0.8	0.8	0.9	0.8	1.4	1.2	0.9	0	0.9	0.9	0.8	0.8	0.7
V	85	8	71	95	67	13	53	85	112	91	170	140	101	6	96	105	89	97	54
Mn	938	552	641	2430	791	120	673	942	506	983	373	371	676	38	649	703	348	339	460
Ni	425	89	306	592	475	39	447	533	67	222	38	31	169	6	164	173	48	39	30
Cu	52	8	44	68	59	2	57	61	38	38	42	34	37	0	37	37	29	33	28
As	8	1	7	9	8	0	7	8	9	9	10	11	9	1	8	9	9	9	10
Rb	97	16	74	129	99	10	87	111	126	148	128	127	162	9	156	168	171	109	99
Sr	71	6	61	80	77	13	66	90	95	89	66	67	82	6	77	86	83	181	150
Ba	236	84	155	407	324	150	179	515	414	470	443	397	369	185	238	500	338	408	368
Pb	20	1	19	22	20	1	19	21	22	22	25	27	22	1	21	23	23	23	24

Tab. 18. Mstěnice – both kilns. Summary of the chemical composition of fabrics (major oxides in wt %, trace elements in ppm).

(kiln 2) is likely untempered, petrographically similar to fabric A but with less frequent serpentinites (Fig. 88: G, H). Rock fragments include occasional migmatite and rare metaquartzite. Amphibole is frequent, while garnet, quartz, feldspars, and biotite are common. Rock and mineral fragments comprise ~25 vol.%. Their average and maximum size is ~100 and 1500 µm respectively. Fabric B3 (kiln 2), also untempered, with particles <2000 µm and 100 µm of average size, contains abundant quartz and biotite. Microstructure is unparallel (Fig. 88: I, J). Glauconite is common, muscovite and feldspars are occasional, and garnet and tourmaline occur in trace amounts. Fabric B4 (kiln 2) shows a bimodal distribution

and is likely intentionally tempered (Fig. 88: K, L). The matrix includes ~5 vol.% silt (< 80 µm) and ~15 vol.% temper (average size ~600 µm, maximum size 2600 µm). Microstructure is parallel. Rock fragments are angular to sub-angular, mainly metaquartzite (frequent), with common migmatite and gneiss (Fig. 89: P). Quartz and polycrystalline quartz dominate; other minerals include feldspars, biotite, glauconite, rare muscovite and Fe-oxyhydroxides, trace amphibole.

Fabric group C, comprising muscovite-rich ceramics, is divided into subgroups C1 and C2 (Fig. 88: M–P). Elemental compositions are similar to fabric B. Parallel microstructure is emphasised by mica flakes. The matrix is composed of silt and sand containing clay. Coarse flakes of muscovite and biotite are included in such amounts suggesting intentional tempering or mica rich alluvial. Fabric C1 (two samples, one per kiln) has a unimodal grain size distribution and abundant muscovite, likely used as temper. Inclusions (~15 vol.%, avg. ~200–300 µm and maximum 2600 µm size) include common migmatite and gneiss, and occasional serpentinized peridotite and metaquartzite. Mineralogy includes common quartz, polycrystalline quartz, frequent biotite, occasional to common feldspars, common orthopyroxene, occasional amphibole, and garnet (Fig. 89: Q), and rare tourmaline, and talc. Fabric C2 (kiln 2) differs by higher inclusion content (30 vol.%, avg. size ~200 µm, maximum size 2500 µm) and only weakly parallel microstructure. Rock fragments include frequent gneiss, common migmatite, and occasional chert. Mineralogy is similar to C1 (Fig. 89: R) but with abundant quartz and occasional micrite.

Fabric D, represented by one sample from kiln 2, stands out by its elevated Ca and Sr concentrations, indicating a calcareous loess-derived clay (Graph 11). The matrix includes numerous silt particles, common microfossils, and iron-rich clay pellets. Non plastic inclusions are of ~200 µm average and 900 µm maximum size. Microstructure is weakly parallel (Fig. 88: Q, R). Rock fragments include frequent gneiss, occasional metaquartzite, and rare migmatite. Minerals include frequent quartz, common plagioclase, occasional feldspars, muscovite, biotite, micrite, and rare amphibole, sparite, and trace garnet (Fig. 89: S).

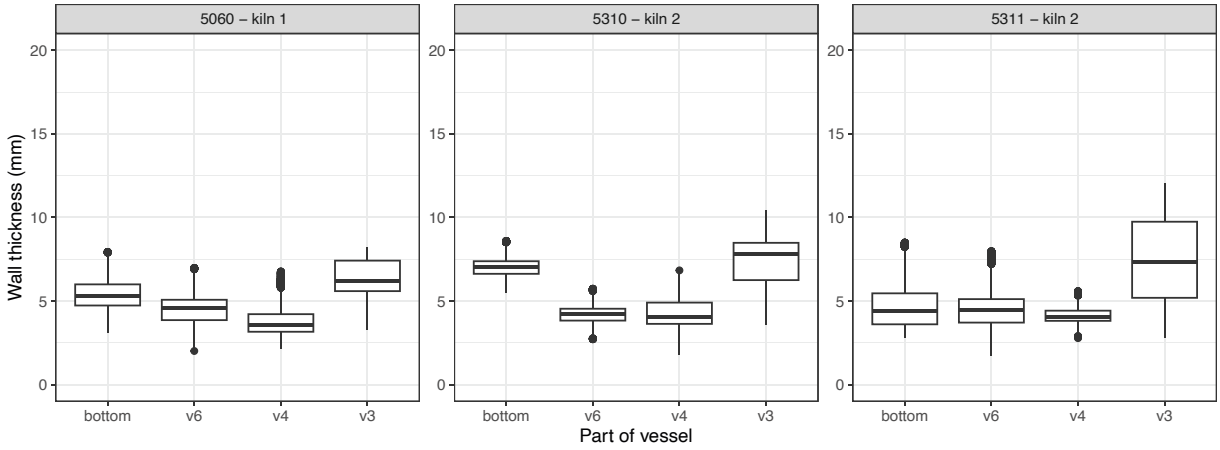
The petrographic composition of all fabric groups corresponds closely to the local geological context. The bedrock underlying the site and its immediate surroundings consists of strongly metamorphosed rocks belonging to the diverse lithological units of the western Moravian Moldanubian Zone. These include serpentinitised peridotites, migmatites, and migmatitic biotite gneisses. To the east, granulites and amphibolites become increasingly prominent. The village was bordered by two streams – Račický potok and Rouchovanka. Their confluence is partly covered by Pleistocene loess containing weathered rock fragments, while the floodplain is composed of Holocene alluvial sediments. A serpentinite body crops out directly at the site, containing intercalated positions of eclogitic amphibolite. This rock was quarried locally and used as construction material for village houses, a mill, and a fortified manor. In addition to quarried serpentinite, boulders of migmatitic gneiss collected from the surrounding landscape were also employed in building structures. Weathered serpentinite served as the raw material for fabric A. The rounded nature of the aplastic grains in subgroup A2 indicates short-distance fluvial transport. Fabric groups B and C exhibit petrographic features suggesting derivation from gneisses. Fabric C was either tempered with muscovite and biotite flakes or comes from mica rich alluvium. The provenance of this temper remains unresolved. It could have been obtained through sorting of weathering products of gneiss in the vicinity of the site. However, it may also have been more easily collected in areas with outcrops of mica schists, the nearest of which lie approximately 13 km to the east north-east near Čučice (within the Vranov–Olešnice Group of the Moravicum Unit), 15 km to the south near Rudlice (the Šafov group of the Moravicum Unit), or up to 20 km southeast near Miroslav (within the same geological group as Čučice outcrops). The loess was used to construct the kiln walls (Fig. 88: S, T; 89: T) and is associated with fabric D. Additional rock types identified at the site include material used for millstones and grindstones, specifically conglomerates (originating from basal Devonian and from the Boskovice Furrow) and durbachites of the Třebíč Massif (cf. Krajíčková 2004; Nekuda, Přichystal 2008). However, none of these rocks were detected in the ceramic fabrics.

Forming

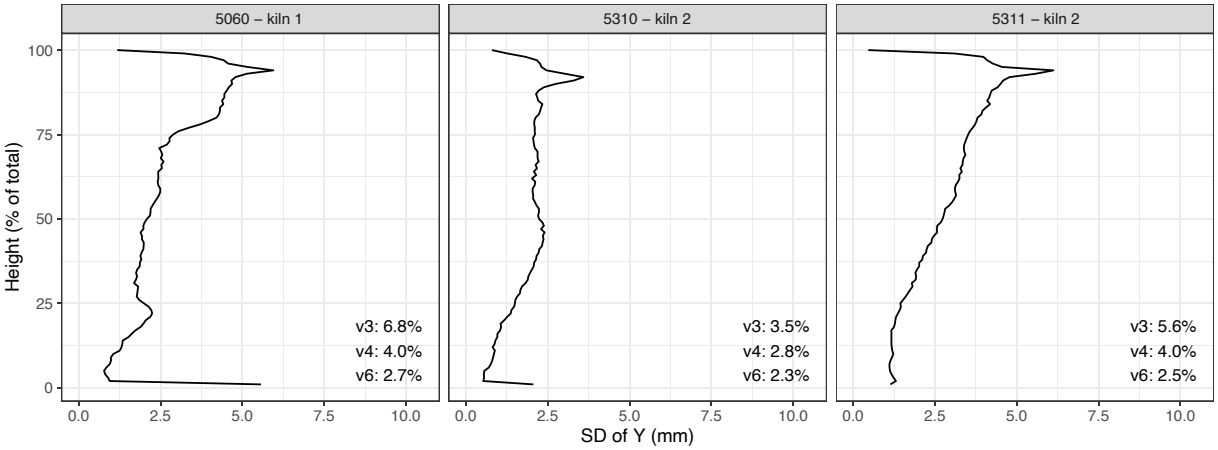
In kiln 1, vessel bases were preserved in thirteen cases, eight of which bore the same potter's mark – a cross within a circle – although only a small portion of these can be verified today. In kiln 2, seven vessels were identified, with the mark appearing on only one base, again of the same motif (Fig. 90: 4). Another small base bore traces of sand dusting. Most of the



Fig. 90. Mstěnice. Technological traces on vessels, inv. No.: 1 – depressions from coils and grooves, 5541, kiln 1; 2 – depressions and lines indicating coiling, 5538, kiln 1; 3 – grooves from rapid rotation, 5348, kiln 2; 4 – depressions turning into rings – evidence of smoothing coil traces during rapid rotation, 5133, kiln 1; 5 – isolated traces of cutting off the bottom, 9988, kiln 1; 6 – rings and grooves, 5357, kiln 2; 7 – cutting off bottom edges during sand dusting and pronounced coil above the bottom, 5477, kiln 1; 8 – (a) sand dusting, traces of attachment of the bottom edges; (b) undulation of the inner surface of the bottom, 5275, kiln 1; 9 – (a) sanddusting, traces of attachment of the bottom edges; (b) smooth inner surface of the bottom, 5065, kiln 1. Photo by M. Košťál.



Graph 12. Mstěnice – both kilns. Boxplots showig variabiality in wall thickness visualising data obtained by 3D scanning (indices of vessel parts: v6 – bottom to maximum belly diameter; v4 – maximum belly to the narrowest part of the neck; v3 – between the neck and the rim's edge). Author K. Slavíček.



Graph 13. Mstěnice – both kilns. Diagram showing the standard deviation of the outer surface from the rotational axis across vessel height. Vessel part indices (v3, v4, and v6) are indicated, along with the corresponding coefficients of variation for each respective vessel part. Author K. Slavíček.

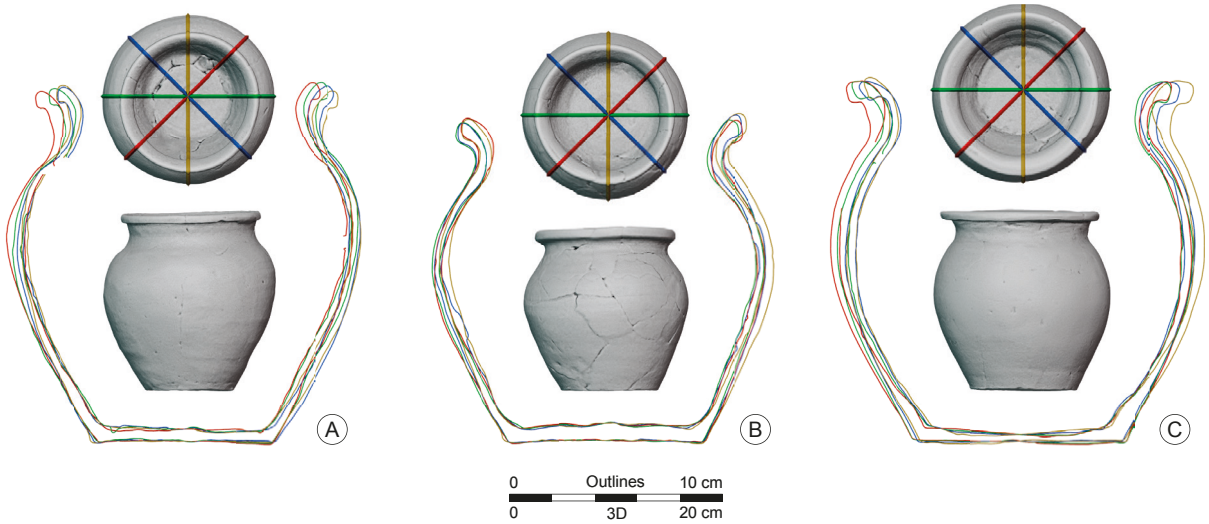


Fig. 91. Mstěnice. 3D models and vertical cross-sections showing degree of vessel symmetry, inv. No.: A – 5060; B – 5310; C – 5311. Author M. Košťál.

pot bottoms from the kilns and the stoking pit show traces of sand dusting (Nekuda 1963, 68–70; 1972, 36; 2000, 152–154; Michna 1966, 5).

The traces observable on the preserved vessels and fragments from kiln 1 were as follows: On the inner surfaces of rims and necks, grooves produced by fingerprints or by a wooden tool could be observed (Fig. 90: 3, 6). Traces of depressions and ridges are found on the inner wall of the vessel bodies – in the upper areas, they are indistinct with grooves; in the lower areas, they are more pronounced and in some cases are accompanied by local traces of coils (dents, vacuoles). (Fig. 90: 1, 2). At the junction between the base and the body, a faint coil ridge above the base could sometimes be noted (Fig. 90: 7). The interior surfaces of the bases were smooth and relatively even, while the exteriors were coarse in texture but occasionally smoothed along the edges, interpreted as evidence of sand dusting.

Similarly, the vessels and fragments from kiln 2 bore traces of grooves (Fig. 90: 3, 6). In the upper body sections, faint ridges or depressions sometimes appeared together with these grooves (Fig. 90: 4, 6). In the lower body parts, the traces are again mostly subtle ridges or depressions that cannot be clearly interpreted. Only in a few cases could they be identified directly as coil depressions (Fig. 90: 1, 2). Occasionally, shallow indentations or faint joining lines between coils were observed. At the junction of the body and the base, a weak coil ridge above the base is present in some cases, though without a sharply defined edge. The interior surfaces of the bases, marked by fine grooves, are regular and even, while the exteriors are coarser, with faint peripheral traces likely indicating removal from a sand-dusted turntable (Fig. 90: 8, 9). Two base fragments made from a more micaceous paste show traces resembling cutting, although given their state of preservation, these may also reflect friction between the vessel base, the sand dusting, and the turntable during removal (Fig. 90: 5).

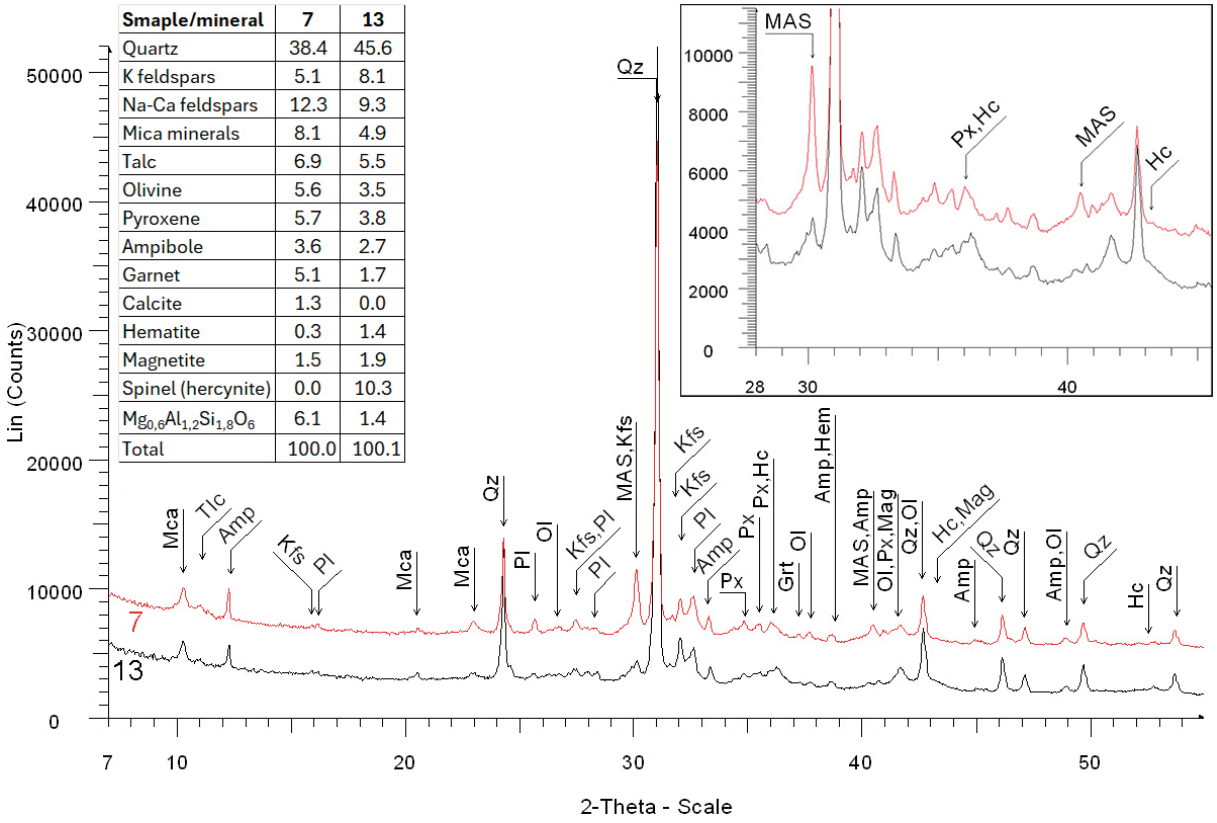
Three vessels were scanned using 3D surface modelling: pot 5060 from kiln 1, and pots 5310 and 5311 from kiln 2. The scans revealed consistent wall thickness (Graph 12; Appendix 3-D): just over 4 mm in the lower body and neck (indices v6 and v4), and 6 mm (kiln 1) and 7 mm (kiln 2) at the rim (v3). The standard deviation in wall thickness for most vessel sections was approximately 1 mm, except for vessel 5311, which reached 2.5 mm (v3). No consistent trend was observed in the coefficient of variation in relation to vessel height – i.e. wall thickness variation did not consistently decrease from base to rim. In general, the rim section (v3) exhibited the greatest wall thickness, likely related to rim form. In terms of axial symmetry, however, a clear trend emerged: variation increased with height from the base (Graph 13; Fig. 91). The coefficient of variation was around 2.5% in the lower body (v6), rising to 3–4% above the point of maximum diameter (v4), and reaching 3.5–6.8% at the rim (v3).

Firing

On the complete and partially preserved vessels, reducing firing predominates, producing dark grey to grey-black colours, occasionally with a slight oxidising layer on the surface and a dark brown surface (Fig. 86). In kiln 1, the pottery is mainly reduced, with medium to dark grey tones. Mixed or oxidising firing occurs only rarely (around 5%), and dark cores or fragments showing signs of overfiring are exceptional. In kiln 2, a higher proportion of mixed-fired pottery and vessels with an oxidising layer on the surface and grey-red surfaces was recorded (around 40%), although pottery with reducing firing in medium to dark grey-brown hues still predominates slightly. The ceramics from the stoking pit associated with the kilns exhibit the same firing characteristics (Nekuda 1963, 66–68; 2000, 152–154; Michna 1966, 1–5).

Samples investigated petrographically from both kilns exhibit evidence of mixed firing conditions. Several sherds show traces of both oxidation and reduction. A sandwich-like effect – where the outer layers and core exhibit distinct firing atmospheres – was observed only in a minority of cases. In most samples, the degree of oxidation or reduction is either consistent across the thin section or manifests as a reductive margin with a predominantly oxidised core. Approximately half of the samples displayed a darker surface relative to the core, which we interpret as evidence of technically imperfect smoked-firing.

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Smaple/mineral	7	13
Quartz	38.4	45.6
K feldspars	5.1	8.1
Na-Ca feldspars	12.3	9.3
Mica minerals	8.1	4.9
Talc	6.9	5.5
Olivine	5.6	3.5
Pyroxene	5.7	3.8
Ampibole	3.6	2.7
Garnet	5.1	1.7
Calcite	1.3	0.0
Hematite	0.3	1.4
Magnetite	1.5	1.9
Spinel (hercynite)	0.0	10.3
$Mg_{0,6}Al_{1,2}Si_{1,8}O_6$	6.1	1.4
Total	100.0	100.1

Graph 14. Mstěnice. Diffractograms of samples 7 (kiln 1) and 13 (kiln 2): angular range 7–55 °2θ and results of quantitative phase analysis of crystalline fractions of the samples. The inset in the upper right corner shows an enlarged area of the record containing well-defined reflections of phases indicating firing conditions. Neoformed spinel (close to hercynite) forms during the firing under reducing conditions at temperatures around 950°C. Another neoformed phase is magnesium aluminosilicate with hexagonal symmetry corresponding to μ-cordierite. Pyroxenes, olivine, and talc are typical phases originating from serpentine rock, which is part of the aplastics. Hematite indicates oxidizing conditions. It can be assumed that during the firing of sample 13, the atmosphere in the kiln was oxidising (based on the presence of hematite), and later changed to reducing, under which spinel (hercynite) crystallized. Magnetite can be either a residue from the raw material or a phase neoformed under reducing conditions. Calcite is of secondary origin. The complexity of the phase composition is due to both the presence of diverse aplastics and neoformed phases; Amp = amphibole, Cal = calcite, Grt = garnet, Hc = spinel close to hercynite, Hem = hematite, Kfs = K felspars, MAS = phase close to Mg0,6Al1,2Si1,8O6 (μ-cordierite), Mag = magnetite, Mca = mica minerals, Ol = olivine, Pl = Na-Ca feldspars, Px = pyroxene, Qz = quartz, Tlc = talc. Author D. Všianský.

Firing temperatures were generally low, not exceeding 700–800°C. This is indicated by the strong pleochroism of biotite, limited oxidation of green amphiboles and mostly moderate to high optical activity of the matrix. In samples of fabric group A, where biotite is predominantly close to the phlogopite end-member, the assessment of firing temperature based on biotite pleochroism was constrained due to the typically lower Fe content. Only two samples, both classified as fabric A1 (samples 7 from kiln 1 and 13 from kiln 2), exhibited signs of higher firing temperatures. These were evidenced by reduced optical activity of the matrix in the core, suggesting firing temperatures possibly reaching up to 950°C. This assumption was confirmed by XRD analysis, which revealed neoformed spinel (close to hercynite) and magnesium aluminosilicate phase aluminosilicate with hexagonal symmetry corresponding to μ-cordierite (Graph 14).

4.5 Žďár nad Sázavou – 'Staré Město'

The 'Staré Město' site is located on the northern edge of Žďár nad Sázavou in central Czech Republic. Today, it is partly covered by a satellite housing estate and partly situated on agricultural fields along the road from the Klafar Spring to Starý Dvůr (Fig. 92). Historical records in the *Cronica Domus Sarensis* date this market village to the early period of the nearby Cistercian monastery, likely established between 1252 and 1257 and abandoned around 1262–1276 (Ludvíkovský et al. eds. 1964). It is believed that the settlement was subsequently relocated to what is now the centre of Žďár nad Sázavou. Archaeological research, which has uncovered nearly the entire settlement area, confirms a short period of occupation, potentially just one generation, as indicated by the absence of overlapping archaeological layers.

Extensive excavations were first conducted by M. Richter (1974), followed by investigations

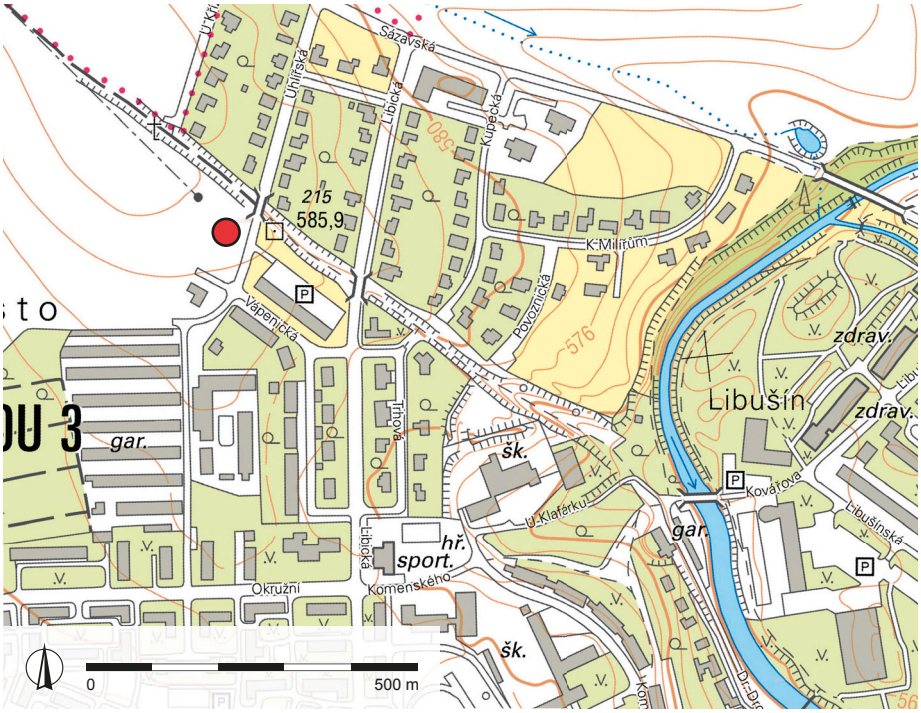


Fig. 92. Žďár nad Sázavou – 'Staré Město'. Location of the kiln on the current map. Source: mapy.cz; graphics by M. Filip.

led by M. Geisler from the Institute of Archaeological Heritage Brno during the 1990s and particularly in 2004–2006 due to construction activities (Zatloukal 1999; Geisler 2006). While most of the settlement has been excavated, only selected areas have been fully evaluated and published, including material from the 1990s (Zatloukal 1999) and pottery from the 2004 season (Těsnohlídková 2021). Ongoing comprehensive analyses are part of D. Václavíková's doctoral research, with the kiln structure previously discussed in K. Těsnohlídková's doctoral thesis and related publications (Těsnohlídková 2021; 2022a). The broader context of medieval ceramic production in the region is summarized by Čapek et al. (2022, 142).

In 2006, the remains of a pottery kiln (feature K 1548) were excavated, though its function was not initially recognized (today Vápenická Street, plot No. 7973/7, 7973/11). A reassessment in 2020 identified it as a pottery kiln and in 2023 the evaluation of its batch was published (Slavíček et al.). Evidence of other crafts, including stone masonry and ironworking (smelting and blacksmithing), highlights the settlement's connection to the nearby Cistercian monastery (Malý, Gonda 2017; Kovář 2006; Geisler, Malý 2005). These activities reflect 'Staré Město's role as a market-oriented settlement with diverse non-agricultural functions. The finds are stored in the Regional Museum of the town of Žďár nad Sázavou. Based on a written record of the settlement's existence, the kiln could be dated to the third quarter of the 13th century, while the material found in it corresponds to the second half of the 13th century.

4.5.1. Kiln relic

The pottery kiln featured a simple, single-chambered design embedded in sandy ground, with base dimensions of 1.2 × 0.95 m and a preserved depth of 0.5 m (Fig. 93; cf. Procházka 2015, 217; Čapek, Preusz 2019, 323, tab. 2). It had a rectangular layout with rounded corners, oriented NNE–SSW, vertically inclined walls, and a slightly sloping floor towards the firing hole. The walls and floor exhibited red, grey, and black firing shades, with a fired layer about 2 cm thick on the walls and thinner on the floor. A sunken stoking channel connected the kiln to a front pit, which was not identified during excavation; the channel was wider near the kiln (30–40 cm wide, 20 cm deep) and narrowed to about 10 cm at its exterior The fill consisted of soil, small stones, charcoal, bricks, and ceramic fragments in at least two layers, with a 1–3 cm thick carbonised layer above the fired floor. No daub or construction elements were preserved, likely due to poor firing quality. Bricks in the upper fill appear unrelated to the kiln, as they are more recent and not in contact with medieval pottery, and medieval bricks are rare at the site. No evidence of fill and fuel separation was observed (Geisler 2006, 35)

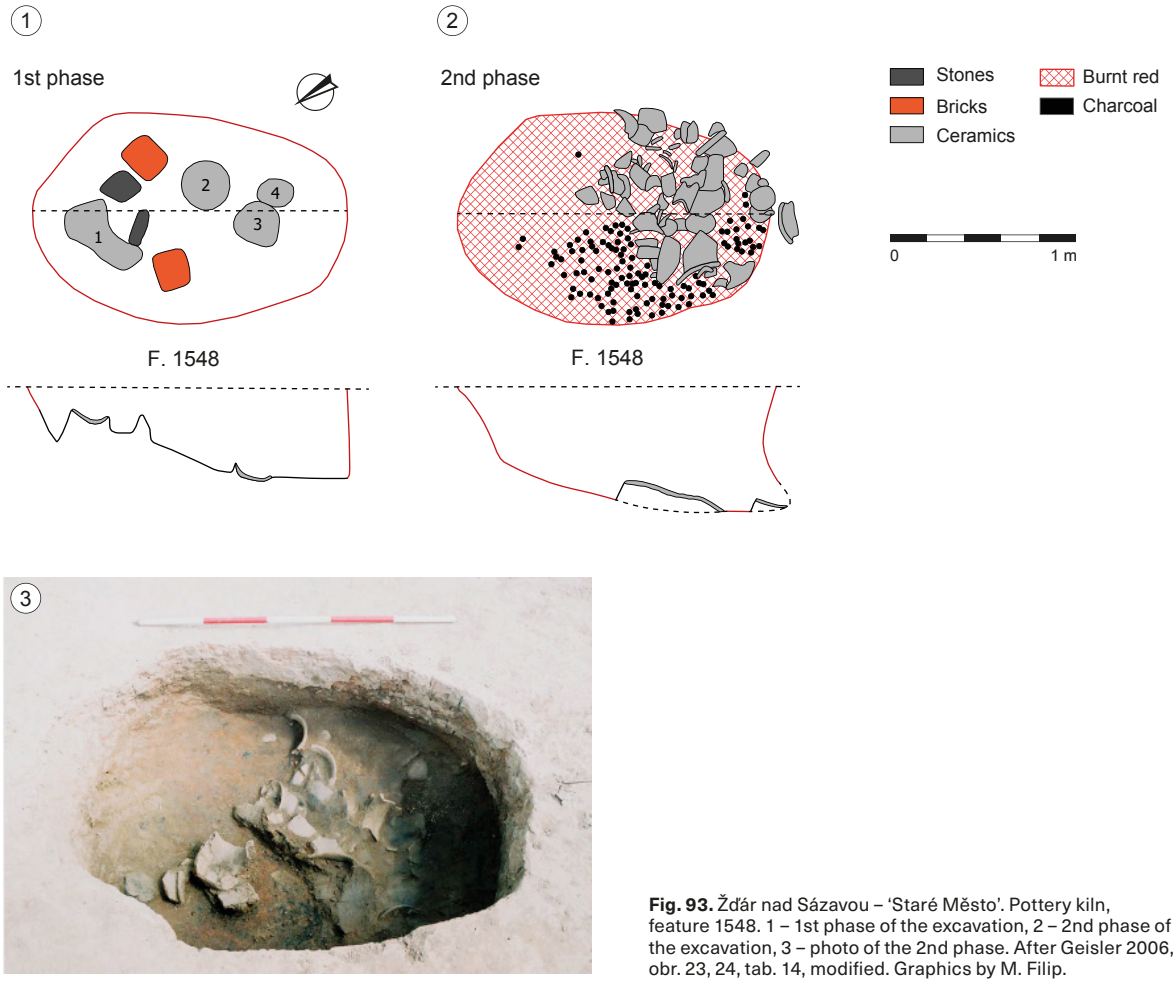


Fig. 93. Žďár nad Sázavou – 'Staré Město'. Pottery kiln, feature 1548. 1 – 1st phase of the excavation, 2 – 2nd phase of the excavation, 3 – photo of the 2nd phase. After Geisler 2006, obr. 23, 24, tab. 14, modified. Graphics by M. Filip.

The kiln contained a fragmented assemblage of 629 ceramic sherds along with 16 complete and partially preserved vessels (Fig. 94). A total of 16 pots were identified, with twelve preserved at 60–95% completeness, while the remaining four were 30–40% intact but retained complete necks or bases with parts of the body. The macroscopic material and technological characteristics of the sherds correspond closely to pottery fragments from settlement contexts (detailed in Slavíček et al. 2023). The identified ceramic fabrics and their distribution within the fragmentary assemblage are comparable to those of the complete vessels found within the kiln. Notably, the fragmentary assemblage displays a richer morphological typology, while the complete vessels consist exclusively of pots. Given the technological affinity between the assemblages, the set of complete vessels is considered sufficiently representative for analysis, offering greater interpretive value regarding the kiln's function and chronology.

4.5.2 Morphology, typology and metric properties of pottery

Vessel shapes were identified based on characteristic fragments, with 65 instances where shapes could be determined. Among sandy ceramics, 41 fragments belonged to pots, seven to bell-shaped lids, and six likely to jugs, while four fragments remained unidentified. One fragment possibly represented a low bowl or flat lid. In graphite ceramics, three fragments were identified as pots, and six as overfired ceramics (Tab. 5; Fig. 12). Bell-shaped lids featured rim types POZ.4.1 (twice), 4.3, and 5.2, with one lid having a measurable diameter of 150 mm (CC 3). A preserved handle measured 15 mm in diameter. Additionally, a flat lid fragment (POP.2) may have belonged to a low bowl (Těsnohlídková 2021, appendix 28). Although various ceramic forms were identified, pots were the most prominent. Therefore, the following text will focus exclusively on them.

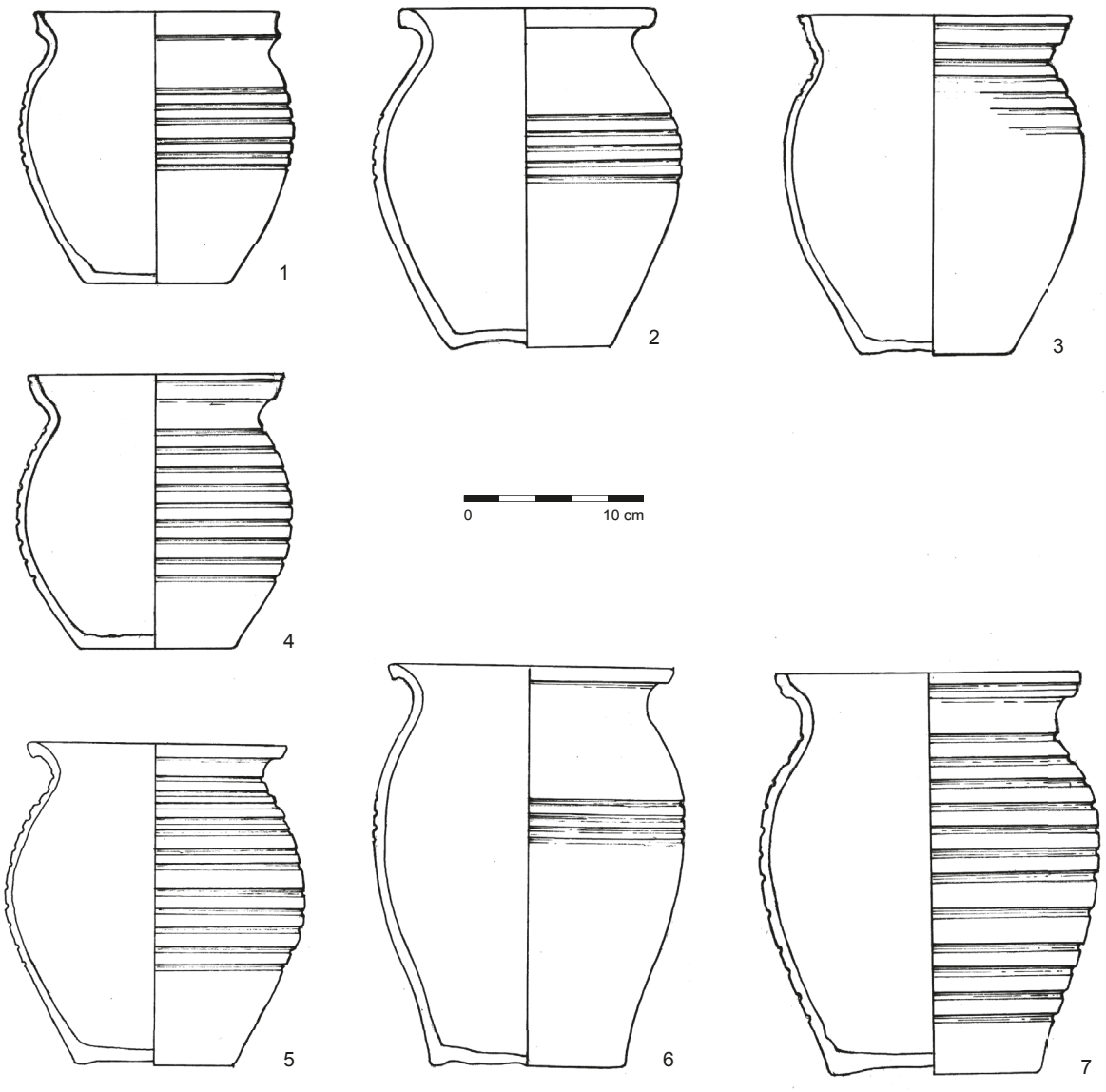


Fig. 94. Žďár nad Sázavou – 'Staré Město'. Pots, inv. No.: 1 – 66/6-349/4; 2 – 66/06-349/2; 3 – 66/6-349/6; 4 – 66/6-349/5; 5 – 66/06-349/3; 6 – 166/06-349/7; 7 – 66/06-349/1. Drawings by L. Dvořáková.

Based on their shapes and dimensions, the study identified five distinct pot types (Fig. 94). Type 1 includes rounded pots that are widest in their upper half. Type 2 features more slender pots with the broadest part around the middle, while type 3 also consists of slender pots, but with the widest point slightly higher up. Types 4 and 5 are smaller, rounder pots; type 4 is widest in the middle, and type 5 is widest closer to the top. All pot types have a smooth curve where the neck meets the body, except for type 5, which has a sharply angled neck. Dimensional analysis focused on height, proportions, and diameters was key for classification (Tab. 2). Heights ranged from 14 cm in type 5 to 21–23 cm in type 2 pots. Rim diameters varied, with type 1 averaging 13.5 cm (±10%) and type 3 reaching up to 19–20 cm. Base diameters were consistent across all types, ranging from 8 to 11 cm. Of the pots preserved at 60% or more, twelve could be classified into these types.

The W, H, D, and Z indices were determined for ten pots (Tab. 19). The mean and median values of the W index fall within the 'low' range, close to the 'medium' threshold; four vessels reach the medium level. Six vessels belong to the high bulbosity (H) category, three to medium, and one to low, with both the mean and median within the 'high' range. The mean and near-identical median values of the D index (indicating bulging) fall within the 'low' level, six

specimens belong here, while the rest fall into the medium level. The Z index shows identical mean and median values, corresponding to the 'medium' level, yet tending toward the 'low' subgroup, which includes three vessels.

Pot rims were focusing on those with more than 15% of the original circumference intact. There were 39 rims: eight type JH, eight type VN, eight type V, seven type S, five type P, two type OV (Fig. 95). Most pots were decorated with grooves, ranging from one to twelve per vessel. Two pots combined grooves with one or two wavy lines.

4.5.3 Ceramic technology

Paste

Sandy pottery was predominant (88%), with twelve vessels classified as medium-grained sandy (CC 3; for detailed characteristics of ceramic classes, cf. Těsnohlídková 2022a, 63–68) and two as fine sandy (CC 2). The remaining two vessels contained graphite, one with matte grains (CC 9) and the other with shiny grains (CC 10; Tab. 3). Most vessels also contained small red clay pellets along with traces of burnt organic matter across all pottery classes.

	No. of pots	W	H	D	Z
Index range	10	0.30–0.46	1.03–1.35	0.41–0.8	1.54–2.04
Mean	10	0.41	1.18	0.63	1.7
Median	10	0.41	1.17	0.67	1.79

Tab. 19. Žďár nad Sázavou – 'Staré Město'. Pot index values.

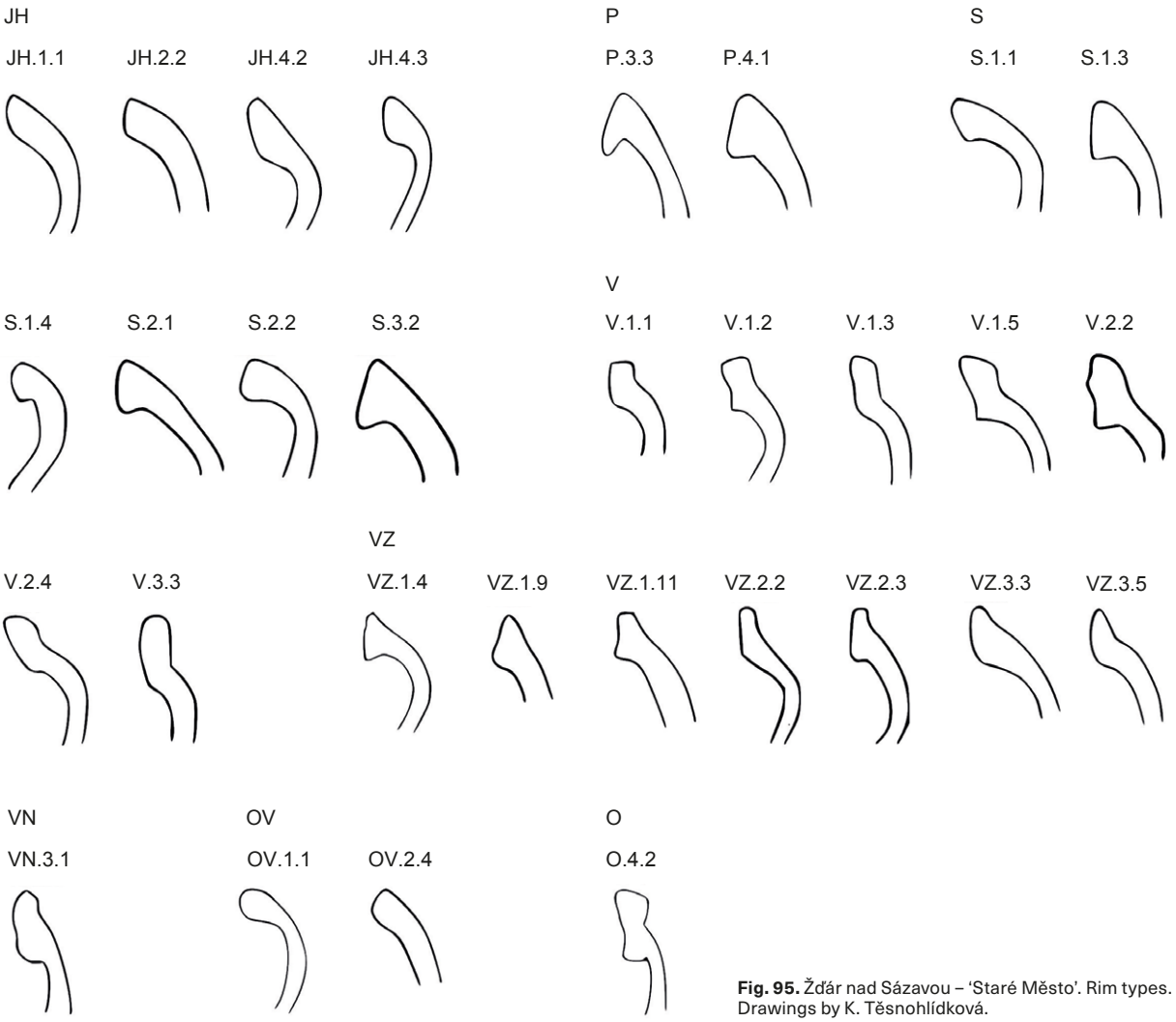


Fig. 95. Žďár nad Sázavou – 'Staré Město'. Rim types. Drawings by K. Těsnohlídková.

The selection of samples for archaeometric analyses considered the diversity of ceramic groups and classes within the kiln (Tab. 20; Fig. 96). Due to the destructive nature of some methods and the limited number of finds, complete or partially preserved vessels were not sampled. Instead, vessel bulge fragments, likely associated with preserved vessels based on macroscopic comparison, were analysed both from sandy ceramics and graphite-tempered pottery.

Archaeometry made it possible to distinguish two fabrics (cf. Slavíček et al. 2023) among CC 3 and CC 2 – fabric A1 and A2 (Tab. 21). All samples within the main fabric (A1) exhibit weakly parallel or parallel microstructure (Appendix 2-E). Aplastic inclusions are poorly sorted with a bimodal grain size distribution. The homogeneous, non-calcareous

ID	Inv. No.	Vessel type	Ceramic class (CC)
1	66/06-349/112	Pot	Sandy (fine-grained)
2	66/06-349/112	Pot	Sandy (fine-grained)
3	66/06-349/112	Pot	Sandy (fine-grained)
4	66/06-349/112	Pot	Sandy (fine-grained)
5	66/06-349/112	Pot	Sandy (fine-grained)
6	66/06-349/112	Pot	Sandy (fine-grained)
7	66/06-349/112	Pot	Graphitic (matte grains)
8	66/06-349/112	Pot	Graphitic (shiny grains)
9	66/06-349/112	Pot	Sandy (fine-grained)
10	66/06-349/33	Pot-lid	Sandy (medium-grained)
11	66/06-349/34	Pot-lid	Sandy (fine-grained)
12	66/06-349/50	Flagon with a stirrup handle	Sandy (fine-grained)
13	66/06-349/22	Bottle	Sandy (oxidised)
14	66/06-349/37	Jug	Sandy (oxidised)
15	66/06-349/15	Brick	×

Tab. 20. Žďár nad Sázavou – 'Staré Město'. Samples selected for analyses.

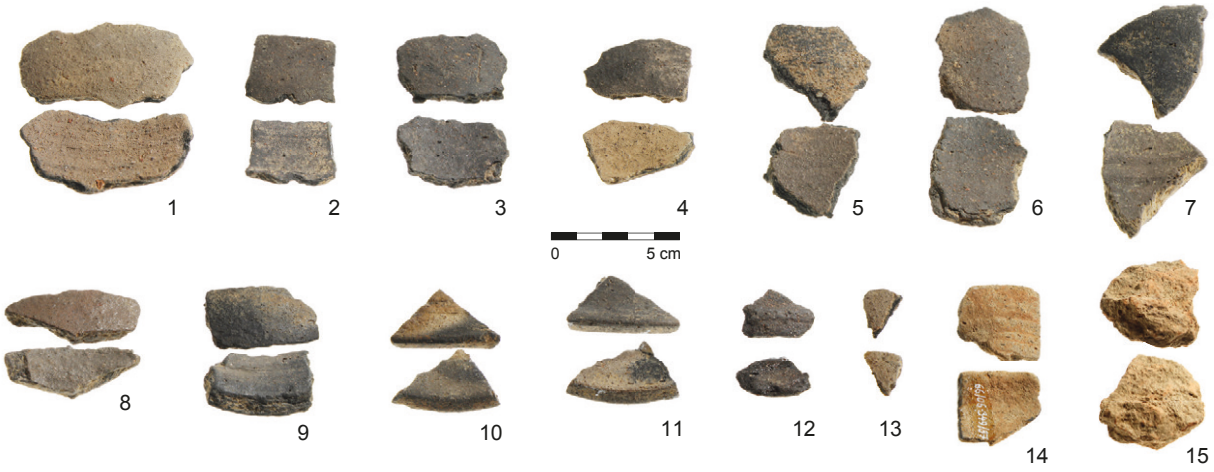


Fig. 96. Žďár nad Sázavou – 'Staré Město'. Photodocumentation of analysed samples. Photo by K. Slavíček.

Fabric	Sample IDs	Fabric description	Fabric features	Petrographic markers	Chemical markers	Possible sources
A1	1-4, 6, 7, 9-14	Clay with silt, rich in biotite, sand tempered	Mostly weakly parallel microstructure, bimodal grain size distribution	Biotite, quartz, gneiss, plagioclase, alkali feldspar, granitoid, metaquartzite, muscovite, mica schist, amphibole, garnet	Representation of 'average' for the site	Clay: local loam or clay loam, rich in biotite derived from Moldanubian crystalline bedrock. Temper: sand from weathered Moldanubian gneiss or granitoids
A2	5	Clay with silt and sand, rich in biotite, non tempered	Unparallel microstructure, unimodal grain size distribution	Biotite, quartz, gneiss, plagioclase, alkali feldspar, granitoid, garnet ,metaquartzite, muscovite, amphibole	Compared to Fabric A1: elevated K, Mn, Fe, Sr, and Ba, lower Al	Clay: the same as fabric A1
B	8	Clay with silt, graphite tempered	Weakly parallel, bimodal grain size distribution	Graphite, graphitic metaquartzite, quartz, metaquartzite, gneiss, alkali feldspar, plagioclase, biotite, muscovite, amphibole	Compared to fabric A1: elevated Ti, V, Cr, Fe, and Ni, lower Al, K, Ca, Rb, and Sr	Clay: local loam or clay loam. Temper: Graphitic metaquartzite, closest known deposts – Cikháj, Herálec, Netín, Vídeň, Zvole

Tab. 21. Žďár nad Sázavou – 'Staré Město'. General description of fabrics (petrographic markers are listed in order of relative abundance).

matrix contains up to 5% silt or fine mineral grains (usually up to 60–80 µm). Notably, short biotite flake fragments are present (size up to 500 µm, avg. size ~100 µm). Tempering was intentional, using sand-sized (average size 250–600 µm and maximum size up to 2000 µm) rock fragments and minerals, predominantly sub-angular to sub-rounded. The mineral temper content ranges from 5–15% (Fig. 97: A–D).

The most abundant rock type among aplastic inclusions, occurring commonly to frequently, is gneiss (Appendix 1-E). Granitoids and metaquartzite are present occasionally to commonly. Mineral composition includes abundant quartz and biotite (Fig. 97: A, B), with muscovite ranging from trace to occasional amounts. Alkali feldspars and plagioclase are common to frequent, with plagioclase slightly more prevalent. Accessory minerals include amphibole (present occasionally in samples 3 and 4) and garnet (identified in sample 11). Plant remains were detected in samples 1, 3, 6, 7, 9, 11, and 12 (Fig. 98: D).

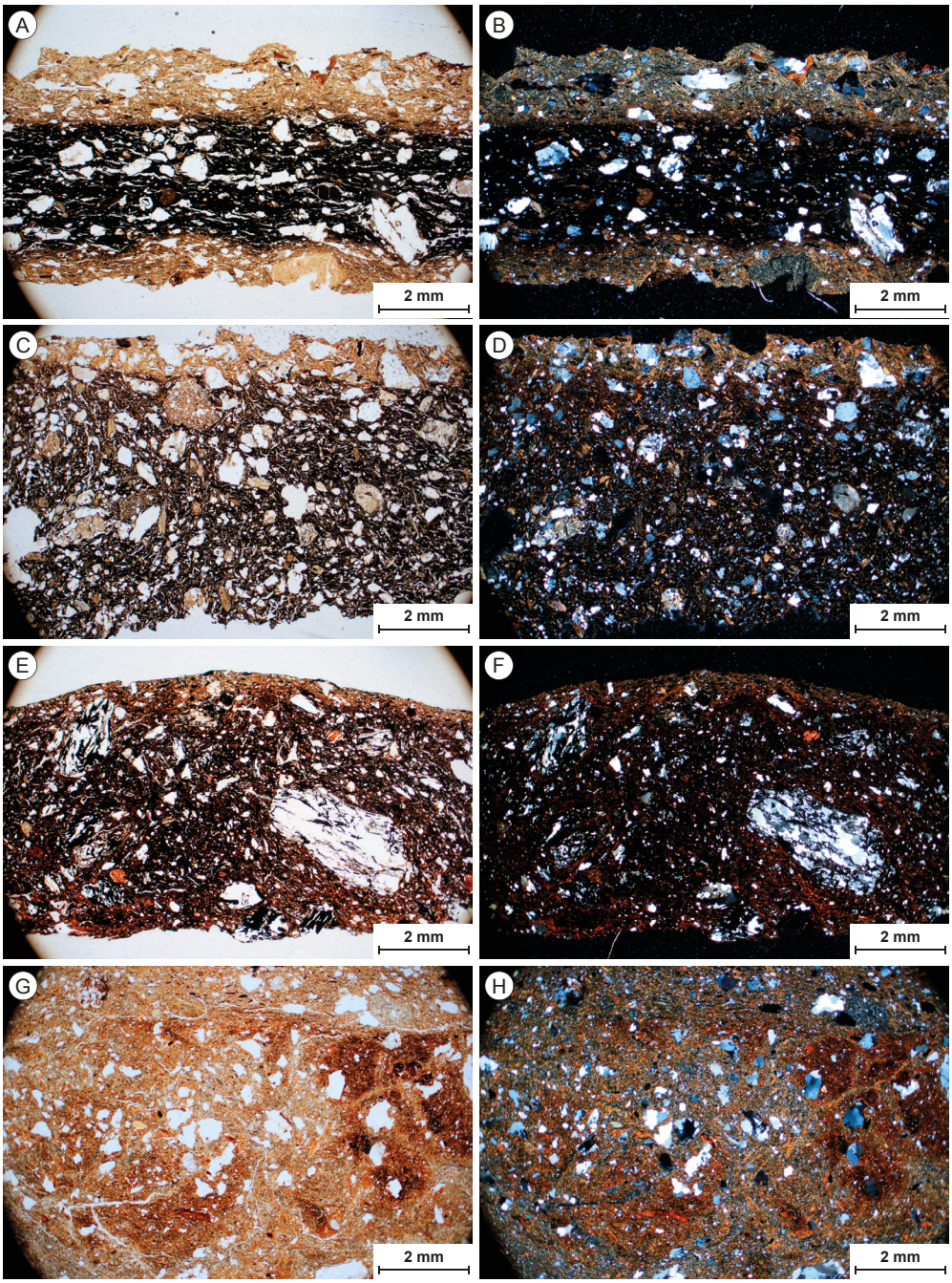


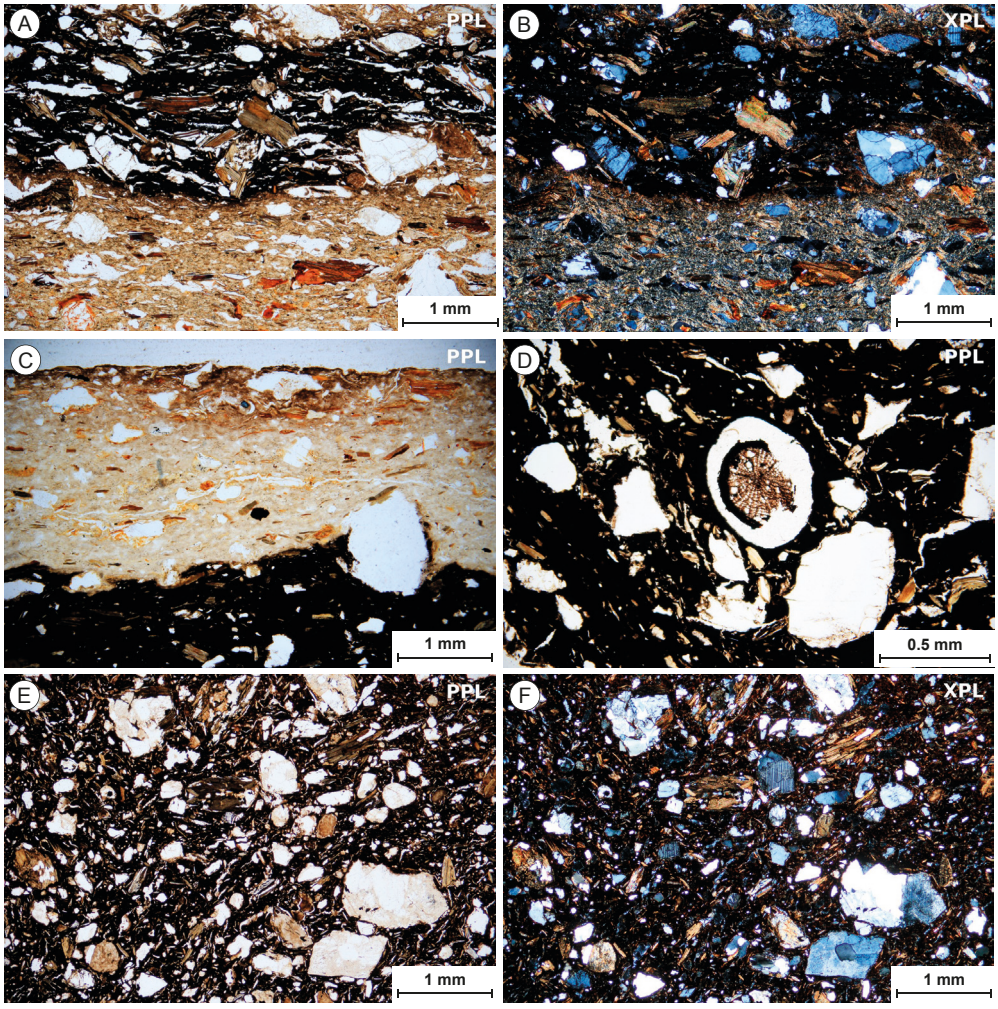
Fig. 97. Žďár nad Sázavou – 'Staré Město'. Overview of the microstructure of each fabric in PPL (left) and XPL (right): A, B – sand tempered fabric, sample 1; C, D – non tempered sample 5, sandy fabric; E, F – graphite pottery, sample 8; G, H – reference sample of a brick, sample 15. Author K. Slavíček.

One sample of sandy paste (specifically CC 3) differed in technology, namely the modality of grain size distribution (Appendix 2-E: sample 5), and therefore it was categorized as fabric A2. Its microstructure is non-parallel. Aplastic inclusions are poorly sorted, displaying unimodal grain size distribution. These inclusions are equant, subangular to subrounded, and relatively abundant, comprising up to approximately 30% of the sample. The grain size is 300 µm on average (maximum size <1300 µm). Due to the higher abundance of inclusions, this sample also differs chemically from the others, showing lower Al content and elevated levels of K, Mn, Fe, Sr, and Ba (Tab. 22; Graph 15).

Gneiss is the most abundant among rock fragments in sample 5 (fabric A2), with granitoids occurring commonly and metaquartzite occasionally (Fig. 98: E, F). The mineral composition includes abundant quartz and biotite, with occasional muscovite. Both plagioclase and alkali feldspars are frequent, with garnet commonly present as an accessory mineral and amphibole occurring occasionally. Occasional plant remains are also present within the clay matrix.

Graphite ceramic (fabric B, sample 8) analyses revealed that the microstructure is weakly parallel. Aplastic inclusions are very poorly sorted with a strongly bimodal grain size distribution (Fig. 97: E, F). The ceramic body contains approximately 5% naturally occurring silt-sized (max. size 80 µm) mineral grains and rock fragments. Sand-sized, and eventually granule-sized, rock fragments and graphitic grains used as temper are elongated to equant and subangular, comprising around 20% of the total ceramic mass. Average size of temper is ~300 µm, while the largest grains reach up to 3500 µm.

Graphitic metaquartzite was the dominant component of temper among graphite pottery (Fig. 98: G, H). Metaquartzite occurs commonly,



while gneiss is observed only occasionally. Mineralogically, it was strongly dominated by graphite, with abundant quartz. Other minerals, including alkali feldspars, plagioclase, biotite, muscovite, and amphibole occur occasionally. This distinct petrography is also reflected in the bulk chemical composition of the graphite ceramics, which show slightly lower contents of Al, K, Ca, Rb, and Sr, and elevated levels of Ti, V, Cr, Fe, and Ni (Tab. 22; Graph 15).

Petrophysical evidence and comparison with the local geology suggest that the fabrics found in the kiln are of local origin. The sandy, non-calcareous fabrics A1 and A2 were likely made from local loam or clay loam, with biotite naturally present in the clay. The increased biotite content supports its natural occurrence and the local origin of the raw material, as confirmed by analyses of a reference sample – a brick recovered from the upper fill of the kiln (Appendix 1-E: sample 15; Fig. 97: G, H; 98: I, J). The temper composition and accessory minerals point to nearby Moldanubian gneiss and granitoids, both present in the region's bedrock and River Sázava sediments. Graphite pottery was tempered with graphitic metaquartzite, likely sourced from deposits 8–20 km away, such as Cikháj, Herálec, Netín, Vídeň, Zvole, or an unlocalised graphite source near Žďár nad Sázavou itself (Burkart 1953).

Forming

Traces of vessel shaping were identified through marks on the bases of several pots. Concentric ridges on the inner bases of three vessels suggest smoothing during fast rotation, with occasional raised centres, central dips, or blade shift marks (Fig. 99: 1, 2, 8, 11). All inner bases show signs of modification via fast rotation. The outer bases reveal how vessels were attached to the potter's wheel, showing rougher surfaces likely achieved by dusting, clearly visible in

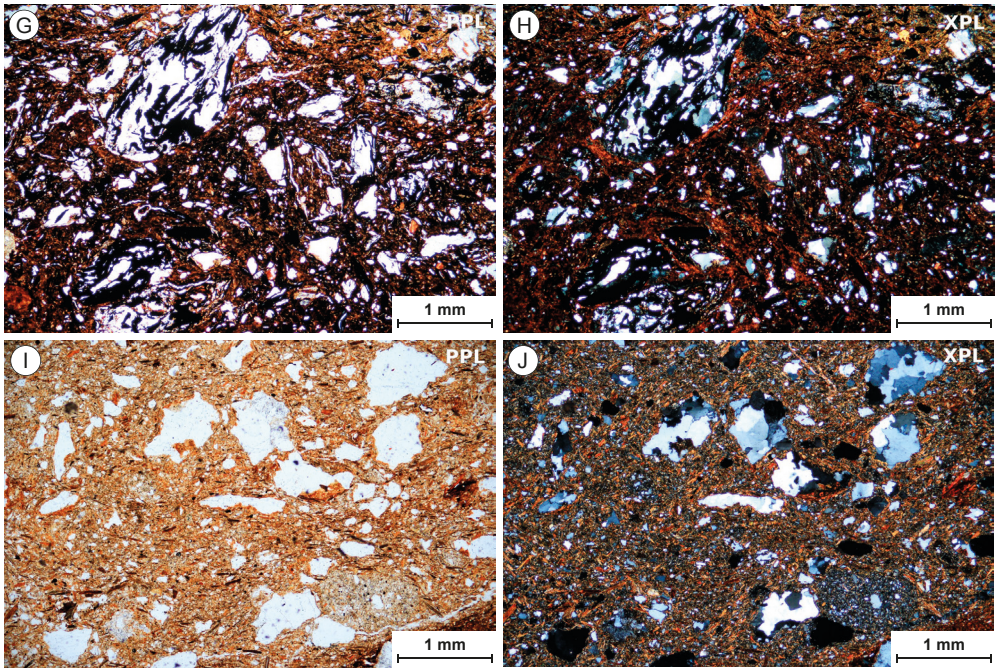
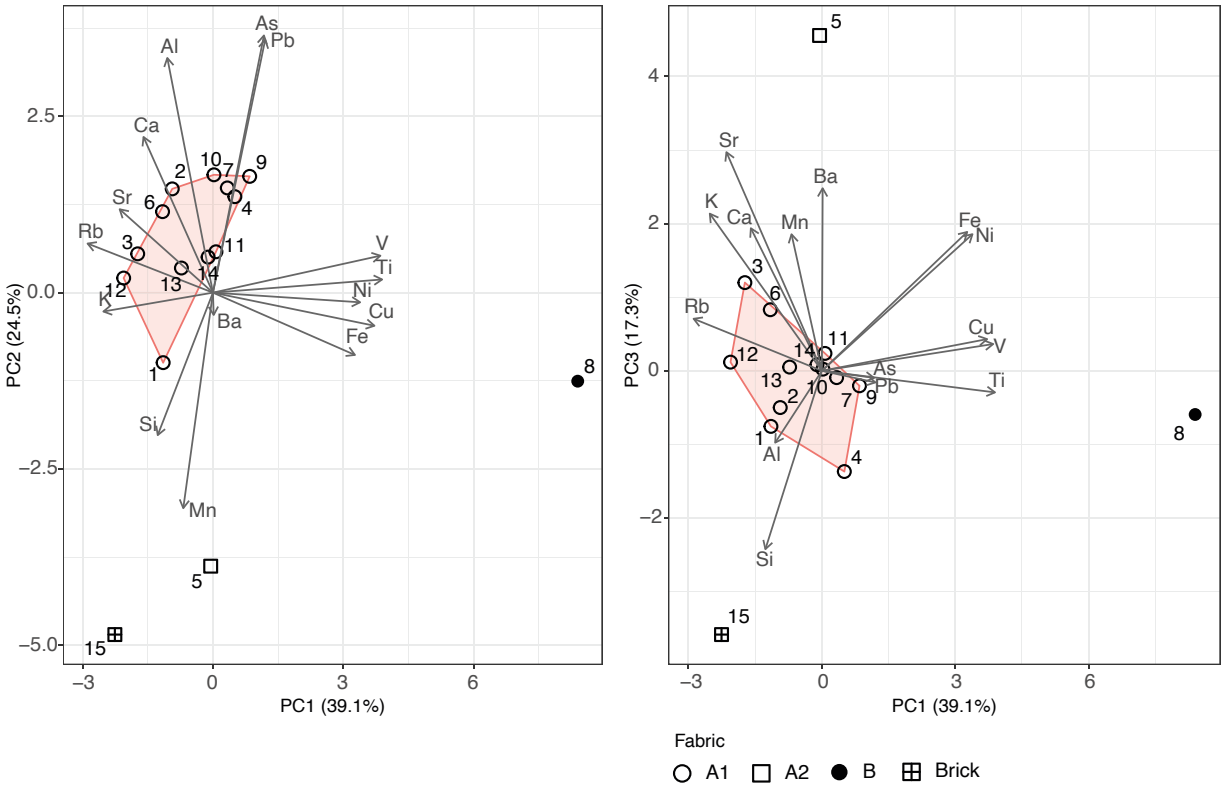


Fig. 98. Žďár nad Sázavou – 'Staré Město'. Photomicrographs highlighting key features in detail: A, B – sample 14 representing the main fabric, an oxidation layer beneath the vessel surface with numerous biotite flakes and fragments of metaquartzite in the ceramic matrix; C – sample 11 showing a pronounced oxidised layer, ceramic matrix contains a lower amount of aplastics demonstrating variability within the main fabric group; D – unburned organic tissue in the reduced core of sample 11; E, F – sample 5 with unimodally distributed aplastics represented by biotite flakes, fragments of gneiss, granitoid rocks, quartz, and feldspars; G, H – graphite pottery (sample 8) displaying a significantly lower content of biotite compared to the main fabric, including isolated graphite grains and fragments of graphitic metaquartzite used as a temper; I, J – intrusive brick sample 15 in PPL (left) and XPL (right) showing a different microstructure compared to the pottery, the predominant rock fragments are metaquartzite with a lower amount of granitoids and gneiss, the entire sample was oxidised. Author K. Slavíček.



Graph 15. Žďár nad Sázavou – 'Staré Město'. Principal component analysis of chemical composition – scatter plots of the first component against the second and third. The chemical composition of fabric A1 is relatively homogeneous, while fabric A2 shows increased concentrations of several elements. Fabric B differs markedly from the other samples, and the chemical composition of the brick is not closely related to any of the identified fabrics. Author K. Slavíček.

	Fabric A1				Fabric A2	Fabric B	Brick
	mean	sd	min	max	–	–	–
SiO_2	63	1.1	61.7	65	64.3	64.4	70.5
Al_2O_3	26.9	1	24.9	28.2	23.2	24.2	21.5
Fe_2O_3	5.7	0.3	5.2	6.1	7.3	7.4	4.6
K_2O	2.3	0.2	2	2.6	2.9	1.6	1.8
CaO	1.1	0.1	1	1.3	1.2	0.9	0.7
TiO_2	0.9	0	0.8	1	0.9	1.3	0.7
V	131	6	120	143	128	238	86
Mn	311	37	262	372	699	298	474
Ni	44	3	38	50	57	68	33
Cu	47	4	43	55	61	147	32
As	14	1	13	16	11	15	9
Rb	163	25	129	202	148	105	155
Sr	91	4	82	95	110	54	62
Ba	638	187	380	994	909	676	565
Pb	28	2	26	30	24	29	23

Tab. 22. Žďár nad Sázavou – 'Staré Město'. Summary of the chemical composition of fabrics (major oxides in wt %, trace elements in ppm).

four cases. Additional features include attachment marks (around the external perimeter) to a board (four instances), cut marks from detachment (four instances), and signs of inset bases where clay was pulled over and attached to a board (Fig. 99: 9, 10). Faint, worn impressions of wooden boards were observed in two cases. These marks were exclusive to sandy ceramics, while graphite vessels showed base marks worn away by abrasion. A prominent coil above the base was found on three vessels – two sandy and one graphite.

Technological traces on vessel bodies were observed as flat features, primarily depressions, present in 11 instances, mostly on the lower parts of the vessels. Depression or ring markings were identified in nine cases, often on the upper halves of vessels, frequently accompanied by deeper depressions on the lower sections. Evidence of coil construction was visible as lines at coil joints in five vessels, recessed joints in six, and uneven walls in two cases. Handling marks were apparent on six vessels, where compression occurred before the clay had fully dried, with one vessel even showing a crack on the inner wall due to this pressure (Fig. 99).

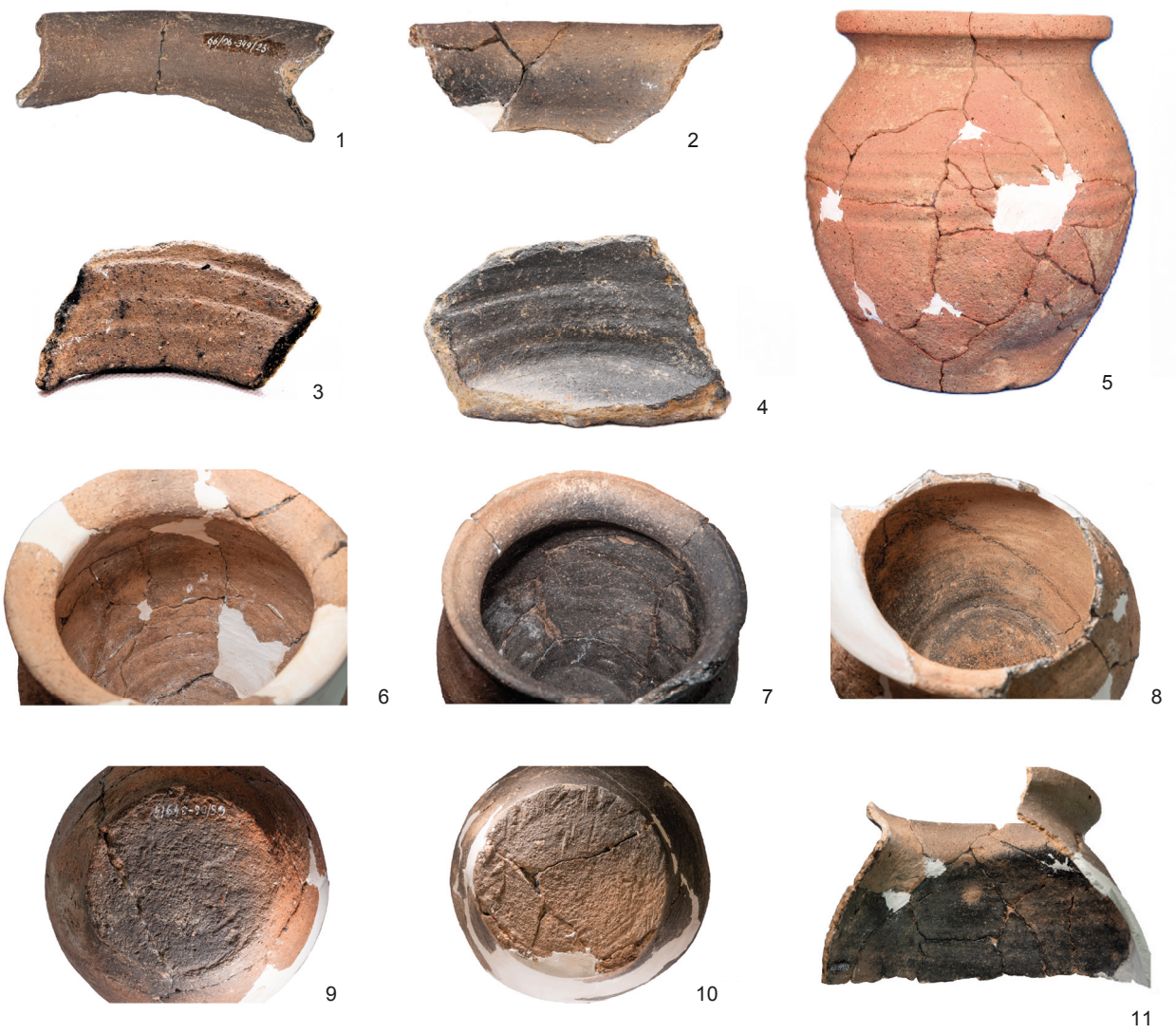
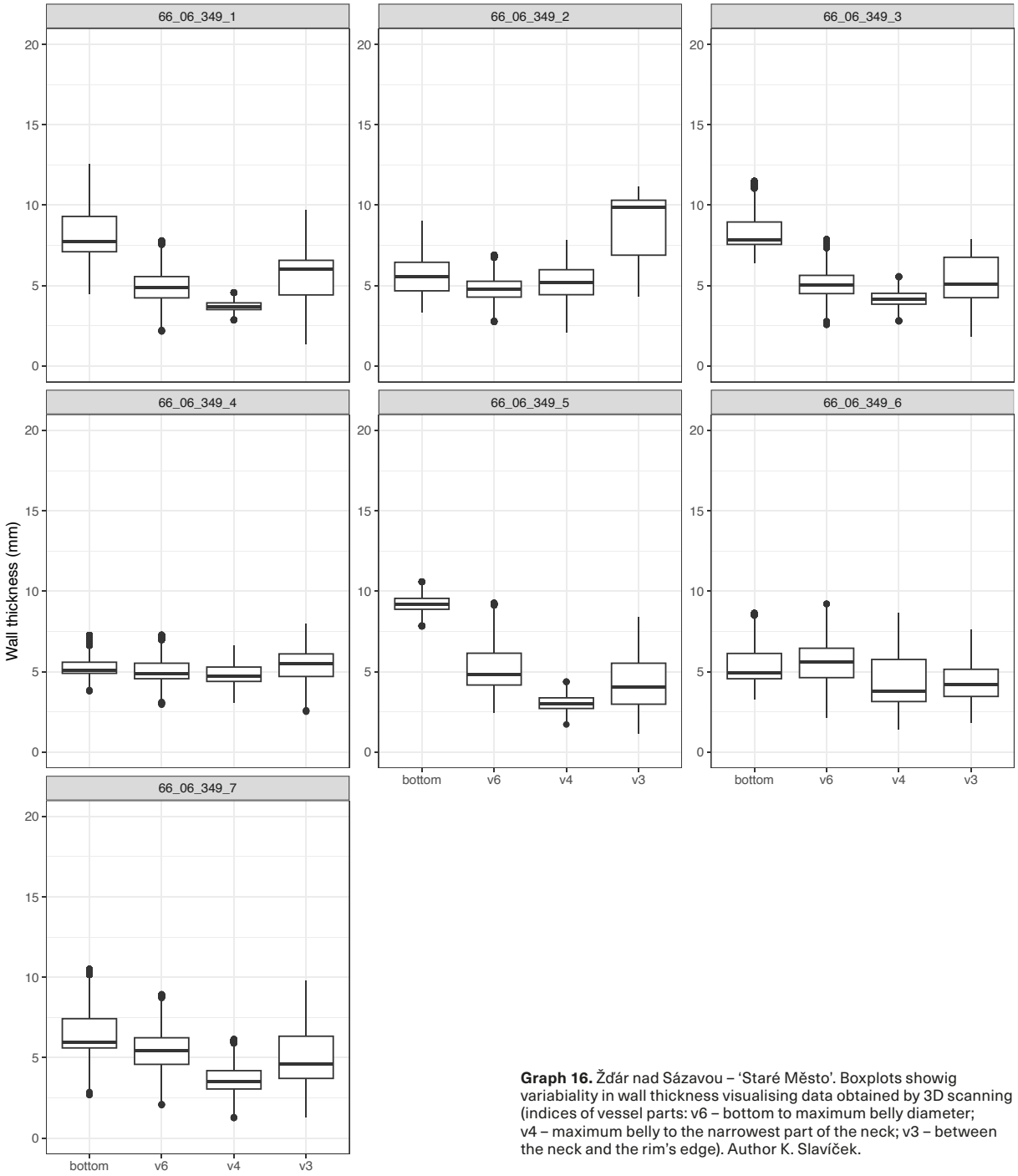


Fig. 99. Žďár nad Sázavou – 'Staré Město'. Technological traces on vessels, inv. No.: 1 – quick rotation marks on necks, 66/06-349/23a; 2 – quick rotation marks on necks, 66/06-349/23b; 3 – depression from coils and groves, 66/06-105; 4 – depression from coils and groves, 66/06-349/97; 5 – pot with traces above the bottom caused by manipulation with the vessel, 66/06-349/2; 6 – depression from coils, grooves and lines, 66/6-349/3; 7 – depression from coils, grooves and vacuoles, 66/6-349/4; 8 – depression from coils, grooves and lines, 66/6-349/5; 9 – traces of dusting and fixation of bottom to the board preserved around the bottom rim, 66/6-349/4; 10 – traces of dusting and cutting off the board, 66/6-349/7; 11 – oxidising biscuit firing oxidised surface of the rim and upper part of the neck, while reduced firing remained inside due to another pot inserted inside, 66/6-349/13. Photo by V. Nosek, M. Košťál.

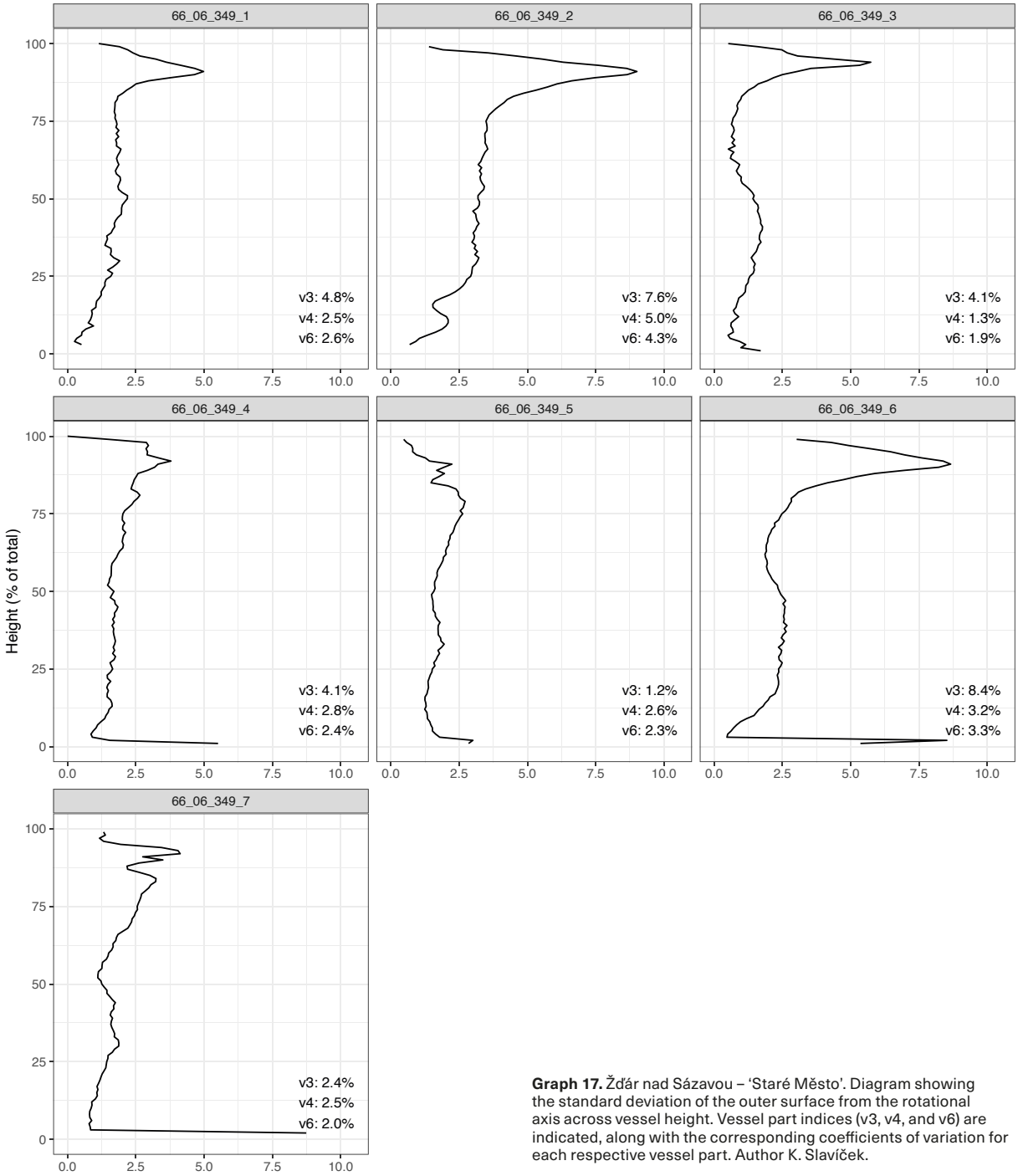
Grooves resulting from papillary lines or fine tools were the most common traces found on vessel rims and necks, present on 13 out of 16 vessels (Fig. 99: 1, 2, 11). One medium-grained sandy vessel (CC 3) showed signs of temper displacement. In contrast, three CC 3 vessels lacked grooves, likely due to surface abrasion or varying states of preservation.

Seven complete vessels – cooking pots – were selected for 3D scanning and subsequent data analysis. The wall thickness analysis yielded several noteworthy observations (Graph 16; Appendix 3-E): in four pots (66_06_349–1, 3, 5, 7), a decrease in wall thickness variability was observed from the lower body to the midsection, followed by a thickening toward the rim. In two vessels (66_06_349–4, 6), wall thickness remained consistent across the entire profile. One vessel (66_06_349–2) exhibited a distinct increase in both wall thickness and its variability at the rim. The average wall thickness across the sample ranged from 3 to 8.7 mm. The most uniformly thick-walled vessel (66_06_349–4) had a consistent wall thickness of approximately 5 mm, with a very low coefficient of variation (v6: 15.7%, v4: 13.2%, v3: 17%).



Graph 16. Žďár nad Sázavou – 'Staré Město'. Boxplots showig variabiality in wall thickness visualising data obtained by 3D scanning (indices of vessel parts: v6 – bottom to maximum belly diameter; v4 – maximum belly to the narrowest part of the neck; v3 – between the neck and the rim's edge). Author K. Slavíček.

Symmetry along the rotational axis, measured by standard deviations from the central axis (Graph 17; Fig. 100), revealed mostly consistent deviations from the base to the rim of the vessels. A notable increase in deviation was typically observed at the rim, with the exception of vessels 66_06_349–4 and 5, which showed uniformly low deviations across their entire profiles, with coefficients of variation below 3%. In two vessels (66_06_349–3, 6), a slight increase in deviation was recorded around the maximum diameter, followed by a decrease toward the rim. Overall, the coefficients of variation were generally low (v6: 1.9–4.3%, v4: 1.3–5%, v3: 1.2–8.4%).



Graph 17. Žďár nad Sázavou – 'Staré Město'. Diagram showing the standard deviation of the outer surface from the rotational axis across vessel height. Vessel part indices (v3, v4, and v6) are indicated, along with the corresponding coefficients of variation for each respective vessel part. Author K. Slavíček.

Firing

The vessels from the kiln were not significantly overfired but exhibited traces of both oxidising and reducing firing atmospheres. Every vessel displayed varying degrees of these characteristics. Oxidised areas suggest that in the later stages of firing, an oxidising atmosphere was present, leaving exposed surfaces with distinct marks. Reduced areas likely indicate parts that either did not reach sufficient temperatures or were covered by other vessels, fuel, or leaned against the kiln wall (Fig. 99: 6–8, 11). Oxidised layers appear on both inner and outer surfaces, while the core remained reduced. Biotite flakes within the samples exhibited pleochroism ranging from medium to strong suggesting firing temperatures of 700–800°C.

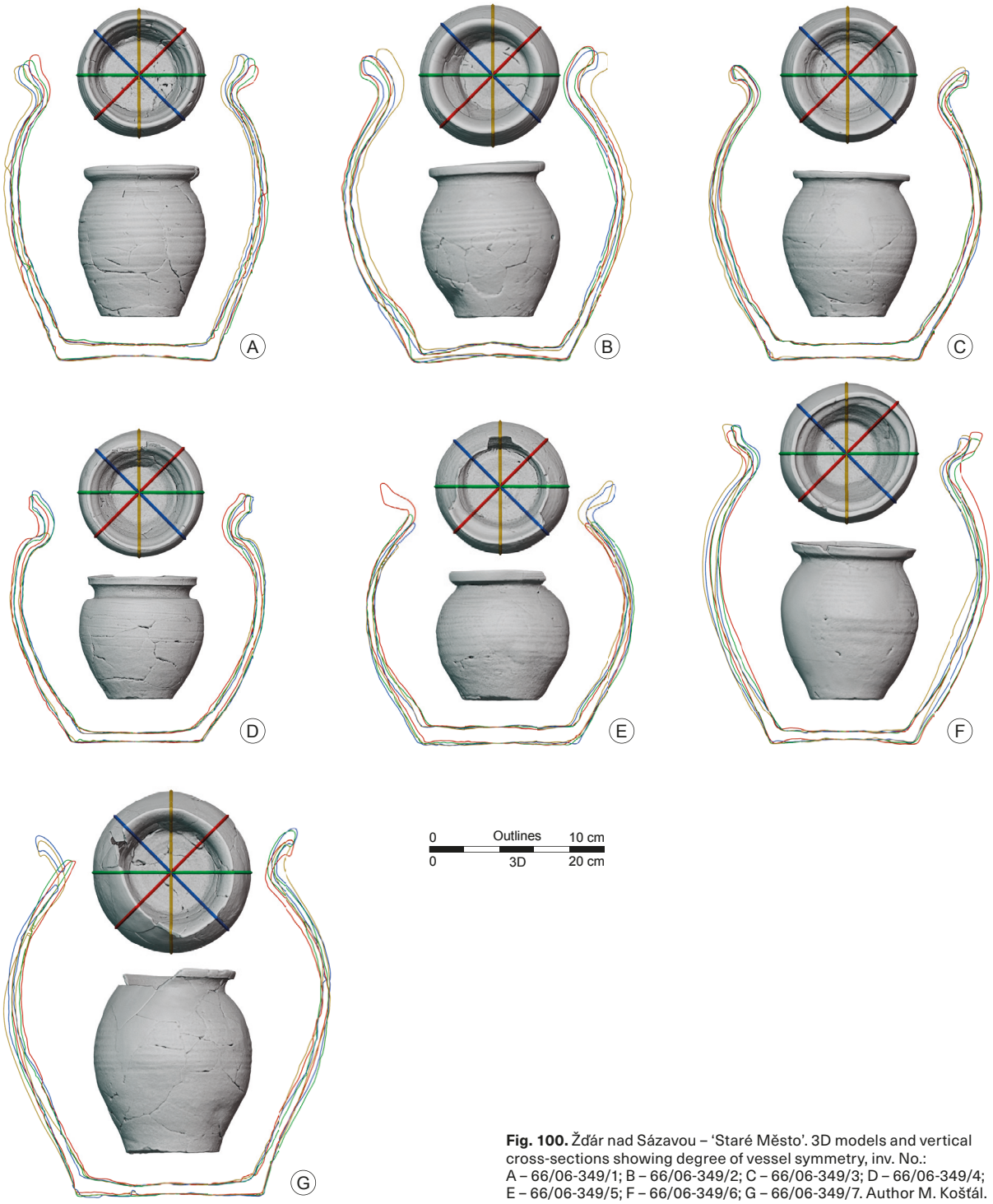


Fig. 100. Žďár nad Sázavou – 'Staré Město'. 3D models and vertical cross-sections showing degree of vessel symmetry, inv. No.: A – 66/06-349/1; B – 66/06-349/2; C – 66/06-349/3; D – 66/06-349/4; E – 66/06-349/5; F – 66/06-349/6; G – 66/06-349/7. Author M. Koštál.

4.6 Staré Město near Uherské Hradiště

At the site of an early medieval centre dating to the Great Moravian period, a market village named Veligrad was founded in the early 13th century along an important communication route, on the initiative of a nearby Cistercian monastery (Fig. 101). In 1257, part of its inhabitants were relocated to the newly established royal town of Uherské Hradiště, founded on an island in the River Morava. In the outskirts of this new centre, the village of Staré Město continued to develop. Evidence of pottery production was discovered during rescue excavations conducted between 1976 and 1978 in the inner blocks north of the historic west–east route. In the area 'Za Zahradou', between today's Rastislavova, Jezuitská, and Velkomoravská streets and náměstí Hrdinů (Heroes'

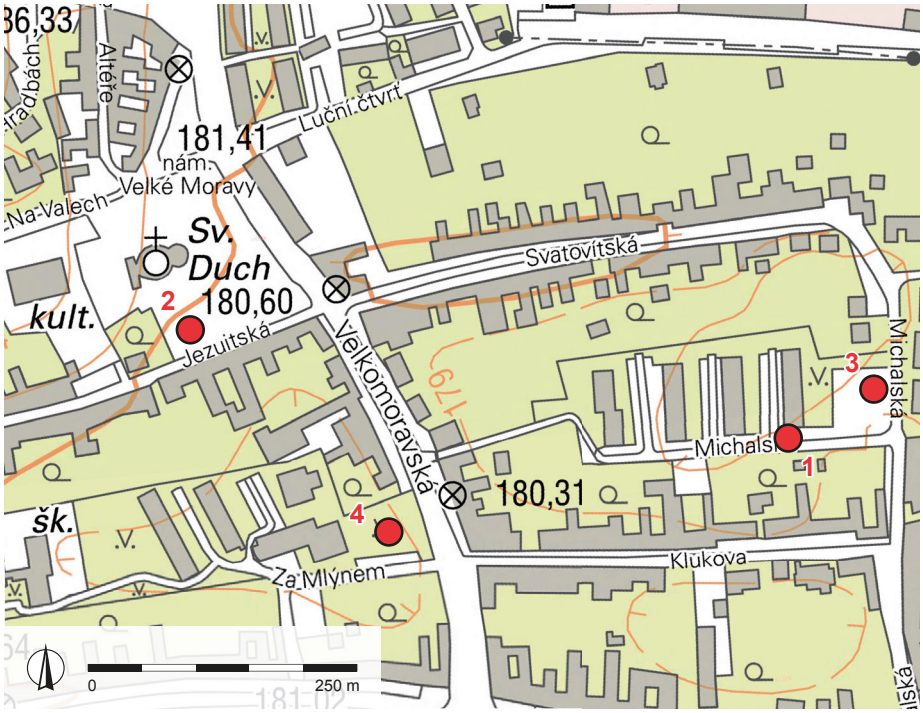


Fig. 101. Staré Město near Uherské Hradiště. Position of pottery kilns and other features related to ceramic production mentionned in the text. 1 – 'Na Kostelíku', feature 11; 2 – 'Na Dvorku', features III/98; 3 – pits and other pottery kiln (?) in the site 'Na Kostelíku'; 4 – pits and pottery kiln (?) in the site 'Za Zahradou'. Graphics by M. Filip. After Procházka et al. 2024, 120, obr. 1, 122, obr. 3.

Square), waste pits containing production waste and one probable pottery kiln dated to the 13th century were uncovered. At the 'Na Kostelíku' site, located between Velkomoravská, Svatovítská, Michalská, and Klukova streets near the newly established Michalská Street, a pottery kiln, a presumed clay storage pit, and a waste dump from the 13th–14th centuries were excavated. A particularly significant find is the partially published hoard of complete vessels (feature 62) dating to the second half of the 14th century, which may be related to a group of deliberately destroyed kilns (Snášil 1982a; 1982b; 1983a; 1983b, 98; Procházka et al. 2024, especially 143–148). Another workshop area was located on the northwestern edge of the historic core, between Jezuitská and Na Valech streets, near Dvorek Street in the 'Na Dvorku' area. From this location comes a pottery kiln dated to the first half of the 14th century and two later pits with pottery waste from the second half of the same century, approximately contemporary with the aforementioned vessel hoard (Galuška 2003; for the topography of research, see Vaškových 2005, 411–421, 430–440; for a summary, see Procházka et al. 2024).

Two confirmed production features were selected for analysis: feature 11 at the 'Na Kostelíku' site (today Michalská Street, plot. No. 44/32) and feature III/98 at the 'Na Dvorku' site (Jezuitská Street, plot. No. 7239). In addition, the hoard of pottery products from pit 62 from 'Na Kostelíku' site was examined primarily from a material perspective; however, due to the large quantity of ceramics and the unfinished conservation and cataloguing, it was characterised only qualitatively, without quantification of material or morphology. The finds are stored in the Slovácko Museum in Uherské Hradiště.

4.6.1 Kiln relic at 'Na Kostelíku'

Feature 11 – pottery kiln (Fig. 102) was excavated in 1976 and has been published in detail (Snášil 1982a). The kiln was exposed from the level of the sandy subsoil and consisted of a firing chamber and a stoking pit. The firing chamber, sunk about 30 cm into the subsoil, had a roughly trapezoidal ground plan, with its longer axis oriented east–west. The narrower eastern side contained the firing channel, followed by the stoking pit. The bottom was flat and slightly sloping along the longer axis; both the bottom and the walls were hard-fired to a grey colour on the inner surface. The stoking pit had an approximately rectangular plan with gently sloping walls articulated into two steps. Its nearly flat bottom lay at the same level as the firing floor. The fill consisted of ash and charcoal, with fragments of fired clay from the kiln wall in the upper part. Some of these fragments, up to 6 cm thick and containing circular perforations about 3 cm in diameter, were interpreted as the remains of a perforated grate. Unfortunately,

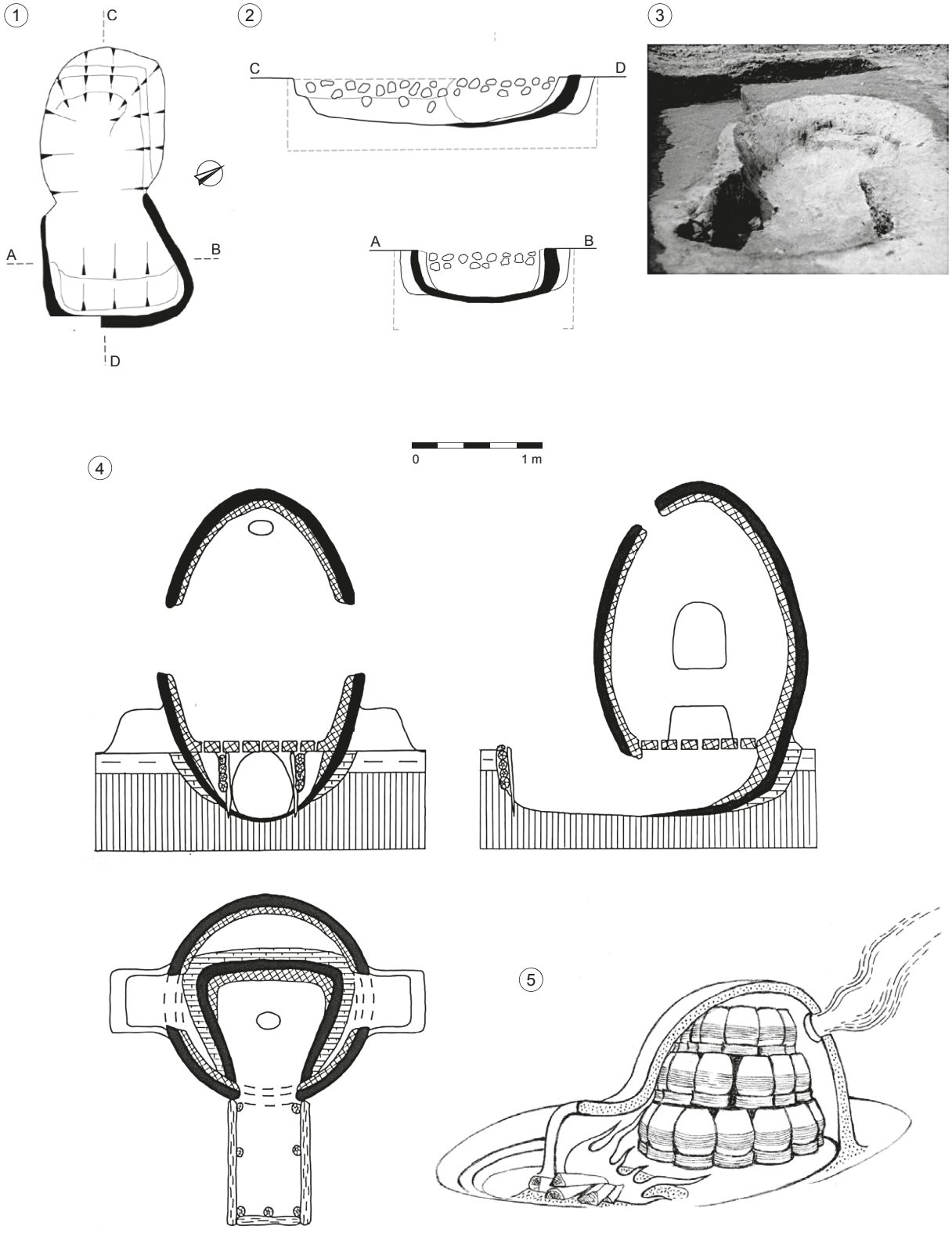


Fig. 102. Staré Město near Uherské Hradiště – 'Na Kostelíku', feature 11 – pottery kiln. 1–2 – plan and cuts; 3 – photo from the west; 4 – reconstruction of kiln (after Snášil 1982, 16, 17, obr. I, II; graphics by V. Kolařík, photo by L. Chvalkovský); 5 – other possible reconstruction of the feature 11. Graphics by P. Kos based on materials of R. Procházka.

the assemblage was damaged during the 1997 flood, and the fragments have not survived. The original photographs used in the publication could not be located either, so only reproductions of two small fragments remain (Snášil 1982a, 20, tab. II: 1, 2). Additional fragments bearing impressions of rods or even flat wooden boards, possibly parts of the kiln wall structure, were also reported. A fragment of a rounded, conically shaped 'brick' thought to have served as a closure element for the flue could not be relocated. Therefore, it remains uncertain whether the mentioned perforated clay fragments, of unknown total number, indeed originated from the kiln grate.

The total length of the kiln reached 190 cm. The firing chamber was 90 cm in length with a maximum width of 82 cm and was sunk 38 cm into the subsoil. The width of the stoking channel was 50–55 cm. The walls were fired to a thickness of 14 cm, and the base to 1–2 cm. The stoking pit was 105 cm long, approximately 90 cm wide at the base, and 62 cm wide at the top, narrowing to 50–55 cm near the bottom. Pottery fragments were reportedly concentrated only within the stoking pit (a total of 366 individuals after conservation). In addition, numerous animal bones, occasional slag fragments, and pieces of fired clay were found, representing typical settlement refuse.

The kiln was in operation around the mid-13th century. According to R. Snášil's interpretation, it was of a vertical two-chamber construction. The excavated lower part represented only the combustion chamber, which was thought to have been separated from the upper firing chamber by a grate situated approximately at the level of the subsoil. The upper chamber was reconstructed as having a circular plan and an oval, strongly vertical profile, with an internal height of about 180 cm and a bottom diameter of 120 cm. The reconstruction further assumes that in its upper part, the kiln's plan changed into a rounded circular shape, with the walls continuously connecting to the excavated lower section. On the drawn reconstruction, the total internal height reaches 230 cm (Snášil 1982a, 17, obr. II: 2). Based on the stepped ledge running along the perimeter of the stoking pit, R. Snášil also suggested the presence of wooden framing, possibly forming a kind of wooden chamber at the front of the kiln (Fig. 102: 4).

The key part of the entire installation is characterised by very small dimensions, with its functional area further reduced by its unusual overall ground plan. Assuming that the kiln was set into the preserved soil layer about 60 cm thick, its total height would have reached slightly less than one meter. We have proposed an alternative reconstruction more consistent with current concepts of kilns of similar or slightly larger size, namely single-chamber firing structures without a grate, whose presence in this case is not entirely certain. It cannot be ruled out that the perforated fired-clay fragments found in the stoking pit originated from the kiln wall construction or from other nearby structures (see Procházka et al. 2024, 131). We therefore consider kiln 11 from Staré Město to represent a small vertical single- or two-chamber kiln, partly sunk into the ground and with a total height of only slightly more than one metre (Fig. 102: 5).

4.6.2 Kiln relic at 'Na Dvorku'

Feature III/98 (Fig. 103, 104). The potter's kiln, thoroughly published by L. Galuška together with the associated pottery assemblage, was located in the front part of the excavated area, approximately 1.3 m north of the building line of Jezuitská Street, with its long axis oriented northeast–southwest (Galuška 2003, especially 593–594, Fig. 2). The kiln itself had a pear-shaped ground plan and can be divided into a firing chamber measuring 195 × 120 cm, equipped with a central spoon (135 cm long, up to 50 cm wide, and 5–8 cm high). The bottom of the flues rose slightly from the edge of the first pit towards the rear of the chamber, forming an incline of about 6°, reaching from the depth of 20 cm under the surface in the front to roughly the level of the subsoil surface in the back. The kiln walls, preserved up to a height of 20 cm, were fired to a thickness of 10–25 cm.

In the northeastern wall, close to the kiln's mouth, a small flue about 30 cm long and 3–4 cm wide passed through the wall and was oriented almost north–south; its interior surfaces were fired hard. The precise function of this channel remains uncertain; it may have served for occasional air injection into the kiln (Galuška 2003, 594). The firing chamber merged smoothly into a rectangular stoking pit measuring 90 × 55 cm, with its rear part forming a continuation of the kiln floor, while the front part consisted of a shallow pit about 80 cm long and 40 cm deep. This section was separated from the stoking pit, which had an oval ground plan (150 × 110 cm) and a depth of 15–20 cm, by a narrow ridge of clay. The original ground surface was not recorded, so at least 40 cm should likely be added to the reported vertical measurements. The kiln belongs to the horizontal single-chamber kiln type with a central spoon shaped firing floor and a projecting but not fully separated stoking pit.

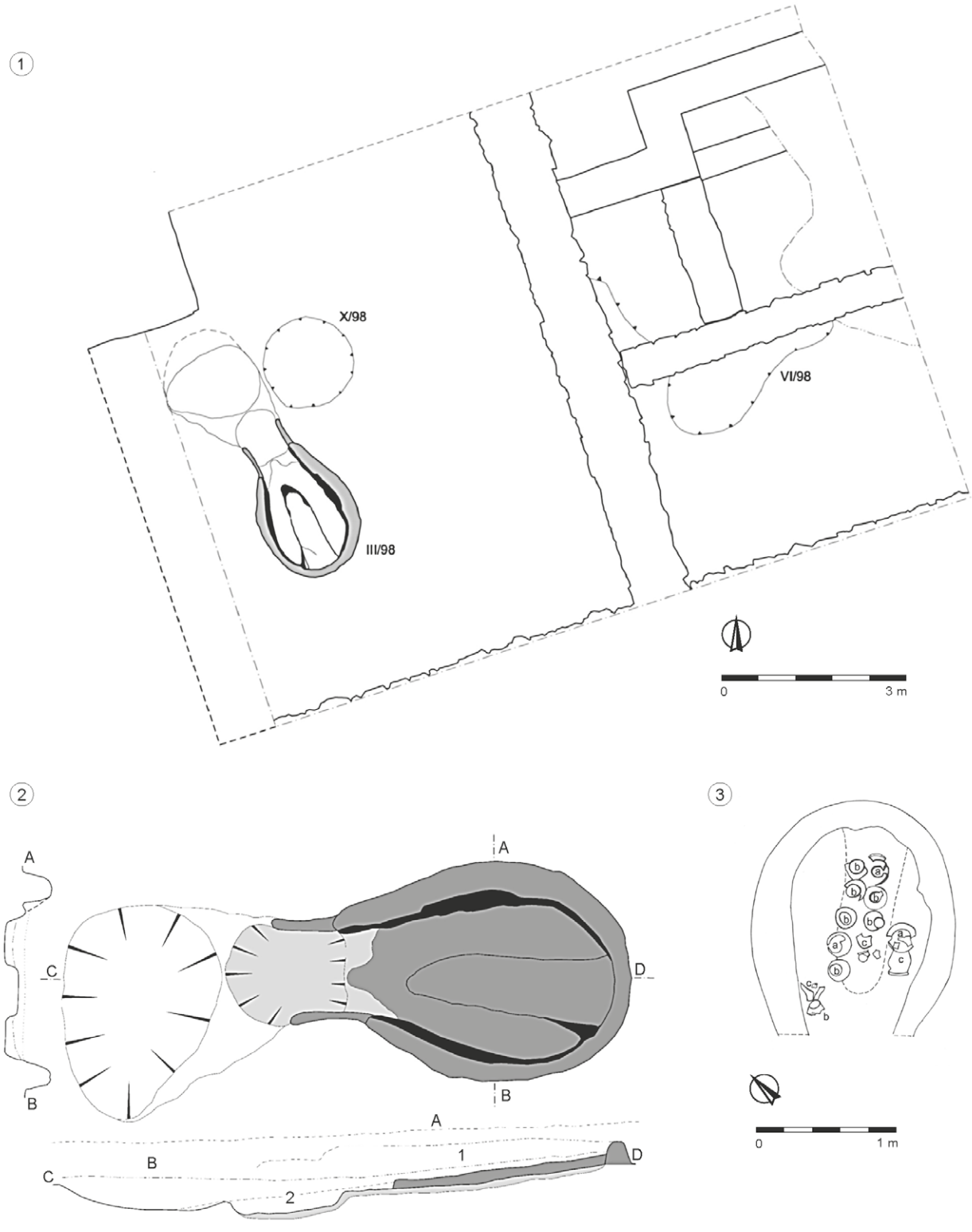


Fig. 103. Staré Město near Uherské Hradiště – 'Na Dvorku'. 1 – pottery features and devices in the southeastern part of the area. 2 – pottery kiln, feature III/98: A – own kiln; B – stoke pit in front of kiln; 1 – firing chamber; 2 – shallow pit; 3 – documented position of vessels on kiln floor: a – bottom–down position; b – bottom–up position; c – vessels on the side. After Galuška 2003, 592, obr. 2, 595, obr. 3: 5, and the field documentation from research stored in at the detached workplace of the Moravian Museum. Graphics by V. Kolařík (1, 2) and L. Dvořáková (3).



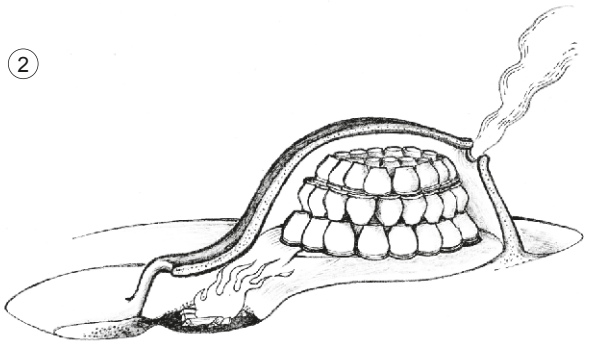


Fig. 104. Staré Město near Uherské Hradiště – 'Na Dvorku'. 1 – photo of the pottery kiln III/98 – firing chamber filled by pottery, in the foreground a stoke pit with a fill heavily mixed with ash; photo by L. Galuška; 2 – possible reconstruction of the feature III/98. Graphics by P. Kos based on materials of R. Procházka.

4.6.3 Morphology, typology and metric properties of pottery

The assemblage from kiln 11 is dominated entirely by cooking pots, which are barrel-shaped or ovoid (Fig. 105–108). A total of five complete vessels and one upper part of a pot were reconstructed. Their heights range from 19.7 to 22.7 cm (median 21.7 cm), and the rim diameters range from 16.1 to 19.2 cm (mean 17.4 cm, median 17.6 cm). When also including measurable rim fragments (n = 21), the average rim diameter reaches 16.9 cm, with a median of 16 cm. The maximum body diameters vary between 15.4 and 19.1 cm (mean 17.5 cm, median 18.2 cm), while the base diameters range from 9.7 to 10.8 cm (mean 10.2 cm, median 10 cm).

Only for three vessels could all indices be calculated, since the lower parts of two incomplete pots had been poorly restored with plaster. The values of the W index (position of the maximum diameter) fall within the low (1) and medium (2) ranges; the H index (bulbosity degree) also ranges between low (1) and medium (2); and the D index (convexity degree) mostly corresponds to the low level (4), with one example reaching the lower boundary of the medium degree. The degree of narrowing of the lower part of the vessel (index Z) is low (Tab. 23).

The rims (n = 29) are almost exclusively of the projecting type SM 6, mostly everted or vertical, with a flat or slightly inward-sloping top surface (Fig. 105, 106, 107: 3). A tendency towards upward expansion is already noticeable, foreshadowing the emergence of type SM 7. The variants SM 6.3.1 and SM 6.3.2 account for about two-thirds of all rims (Fig. 106: 2–4; 107: 6), while the remaining examples represent the earlier parallel-sided variant SM 6.1 (Fig. 106: 1, 6; 107: 3). Occasionally, upward tapering rims of type 5 occur (Fig. 105). The lower edge of the rim is usually sharp (e.g., Fig. 106: 3), more rarely rounded (Fig. 105, SM 6.2). With an average height of 25 mm, the rims correspond typologically to northern Moravian analogies (e.g. Goš et al. 1985, 208). The outer surface is consistently

Inv. No.	W	H	D	Z
A31249			0.58	
A31250			0.49	
A31299	0.48	1.08	0.49	1.57
A 3300	0.37	1.22	0.66	1.78
A 3301	0.4	1.25	0.71	1.63

Tab. 23. Staré Město near Uherské Hradiště – 'Na Kostelíku', kiln 11. Pot index values.

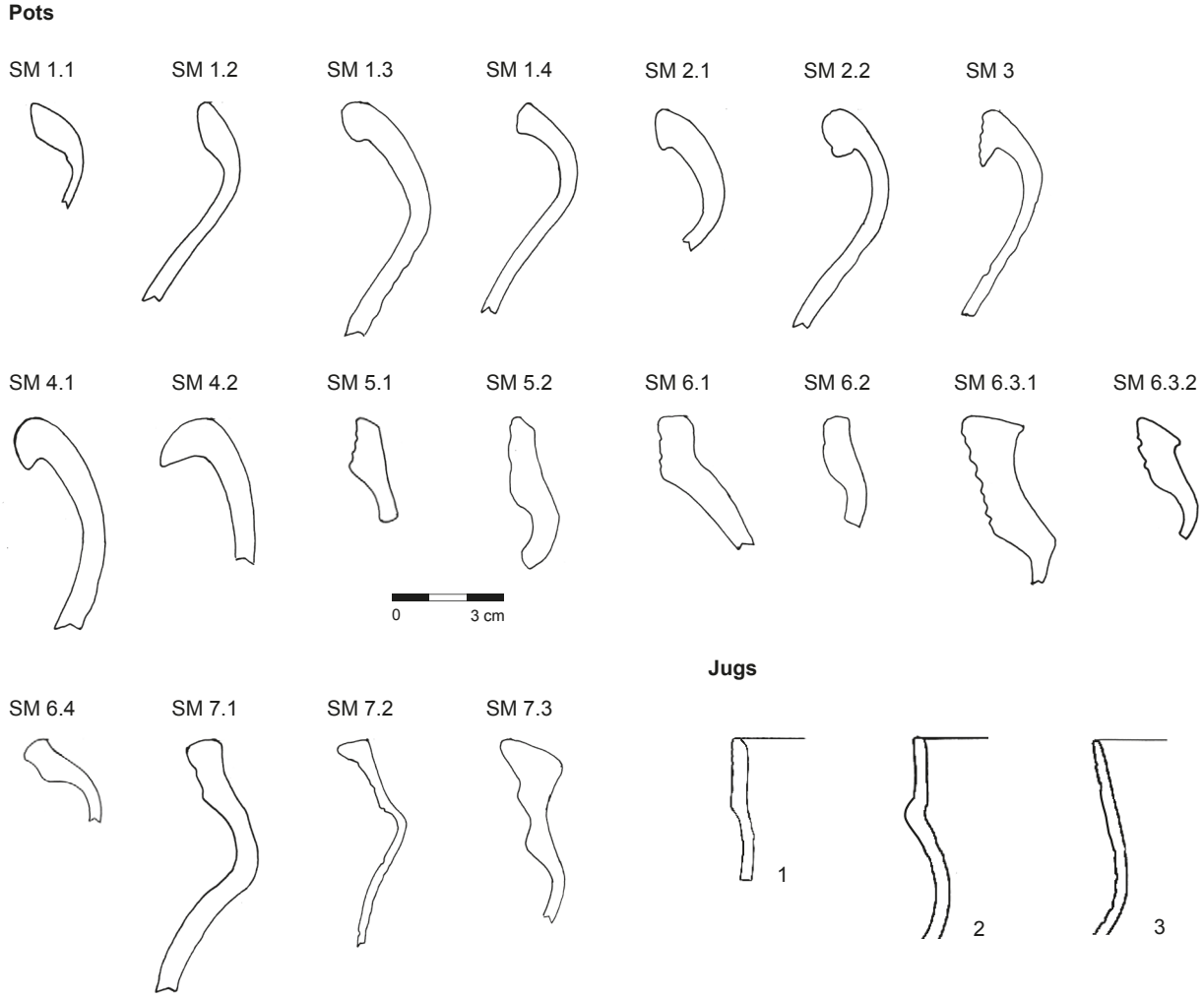


Fig. 105. Staré Město near Uherské Hradiště. Rim types. Drawings by L. Dvořáková.

decorated, most often with horizontal grooves or channels (Fig. 106: 1), less frequently with wavy lines, occasionally double or triple, sometimes placed between two grooves, and rarely with a comb-like wave pattern (Fig. 106: 4; 107: 6). When several wavy lines occur, they are either parallel or in different phases. Roulette impressions are extremely rare. Incised decoration also appears below the neck, often reaching beneath the point of maximum diameter. It is dominated by horizontal channels or, less often, grooves (a 'channel' being defined here as wider than 3 mm), arranged densely, at intervals, or in bundles separated by gaps. On the shoulder and under the neck, in addition to the prevailing grooves (Fig. 106), there occasionally appear oblique incisions, simple wavy lines, or more rarely undulating bands, usually arranged in a single register, always in combination with grooves or channels below (Fig. 107: 3–5; see below Fig. 110). Rarely, all three elements occur together – incisions above a wavy line, or a wavy line framed between two grooves.

On two reconstructed pots, two lower-body fragments, and two base sherds, identical potters' marks were recorded, resembling, according to R. Snášil, the minuscule letter 'h' (Snášil 1982, 12, obr. III; Beránek 1982, 35). One of the marks is very indistinct and lacks one arm; therefore, the presence of five identical marks can be confirmed with reasonable certainty (Fig. 106: 1, 2; 107: 2). In the fill of the stoking pit, several small fragments of early medieval pottery were also found, including three sherds bearing parts of relief potters' marks.

A unique form is represented by a hollow – conical, or less likely bell-shaped – lid, preserved in four rim fragments (Fig. 107: 1). It belongs to petrographic group B3 and was fired in a reducing atmosphere (sample 14, see below Fig. 110). The outer surface bears concentric incised lines as decoration.

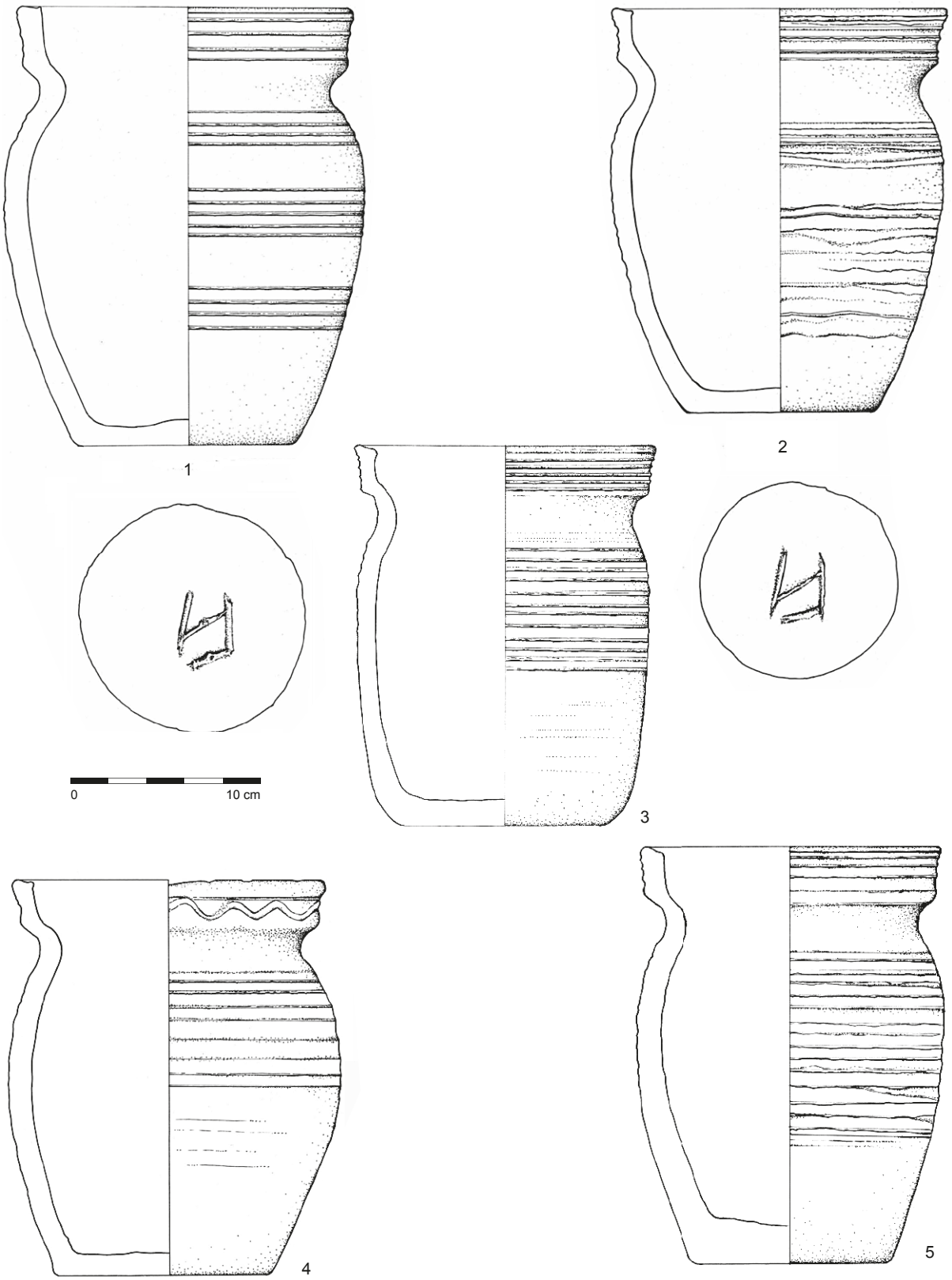


Fig. 106. Staré Město near Uherské Hradiště – 'Na Kostelíku', kiln 11, pots, inv. No.: 1 – A31301; 2 – A31300; 3 – A31250; 4 – A31299; 5 – A31249. Drawings by R. Pavelková.

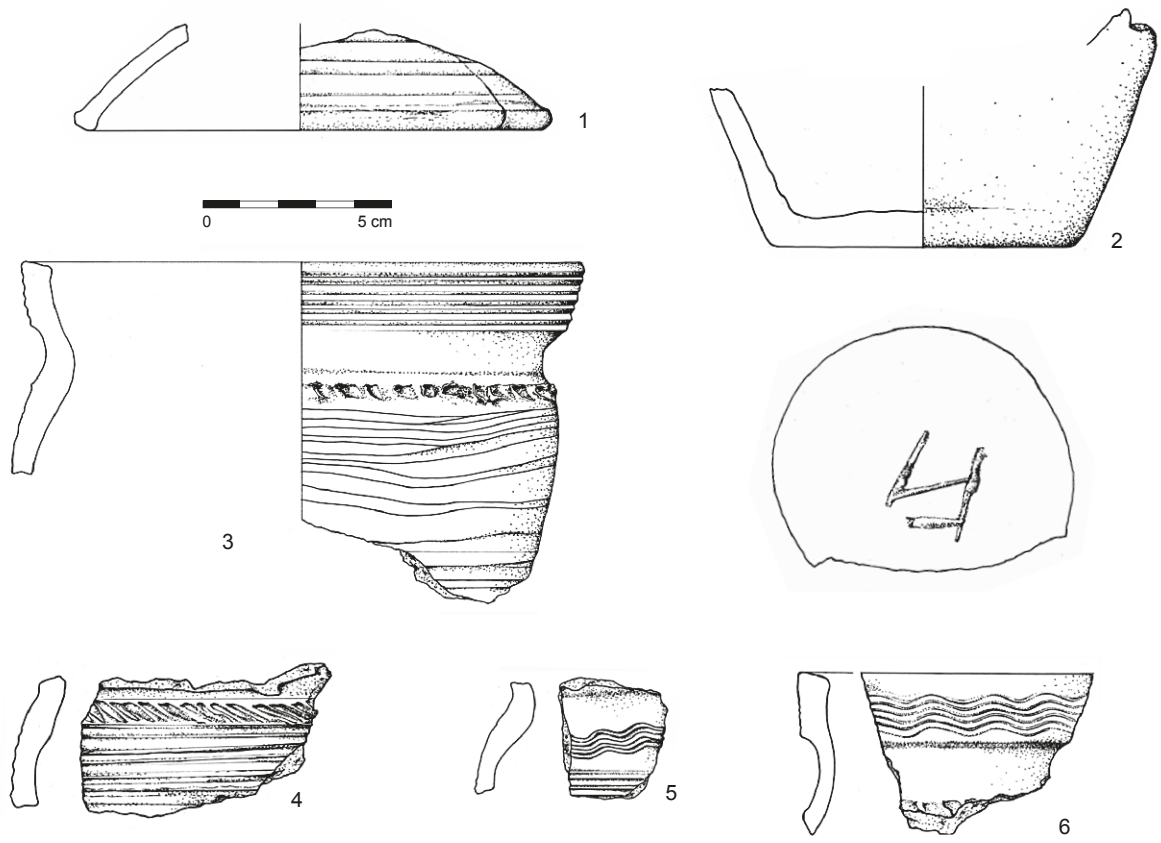


Fig. 107. Staré Město near Uherské Hradiště – 'Na Kostelíku'. Kiln 11, pottery, inv. No.: 1 – hollow lid, A31266; 2–6 – fragments of pots; 2 – A31268; 3 – A31262; 4 – A31254; 5 – A31251; 6 – A31253; 7 – A31258. Drawings by R. Pavelková.

The assemblage from kiln 11 displays both technological and morphological traits characteristic of the final phase of the local ceramic tradition. In this form, it can be dated to the second or third third of the 13th century, marking the transition toward fully developed high medieval pottery, which became established in the second half of the 13th century (see in detail Procházka 1984; Procházka et al. 2024, 135–143).

The assemblage from feature III/98 in the 'Na Dvorku' area is thus much larger than that from kiln 11. The fill of kiln III/98, the stoking pit, and the immediate surrounding area, four complete pots and four reconstructed ones (+one lacking a base), two upper parts preserved down to the level of maximum diameter, five lower parts without rims (Fig. 108: 1, 2, 4, 8, 9, 11) two as well as one bowl (Fig. 108: 3) and two hollow lids (Fig. 108: 7, 10) were recovered. One vessel could not be relocated. The assemblage is dominated by sherds, mostly very small (under 9 cm^2), and also contains fragments of flat lids, bowls, and jugs (Fig. 108: 5, 6, 13–15); in total, it comprises over 4,500 inventoried pieces. It is evident that this represents a partially broken firing batch, particularly its lower layer (104: 1). The positions of thirteen complete vessels and large fragments were recorded on the excavation plan, including the orientation of each vessel (Galuška 2003, 595–601; Fig. 103: 3). On the central spoon, nine pots were found arranged in two rows, four of which were heavily damaged. Seven pots were originally placed upside down. It can be assumed that the missing parts of partially preserved vessels were once present within the collapsed kiln batch but were either not recovered or removed during past ground-level reductions, which also destroyed most of the kiln structure.

The pottery found in the remaining part of the kiln was fairly evenly fired, suggesting that this was not a misfired batch. Within the firing chamber, mainly the lower layer of the kiln batch and possibly some fragments from higher levels were preserved. However, the large quantity of irreconstructible sherds indicates that most of the fill is of secondary origin.

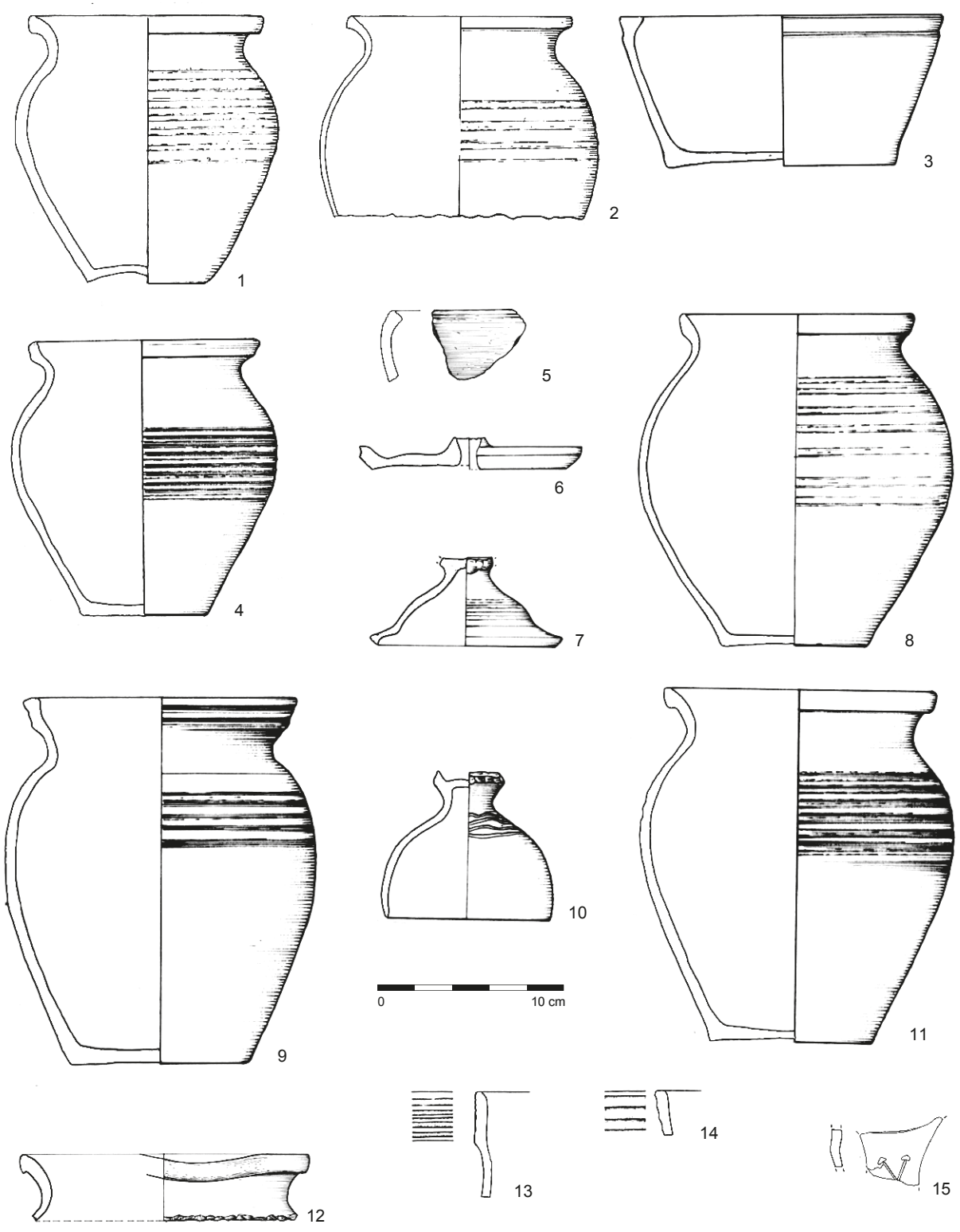


Fig. 108. Staré Město near Uherské Hradiště – 'Na Dvorku', kiln III/98, pottery, inv. No.: 1–4, 8, 9, 11, 12 – pots; 1 – NV40008; 2 – NV12410; 3 – bowl, NV12406; 4 – NV12396; 5 – bowl, NV12837; 6 – flat lid, NV16036; 7 – bell shaped lid, NV12407407; 8 – NV12400; 9 – NV12407; 10 – hollow lid, NV 4006; 11 – unregistered; 12 – NV12591; 13 – jug, NV12708; 14 –jug, NV12918; 15 – jug-handle, NV16050. Drawings by L. Dvořáková after Galuška 2003, 595, 599, 600, 602, 605, obr. 3: 6; 4: 1, 3, 6; 5: 1–3; 6: C, D3; 7: 2, 4.

Because most of the kiln structure was removed and a considerable portion of the fill likely represents redeposited waste from the surrounding area, it is difficult to estimate the minimum number of vessels from the original firing batch. However, about 30 rim fragments of size category 3 (> 36 cm²) can probably be attributed to it. The lower level of the kiln could have accommodated roughly 36 pots, and given its estimated height of 1.2–1.4 m, the total load may have comprised up to 100 vessels.

The dominant vessel form, a cooking pot, is characterised by an oval, bulbous body with the maximum diameter located in the upper third of the height. The heights of complete vessels range from 15 to 23 cm (mean = 17.5 cm, median = 16.2 cm). Rim diameters vary between 13 and 16.3 cm (mean = 14.1 cm, median = 13 cm); maximum body diameters between 14.8 and 18.6 cm (mean = 16.8 cm, median = 16.8 cm); and base diameters between 6.6 and 10.6 cm (mean = 8.6 cm, median = 8 cm). When rim fragments are also considered, the average rim diameter reaches 16.9 cm (median = 16 cm).

For eight pots, indices W, H, D, and Z were calculated (Tab. 24). The W index places most vessels (six) in the medium category, corresponding to egg-shaped forms, and the remaining two in the low category. In terms of body's convexity (D), six pots fall into the medium degree, while two belong to the high category. Only one pot reaches a high degree of bulbosity (H), with the others ranking as medium. The average and median values of the Z index both equal 2, indicating a tendency toward a narrowing of the lower vessel part (a high degree, values > 1.9).

Among all examined assemblages, the Staré Město pots uniquely exhibit average and median Z-index values within the high category, although they are closer to its lower threshold. Only two pots fall into the medium range.

The rims can be divided into two main groups. Group A includes type SM 1, with the distinct variant SM 1.2, as well as type SM 2, represented mainly by variant SM 2.2 (Fig. 108: 1, 2, 8, 11, 12); type SM 4 occurs rarely. Group B comprises type SM 5 and type 6, with variants SM 6.1 and SM 6.4; the first one has a straight profile, while the second variant is profiled concave on both sides (Fig. 105, 108: 4). For group B, within the studied region and chronological horizon 2, the rims are typically low, averaging around 12 mm in height. The majority (64%) are undecorated, while the decoration of the remainder consists almost exclusively of horizontal grooves or wider incised lines, only occasionally combined into a continuous rib–groove sequence – unless these represent later intrusions. Only a few fragments exceed a rim height of 1.5 cm (type SM 7, Fig. 108: 9). In general, rim types 1 and 2 strongly predominate (78%) over types 5, 6 and 7 (21%).

The decoration is reduced to a spiral composed of continuous, broad grooves running around the upper and middle parts of the vessel. Its execution, however, remains highly irregular, sometimes even within a single pot. This type of decoration represents transitional forms evolving from earlier horizontal grooving (Fig. 108: 1, 2, 4, 8, 9, 11).

Other vessel forms are much less frequent in the assemblage. Among them are jugs, identified through six rim fragments: type SM 1 – with upright rims decorated with grooves (Fig. 108: 13), and type SM 3 – funnel-shaped rims (Fig. 108: 14). Jugs are further evidenced by two handles of an oval cross-section (Fig. 108: 15). Two diagnostic bowl fragments belong to the type with a rounded, slightly inward curved upper part (Fig. 108: 5). The complete bowl has straight, slanting walls, and a thickened, club-like rim (Fig. 108: 3). Approximately ten fragments represent flat lid rims with a typical local feature – an externally offset lower wall section. A single fragment preserves almost the entire profile of such a vessel (Fig. 108: 6). The presence of one complete bell-shaped lid and five thin-walled rim fragments with advanced profiling, featuring an S-shaped curvature below the rim and a distinct inward-drawn rim ring, is of chronological importance and allows the assemblage to be placed within the first half of the 14th century (Fig. 108: 7). A hemispherical lid, decorated with wavy lines on the shoulders and a deeply incised decoration, also on the knob, is a unique form (Fig. 108: 10). This vessel, belonging to the final firing batch, currently has no known analogies. A single small fragment

	No. of pots	W	H	D	Z
Index range	8	0.38–0.42	0.88–1.17	0.8–1.11	1.8–2.4
Mean	8	0.39	1.07	0.94	2.04
Median	8	0.39	1.08	0.9	2

Tab. 24. Staré Město near Uherské Hradiště – 'Na Dvorku', kiln III/98. Pot index values.

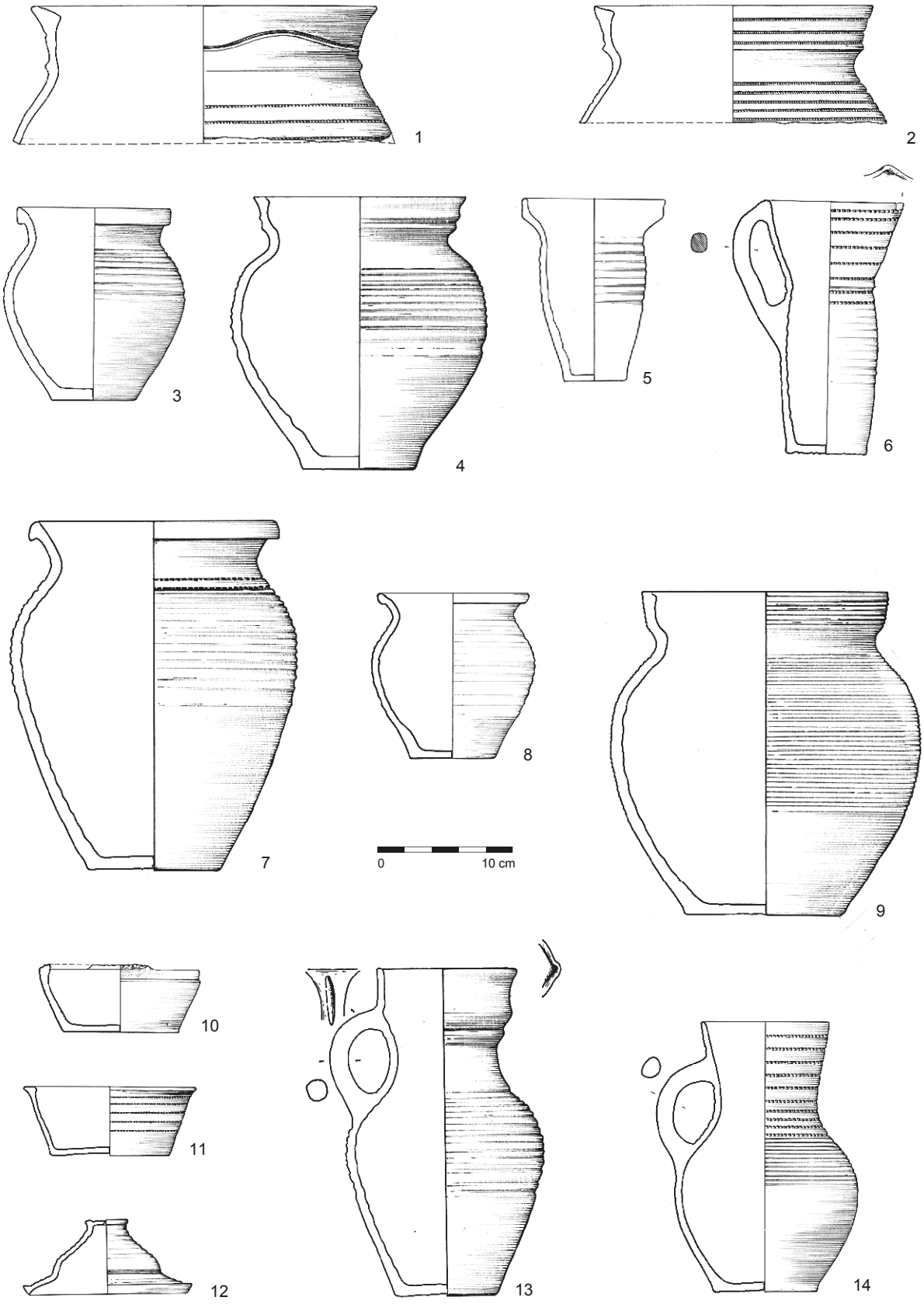


Fig. 109. Staré Město near Uherské Hradiště – 'Na Kostelíku'. Vessels from the ceramic hoard, feature 62, not registered. 1–4, 7–9 pots; 5 – cup, 6, 13, 14 – jugs; 10 – flat based pan; 11 – bowl; 12 – bell shaped lid. Drawings by L. Dvořáková.

of a bowl-shaped lamp was also recorded. All these forms, except for the conical bowl, one flat lid, and one hemispherical lid, occur in highly fragmentary condition. Stirrup-handled ewers are entirely absent from the assemblage.

Based on a comparison with common settlement pottery from the same site and from the town of Uherské Hradiště, we assume that many of the traits identified in the assemblage from kiln III/98 appear in the Uherské Hradiště region by the second half of the 13th century at the latest, and that this type of production coexisted for some time with the earlier pottery tradition represented by kiln 11.

The assemblage from hoard 62 is estimated to comprise approximately 300–350 vessels. It includes handleless pots, small handled pots, jugs, cups, conical bowls (Fig. 109: 11), ladles (Fig. 109: 10), and bell-shaped lids. An exceptional find is an alembic, the upper part of a distillation apparatus (Snášil 1983a). The pots feature oval-shaped bodies. In terms of rim morphology, tall variants of type SM7, often exceeding 2.5 cm in height, are predominant (Fig. 109: 1, 2, 4, 9). The second major group consists of type SM 2 and rims with a pronounced undercut profile (type SM 3; Fig. 109: 3, 7), followed by type SM 4 rims, including subvariant SM 4.2, which is markedly grooved on the underside (Fig. 105). Type 1 occurs rarely (Fig. 109: 8).

The decoration of pots is enriched with new ornamental elements. The grooved spiral motif is particularly prominent (e. g. Fig. 109: 7, 9) accompanied in some cases by roulette-stamped decoration covering larger surface areas (Fig. 109: 1, 2). On larger vessels, composite decoration is most frequent: the spiral grooving covering most of the body is often combined with bands of roulette impressions beneath the rim (Fig. 109: 7), sometimes accompanied by one or more wavy lines. Similar decorative elements also appear on rim type SM 7, including wavy lines, multiple wavy-line motifs, roulette impressions, and horizontal grooves or incised lines (Fig. 109: 1, 2, 9) that occasionally give the outer surface of the rim a distinctly profiled appearance (type 7: 3; Fig. 109: 4).

The assemblage includes two main types of jugs. The first type comprises two variants. The first variant has an oval body of varying height, with a vertical mouth separated from the neck by a narrow horizontal ridge (rim type SM 2, Fig. 109: 13). The second variant features a short, globular body that transitions into a funnel-shaped mouth (type SM 3 rim; Fig. 109: 14). While the first variant carries spiral grooving only on the body, the second exhibits roulette-stamped bands around the mouth; the body may bear a spiral motif or, in some cases, remain undecorated. The second jug type, of goblet-like form, has a slender body and a directly flaring, smoothly rounded rim. Its decoration consists of roulette impressions in the upper body part, and the spiral grooves on the body (Fig. 109: 6). The handles are arched and slightly flattened in profile. Cups, which occur only sporadically, have a slender body decorated with spiral grooves and a low collar-shaped rim (Fig. 109: 5). The bell-shaped lids exhibit an advanced, pronounced profiling; however, some of their handles are not yet separated from the body by a concave neck (Fig. 109: 5). The assemblage as a whole is dated to the second half of the 14th century, or possibly the early decades of the 15th century (Procházka et al. 2024, 143–148).

4.6.4 Ceramic technology

Paste

The pottery from the stoking pit of kiln 11 was predominantly highly fragmented, with nearly 70% of the sherds measuring less than 9 cm². Based on macroscopic assessment, the material was classified as class SM1 – sandy pottery (petrographic groups A and B). Excluding graphite-tempered (SM3) and mica-tempered (SM4) ceramics, considered as an intrusion, the distribution of petrographic groups within the kiln 11 assemblage shows no significant difference (group A – 6 samples, group B – 9 samples).

In the case of kiln III/98, pottery belonging to petrographic groups A and B was classified into a single technological class SM2, which clearly predominates in the assemblage. The distinction from class SM1 is reflected mainly in surface colouration, with brick-red hues occurring more frequently in SM1, and in forming technique. Class SM4, containing mica temper, was recorded only sporadically. Somewhat surprisingly, a slightly larger proportion, though still only about 2%, belongs to subclass SM4a, characterised by surface micaceous slip, often partially abraded (Fig. 108: 4, 112: B, 116: 3). Within this class, one complete pot was also identified (Galuška 2003, 600, 603).

A total of 40 ceramic samples were analysed (Tab. 25; Fig. 110), comprising 18 from feature 11 ('Na Kostelíku', samples 1–18) and 22 from kiln III/98 ('Na Dvorku', samples 19–40). Sample 40 was examined separately for the presence of mica only, while the remaining specimens were classified based on

ID	Inv. No.	Site	Vessel type	Ceramic class
1	A31168	Feature 11	Pot	SM1
2	A31128	Feature 11	Pot	SM1
3	A31192	Feature 11	Pot	SM1
4	A31190	Feature 11	Pot	SM1
5	A31137	Feature 11	Pot	SM4
6	A31140	Feature 11	Pot	SM1
7	A31197	Feature 11	Pot	SM1
8	A31146	Feature 11	Pot	SM1
9	A31194	Feature 11	Pot	SM1
10	A30971	Feature 11	Pot	SM1
11	A30953	Feature 11	Pot	SM3
12	A31186	Feature 11	Pot	SM3
13	A31257	Feature 11	Pot	SM1
14	A31266	Feature 11	Lid	SM1
15	A31189	Feature 11	Pot	SM1
16	A31259	Feature 11	Pot	SM1
17	A31255	Feature 11	Pot	SM1
18	A31273	Feature 11	Pot	SM1
19	12401	Feature III/98	Pot	SM2
20	12402	Feature III/98	Pot	SM2
21	15369	Feature III/98	Pot	SM2
22	15779	Feature III/98	Pot	SM2
23	15351	Feature III/98	Pot	SM2
24	15562	Feature III/98	Pot	SM2
25	15724	Feature III/98	Pot	SM2
26	15297	Feature III/98	Pot	SM2
27	13444	Feature III/98	Pot	SM2
28	15371	Feature III/98	Pot	SM2
29	12674	Feature III/98	Pot	SM2
30	12877	Feature III/98	Pot	SM2
31	12534	Feature III/98	Pot	SM2
32	12791	Feature III/98	Pot	SM2
33	12799	Feature III/98	Pot	SM2
34	12807	Feature III/98	Pot	SM2
35	12789	Feature III/98	Pot	SM2
36	12655	Feature III/98	Pot	SM2
37	12787	Feature III/98	Pot	SM2
38	12868	Feature III/98	Pot	SM2
39	12821	Feature III/98	Pot	SM2
40	12396	Feature III/98	Pot	SM4a
41	-	Feature 62	Pot	SM2
42	-	Feature 62	Pot	SM2
43	-	Feature 62	Pot	SM2
44	-	Feature 62	Pot	SM2
45	-	Feature 62	Pot	SM2
46	-	Feature 62	Pot	SM2
47	-	Feature 62	Pot	SM2
48	-	Feature 62	Pot	SM2
49	-	Feature 62	Pot	SM2
50	-	Feature 62	Pot	SM2
51	-	Feature 62	Pot	SM2
52	-	Feature 62	Pot	SM2
53	-	Feature 62	Pot	SM2

Tab. 25. Staré Město near Uherské Hradiště – kiln 11 and III/98. Samples selected for analyses.

their chemical composition, petrography, and technological characteristics. Initially, analyses were conducted separately for each context, but due to material similarities, a unified classification system was subsequently applied. The ceramics were grouped into three primary groups: sandy (fabrics A and B), graphite-tempered (fabric SM3), and micaceous wares (fabric SM4; Tab. 26; Appendix 1-F).

The dominant sandy group was subdivided into fabric A (6 from kiln 'Na Kostelíku', 18 from 'Na dvorku') and B (9 from kiln 'Na Kostelíku', 4 from 'Na Dvorku'), based on the grain size distribution of non-plastic inclusions – group A exhibited a unimodal and fabric group B a bimodal distribution (Appendix 2-F). Fabric group B was further divided into three subgroups according to differences in matrix grain size and chemical composition (Tab. 27; Graph 18). Graphite-tempered ware was represented by two samples from 'Na Kostelíku', and micaceous ware by a single sample from the same context. We consider this pottery to be an outlier, and it was probably not produced in a kiln.

Fabric A is defined by a unimodal distribution of non-plastic inclusions and a variable, generally elevated proportion of fine particles. The ceramic matrix in fabric A samples was poorly to very poorly sorted, reflecting a wide grain-size spectrum ranging from silt-sized particles to coarse sand (of maximum sizes usually less than 2000 µm) or granules in one case (size up to 2200 µm; Fig. 111: A, B). The average grain size was in the range of 100–200 µm. The overall content of non-plastic inclusions ranged from 15 to 40 vol.%. Grain shapes were approximately equant in half of the samples, while the remainder exhibited more elongated forms. The degree of rounding varied from sub-angular to rounded. The microstructure was unparallel to weakly parallel. The parallel structure was inferred from elongated, planar pores whose orientation was often – but not always – aligned with the vessel axis. In many cases, the orientation plane was undulating or curved, and the term 'planar' refers to this general orientation rather than a strict alignment with the vessel's axis. Vugh pores were also commonly observed. Total porosity ranged from 1 to 20%.

The non-plastic component of fabric A ceramics was dominated by quartz, which was generally abundant and, in some cases (e.g. samples 19 and 30), even predominant. Feldspars formed the second most frequent group of mineral inclusions, with alkali feldspars commonly present and more abundant than plagioclases, which occurred mostly occasionally,

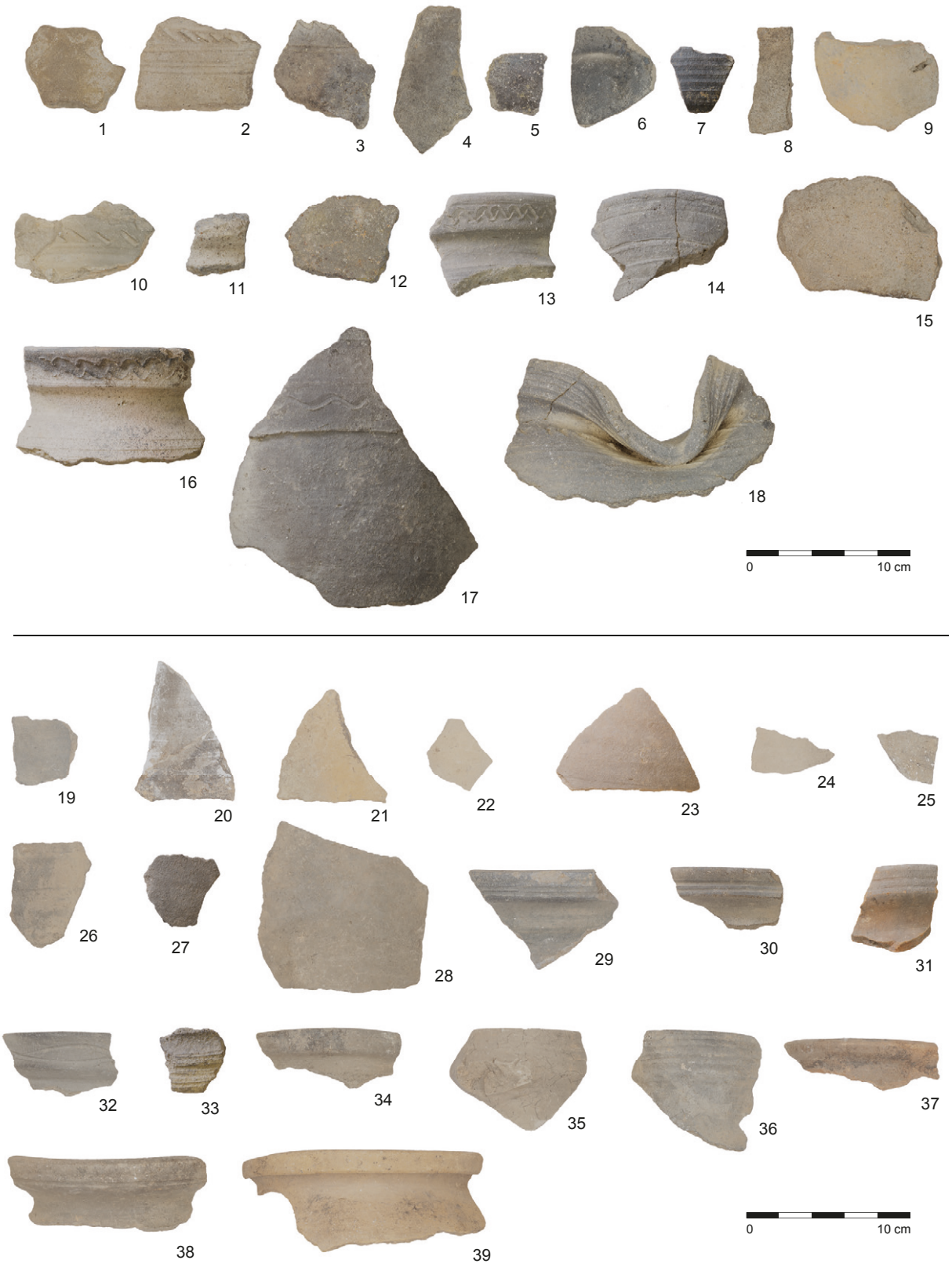


Fig. 110. Staré Město near Uherské Hradiště. Analysed pottery samples.1–17 – kiln 11, 18–39 – kiln III/98. Photo by M. Košťál.

Fabric	Sample IDs	Fabric description	Fabric features	Petrographic markers	Chemical markers	Possible sources
A	1, 2, 4, 6, 10, 13, 19, 20, 23, 25–32, 34, 35, 37–40	Silty clay with sand, non tempered	Weakly parallel or unparallel microstructure, unimodal grain size distribution	Quartz, metaquartzite, alkali feldspar, glauconite, sandstone, granitoid, plagioclase, biotite, muscovite, amphibole, chert, phyllite, pyroxene, tourmaline, garnet, andesite, siltstone, mudstone, gneiss, schist, amphibolite	Representation of 'average' for the site, overall similar to fabrics B1, B3	Neogene deposits (specifically Bzenec and Gbely formations) or Quaternary alluvium within close vicinity of the site
B1	15, 16, 33	Clayey matrix, sand tempered	Parallel or unparallel microstructure, bimodal grain size distribution	Quartz, metaquartzite, alkali feldspar, granitoid, sandstone, glauconite, chert, plagioclase, muscovite, biotite, amphibole, siltstone, pyroxene, phyllite, schist, andezite	Compared to B2 and B3: elevated K and Sr and lower Fe and Ti	
B2	3, 7–9, 21, 24, 36	Clayey matrix, sand tempered	Weakly parallel microstructure, bimodal grain size distribution	Quartz, metaquartzite, alkali feldspar, sandstone, granitoid, chert, glauconite, plagioclase, biotite, muscovite, amphibole, pyroxene, siltstone, tourmaline, garnet, gneiss, andezite, serpenite, phyllite	Compared to A, B1 and B3: elevated Ca, Al, Ni	
B3	14, 17, 18	Loam, sand tempered	Weakly parallel microstructure, bimodal grain size distribution	Quartz, metaquartzite, alkali feldspar, granitoid, glauconite, biotite, plagioclase, muscovite, amphibolite, glauconite, sandstone, siltstone, mudstone, garnet	Compared to B2 and B3: elevated Ba and Rb	
SM3	11, 12	Graphite tempered, clay with silt	Weakly parallel, bimodal grain size distribution	Graphite, metaquartzite, graphite metaquartzite, biotite schist, chlorite schist, quartz, biotite, muscovite, sillimanite, chert, amphibole, chlorite, glauconite, graphite gneiss, andesite	Compared to local fabrics A, B: elevated Ca, Ti, Fe, Ni, poorer in Si	Non local, origin of graphite is distant: Vranov-Olešnice group (Moravicum), or Desná group (Silesicum)
SM4	5	Mica tempered, fine clay	Weakly parallel, bimodal grain size distribution	Muscovite, biotite, mica schist, gneiss, plagioclase, quartz, alkali feldspar, metaquartzite, garnet	Compared to local fabrics A, B: elevated of Al, K, Rb, and Ti	Non local, origin of mica is distant: Čučice by Oslavany, Lukov and Bílý Potok groups, Jeseníky mnts., Tatric unit near Devín (Slovakia)

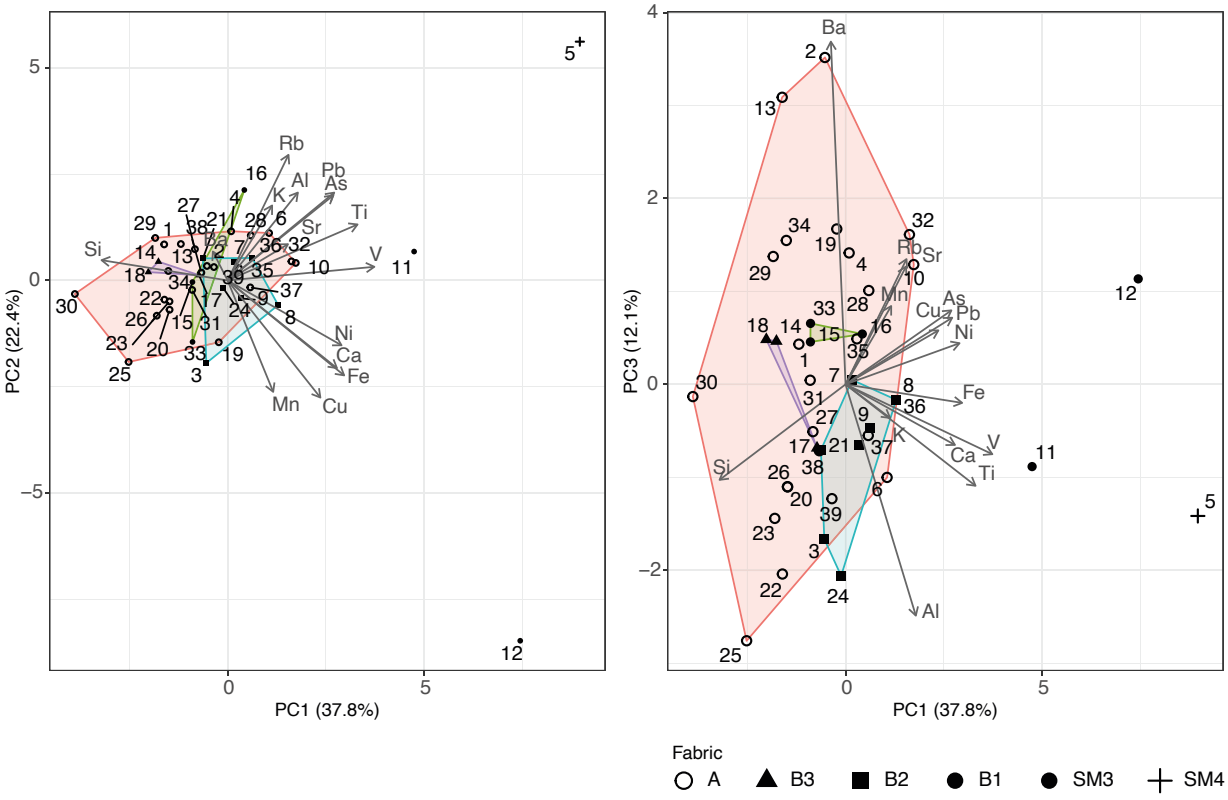
Tab. 26. Staré Město near Uherské Hradiště – kiln 11 and III/98. General description of fabrics (petrographic markers are listed in order of relative abundance).

except in samples 4 and 34, where they were more frequent. Micas, both muscovite and biotite, and amphibole were identified in trace to occasional amounts. Pyroxenes were identified in about half of the samples, although generally less abundant than amphiboles. Minor amounts of tourmaline or garnet grains were observed in some specimens. Glauconite was present in nearly all samples at generally common frequencies.

Among the psammitic rock fragments, granitoid, sedimentary, metamorphic, and volcanic types were identified. Granitoids were present in variable but generally low amounts, with graphic textures observed in samples 2, 20, and 30. Clastic sedimentary rocks were mostly represented by sandstone (typically rare), with subordinate amounts of siltstone and, very occasionally, mudstone. Chert was found in nearly all samples, albeit

	Fabric A				Fabric B1				Fabric B2				Fabric B3				Fabric SM3				Fabric SM4
	mean	sd	min	max	mean	sd	min	max	mean	sd	min	max	mean	sd	min	max	mean	sd	min	max	–
SiO_2	76	1.3	73.7	79.1	75.2	0.8	74.3	75.9	75.7	1.1	74.3	76.8	77.1	1.4	75.5	78	65.5	4.2	62.5	68.5	62.9
Al_2O_3	14.1	0.9	11.9	15.8	14.7	1.7	13.2	16.5	14.8	0.7	13.8	15.8	13.5	0.9	12.9	14.5	16.2	2.5	14.4	18	21.5
Fe_2O_3	5.2	0.6	4	6.8	4.7	0.9	3.7	5.5	4.8	0.4	4.5	5.7	4.6	0.3	4.3	5	11.9	6.1	7.6	16.2	8.4
K_2O	2.8	0.2	2.5	3.5	3.4	0.2	3.2	3.6	2.6	0.2	2.4	3	3	0.1	2.9	3.1	3.2	0.1	3.1	3.2	4.3
CaO	1.1	0.1	0.9	1.4	1.2	0.1	1.1	1.3	1.2	0.1	1.1	1.4	1	0	1	1	2.1	0.6	1.6	2.5	1.4
TiO_2	0.7	0.1	0.6	0.8	0.7	0	0.6	0.7	0.7	0	0.6	0.7	0.7	0.1	0.6	0.7	0.9	0	0.9	0.9	1.3
V	77	12	45	96	70	7	62	75	79	8	71	89	68	9	61	78	133	3	131	135	171
Mn	704	338	406	1950	886	544	267	1290	662	396	438	1510	627	80	535	676	1471	1158	652	2290	403
Ni	39	4	33	50	43	3	40	47	46	6	39	57	40	2	37	41	54	15	43	64	51
Cu	34	2	29	39	33	2	32	36	35	3	33	40	34	2	32	35	54	18	41	66	32
As	8	0	7	9	8	0	8	9	9	0	8	9	8	0	8	8	9	0	8	9	10
Rb	128	17	93	152	141	20	128	164	114	7	103	123	142	7	134	146	122	39	95	150	219
Sr	81	16	58	142	92	2	91	94	91	16	67	107	79	6	72	83	97	18	84	110	94
Ba	525	280	116	1150	558	87	458	615	330	148	131	486	466	127	320	554	406	71	356	456	305
Pb	21	1	19	23	21	1	20	22	22	1	20	23	21	0	20	21	21	1	21	22	25

Tab. 27. Staré Město near Uherské Hradiště – kiln 11 and III/98. Summary of the chemical composition of fabrics (major oxides in wt %, trace elements in ppm).



Graph 18. Staré Město near Uherské Hradiště. Principal component analysis of chemical composition – scatter plots of the first component against the second and third. Fabric A represents a broad group, and fabrics B1–B3 differ in chemical composition from each other but remain consistent with fabric A, indicating proximity of the raw material source. The graphite-tempered samples (SM3) and the mica-tempered sample (SM4) differ markedly in chemical composition. Author K. Slavíček.

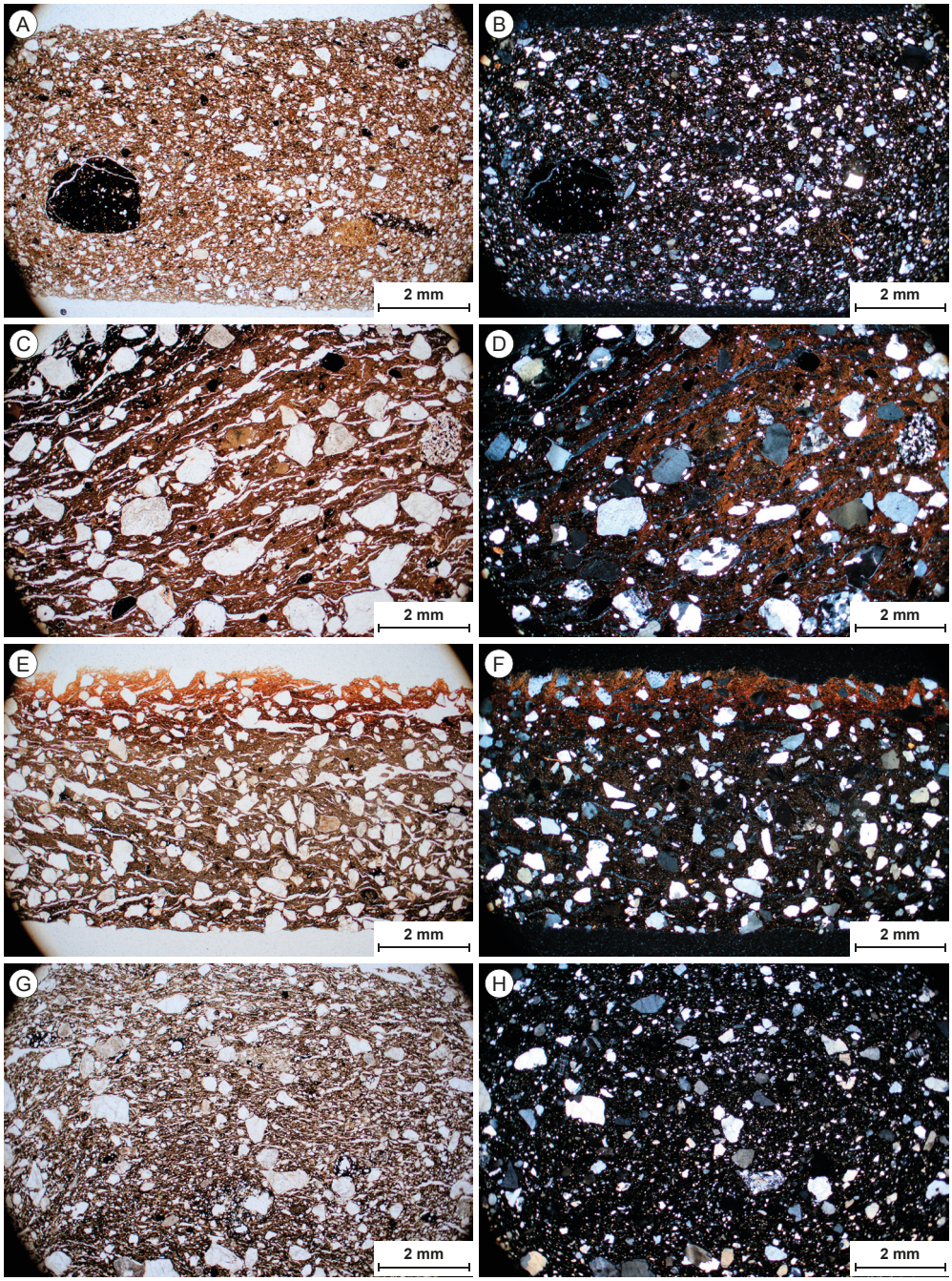


Fig. 111. Staré Město near Uherské Hradiště. Overview of the microstructure of each local fabric in PPL (left) and XPL (right) – part 1: A, B – untempered sand fabric A, sample 35; C, D – tempered sand fabric B1, sample 33; E, F – tempered fabric B2, sample 8; G, H – tempered sand fabric B3, sample 18. Author K. Slavíček.

rarely. Metaquartzite was commonly to frequently present across the assemblage. Other metamorphic rocks – such as phyllites, schists, gneisses, sillimanite-bearing gneisses, and amphibolites – were recorded in about half of the samples, generally in minor to occasional amounts. Volcanic rock fragments were identified in five samples (13, 20, 31, 37, 38), mostly in trace quantities.

Sample 40 (fabric A) was taken from vessel inv. No. 12396 (Galuška 2003, 600), which has been identified in the literature as the only micaceous find from the 'Na Dvorku' kiln. As the vessel was preserved whole, the sample was extracted using a core drill from the area with the highest visible mica concentration, approximately at the point of maximum bulge. Petrographic analysis revealed that mica was present only on the surface (Fig. 112: B). In one instance, a garnet grain was found embedded in the outer surface (Fig. 112: C). The micaceous appearance of the vessel was achieved by applying crushed material derived from a mica-rich rock containing garnet – most likely a mica schist.

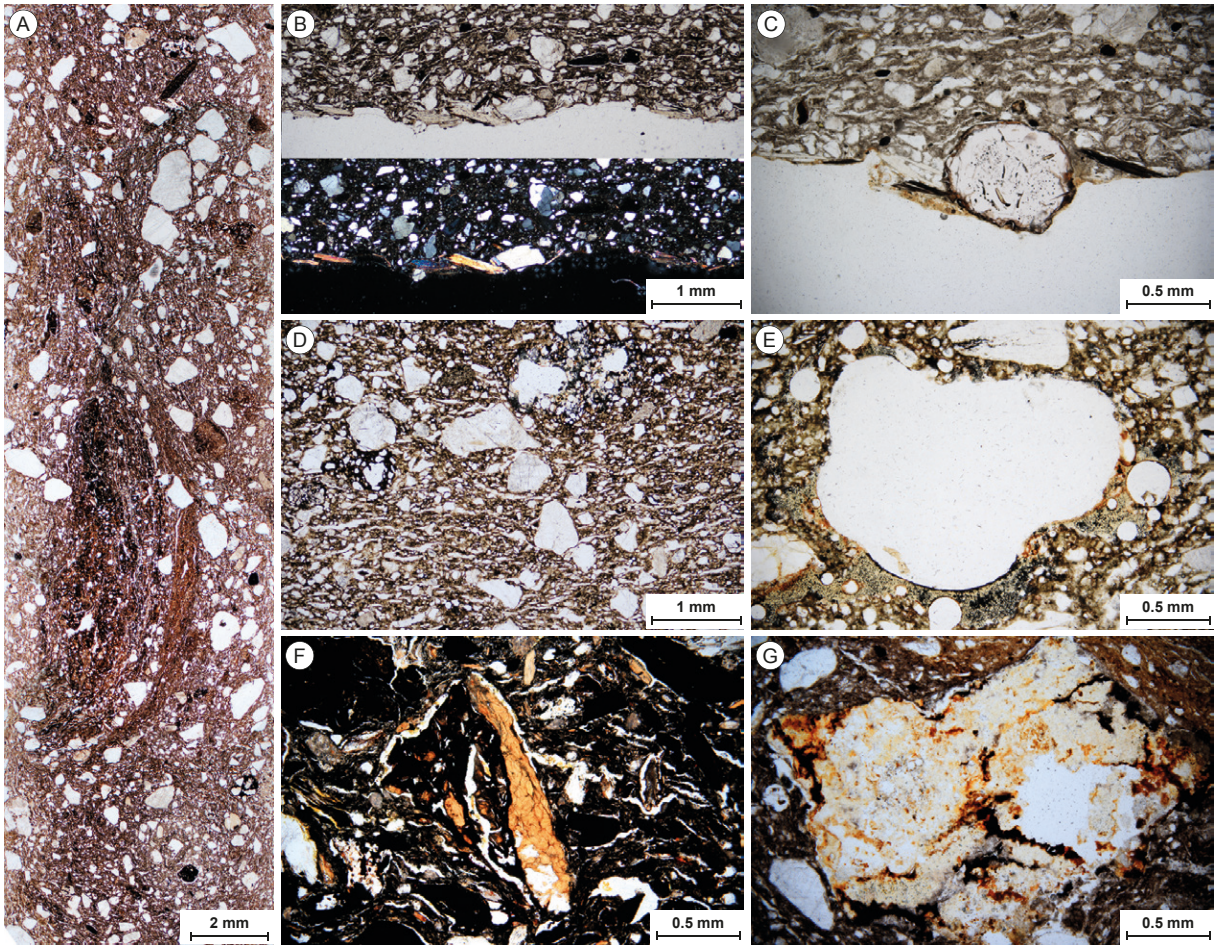


Fig. 112. Staré Město near Uherské Hradiště. Photomicrographs highlighting key features in detail: A – remnants of coiling in the form of structures formed by oriented particles (sample 17, PPL, fabric B3) are pronounced in the composition of several photomicrographs; B – mica flakes on the surface of sample 40 (fabric A); C – garnet pressed into the surface along with mica flakes (sample 40, PPL); D – microstructure of sample 18 (fabric B3, PPL) affected by high firing temperature – forming of bubbles; E – melt at the edge of a void (sample 18, PPL); F – graphite schist with chlorite (sample 12, PPL, graphitic fabric); G – piece of slag (sample 43, feature 62, fabric A). Author K. Slavíček.

In contrast to the subgroups of fabric B, bulk chemical composition of fabric A is less tightly constrained, although it typically shows lower concentrations of Ca, Al, and Ni compared to subgroup B2 (Tab. 27; Graph 18). No further subdivision was made within fabric A, as no consistent clusters of features were observed in terms of chemical composition, petrography, or technological attributes.

Fabric group B ceramics are characterised by a very fine-grained matrix (<100 µm, often <60 µm) with a variable content of silt-sized particles (1–15 vol.%). Based on the increasing proportion of this fine fraction, the fabric was divided into three subgroups: B1 (3 samples – 2 from kiln 'Na Kostelíku', 1 from 'Na Dvorku'), B2 (7 samples – 4 from 'Na Kostelíku', 3 from 'Na Dvorku'), and B3 (3 samples – all from kiln 'Na Kostelíku'). Subgroups B1 and B2 consist of a pelitic matrix with minimal aleuritic grains, while the ceramic paste in B3 is best described as loam (Fig. 111: C–H). This classification is further supported by chemical analysis: B1 is marked by elevated K and Sr and lower Fe and Ti contents; B2 exhibits higher levels of Ca, Al, and Ni; and B3 is distinguished by increased Ba and Rb concentrations. All samples contained poorly to very poorly sorted non-plastic inclusions ranging from silt to coarse sand or even granule. The average grain sizes were 250–700 µm, while the largest grains reached up to 2600 µm. The coarse fraction amounted to 20–30% in B1 and B2 and 15% in B3. These grains were typically variable in shape (equant to elongated) and sub-angular to sub-rounded. The microstructure was parallel or weakly parallel. Observed pore types included planar, vughs, and, in isolated cases, chambered or vesicular forms. Total porosity ranged from 5 to 30%.

Petrographically, the three subgroups of fabric B are closely related. All samples contained common to abundant quartz. Alkali feldspars, especially microcline, were common to frequent and significantly outnumbered plagioclases, which were only rare

to occasional. Micas (both muscovite and biotite) were present only in trace to rare amounts, with no apparent dominance of one over the other. Glauconite content varied from absent to common. Accessory minerals were relatively frequent: amphibole occurred in nearly all samples, pyroxene was also frequently identified, and garnet and tourmaline appeared in three samples each. One sample contained serpentine. Among the rock fragments, metaquartzite was most abundant. Granitoid inclusions were variably represented, with occasional to common occurrences in B1 and B3, but only rare to occasional in B2. Graphic texture was observed in one sample. Clastic sedimentary rocks were mostly represented by sandstone (typically occasional to common), with subordinate occurrences of siltstone and, in one case, mudstone. Chert fragments were present in all samples in rare to occasional amounts. Three samples included phyllite fragments, one contained gneiss, and one gneiss with sillimanite. Volcanic rocks were identified in only two samples.

The two graphitic pottery samples (fabric SM3) differ in both chemical composition and technological and petrographic characteristics. Sample 11 shows notably higher concentrations of Al, Rb, and Sr, whereas sample 12 is richer in Ca, Mn, Fe, Ni, and Ba. Within the context of the entire examined assemblage, graphitic pottery is distinguished by a lower Si content and higher levels of Ca, Ti, Fe, and Ni (Graph 18). In both samples, graphite occurs predominantly as isolated grains and less frequently as fragments of graphitic rocks; fine-grained impregnation of the clay matrix with graphite powder was not observed.

Sample 11 has a poorly sorted non-plastic component with a bimodal distribution of aplastic inclusions. The naturally present silty fraction makes up less than 5 vol.%, while psammitic temper (avg. size 600 µm, max. size 1500 µm) is sub-angular to sub-rounded, amounting to about 10 vol.%. The microstructure is weakly parallel, and the porosity (~10 vol.%) consists of planar pores and vughs. Graphite was abundant and represented the dominant inclusion (Fig. 113: C), accompanied, although less frequently, by graphitic metaquartzite, graphitic gneiss, and metaquartzite. Other minerals occurred occasionally or rarely, including quartz, glauconite, and biotite (prevailing over muscovite), with feldspars present only in trace amounts. Accessory minerals include amphiboles and sillimanite. Rock fragments also include rare chert and volcanic rocks. Plant tissue remains were observed only sporadically.

Sample 12 is very poorly sorted with a bimodal distribution of non-plastic inclusions. The matrix is fine-grained, containing up to 1 vol.% of aleuritic particles. The temper, amounting to 25 vol.%, consists of sub-angular to sub-rounded sand grains and granules (Fig. 113: D). The temper size is ~1200 µm on average (maximum size 4000 µm). The microstructure is weakly parallel, with localized vitrification. Planar and vesicular pores make up about 20 vol.% of total porosity. Graphite grains constitute the dominant component of the sample. Graphite also occurs within rock fragments, mainly as occasional metaquartzites. Quartz is common, feldspars occur in trace amounts, muscovite appears occasionally, biotite is rare, amphibole is occasional, and sillimanite occurs rarely. Notably, chlorite and chloritic schists are relatively common (Fig. 112: F). Other rock fragments include biotite gneisses, metaquartzites, and rare granitoids and chert.

Sample 5 represents the only specimen of mica-tempered pottery (Fabric SM4) within the analysed assemblage. Its chemical composition shows markedly elevated concentrations of Al, K, Rb, and Ti (Graph 18). The matrix is rather fine-grained, containing less than 5 vol.% of aleuritic particles. The overall grain-size distribution is very poorly sorted, which results from the dense tempering with mica flakes of variable size (500 µm on average, max. 3000 µm; Fig. 113: A, B). The temper constitutes about 35 vol.% of the sherd. Due to the character of the inclusions, individual grains are elongated and sub-angular. The microstructure is weakly parallel. Porosity is low (approximately 5 vol.%), consisting mainly of vughs. Mineralogically, the sample is defined by dominant muscovite and abundant biotite. Quartz and alkali feldspars occur occasionally, while plagioclases are common. Garnet appears rarely. The rock fragments include frequent mica schists and gneisses, and occasional metaquartzites.

The provenance of the sandy fabrics (A, B) likely reflects the use of local clay sources available in the surroundings of Staré Město and Uherské Hradiště. Three primary sediment types are present in this region: loess and loessic clays, Quaternary fluvial sediments, and Neogene sediments of the Vienna Basin. Given the consistent chemical composition of the sandy ceramics and the frequent presence of glauconite – a mineral formed in marine environments – the use of loessic materials is considered unlikely. Instead, the raw material may have been derived from Neogene deposits (specifically the Bzenec and Gbely formations), which are exposed just below the Quaternary

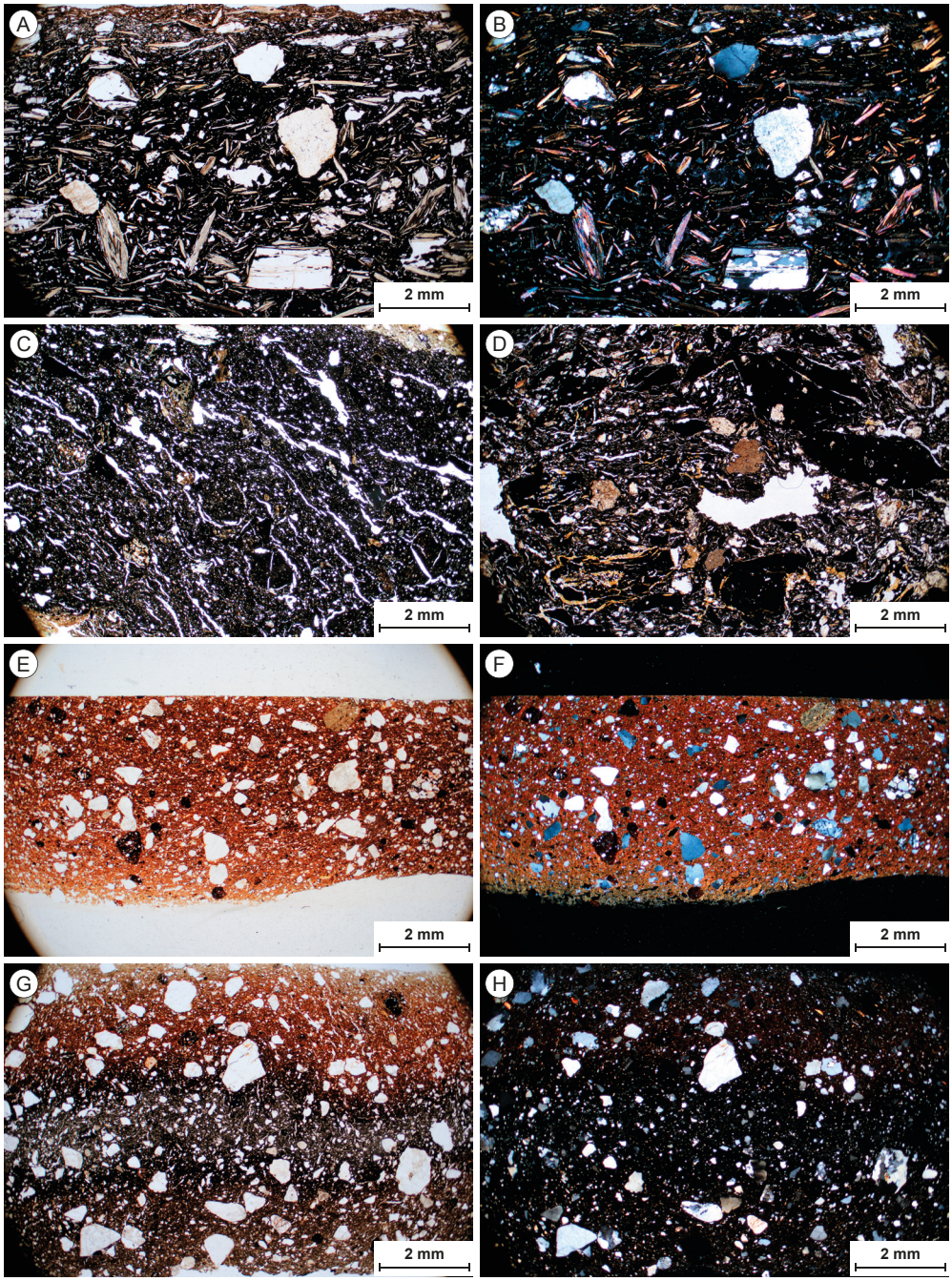


Fig. 113. Staré Město near Uherské Hradiště. Overview of the microstructure of each fabric in PPL (left) and XPL (right) – part 2: A, B – micaceous fabric SM4, sample 5; C, D – graphitic fabric SM3, samples 11, 12 (both in PPL); E, F – pottery hoard sample 8; G, H – pottery hoard sample 9. Author K. Slavíček.

cover in the western and northwestern parts of Staré Město. These formations consist of clays, silty clays, silts, and siltstones, with intercalated sands and silty sands, closely matching the observed granulometric characteristics of the ceramics. The depositional environment of these formations transitioned from brackish to freshwater lake conditions, and the sediments were likely supplied by the River Morava, transporting eroded material from the Silesian crystalline basement and eastern volcanic sources. The presence of metamorphic and granitoid inclusions, as well as volcanic lithics, suggests that some temper material may also have been introduced via Quaternary alluvium. However, at the current stage of research, it is not possible to determine conclusively whether the clay was sourced directly from the Neogene formations or from reworked Quaternary sediments (Buchta et al. 2021, ČGS 2025).

Previous petrographic studies from Uherské Hradiště (Zacherle 1985) similarly identified poorly sorted ceramic fabrics dominated by quartz, with minor feldspars, micas, and fragments of metamorphic rocks. These findings are consistent with the present study, although no ceramics corresponding to Zacherle's fine-grained group A were observed in the current assemblage. Additional comparative data were provided by the analysis of 13 unpublished samples from a ceramic hoard in Staré Město (feature 62). These sherds correspond closely to fabric A in both mineralogical composition and texture, displaying predominantly unimodal grain-size distributions, with three samples weakly bimodal (Fig. 113: E–H). Petrographic features are largely identical, although the hoard samples contain a slightly higher proportion of sandstone fragments. One distinctive inclusion was identified – yellow-red glassy particles, likely slag (Fig. 112: G). Their sporadic presence suggests incidental incorporation rather than intentional addition as a temper to enhance thermal resistance. However, this slag may explain the slightly elevated Fe and Ti contents observed in the hoard samples compared to fabric A and B ceramics from the kilns. The slag is likely related to local ironworking or blacksmithing activity.

Further comparative insight is offered by ceramics from the 'U Víta' site, which represent refuse contexts dated to the Great Moravian period. Analyses indicate that the hillfort was supplied with ceramics from nearby production areas (Hlavica et al. 2024). A partial overlap in chemical composition was observed between the current assemblage and one group of ceramics at 'U Víta', which was provenance-associated with the River Olšava basin near its confluence with the River Morava. This interpretation is further supported by the presence of volcanic rock fragments in the sandy ceramics.

There is no direct evidence of on-site production of mica-tempered pottery, such as *in situ* kiln contexts or natural clay deposits rich in mica. The only indication is vessel 5 (inv. No. 12396, sample 40) from the 'Na Dvorku' kiln, with surface mica coating.

The mica temper (mica schists or mica rich gneisses) must have been imported. Mica schist grinding stones are common in Early Medieval contexts across southern Moravia and the Morava River basin, including Staré Město and Uherské Hradiště (Hrubý 1965, 243; Zacherle 1977, 37). Petrological and mineralogical analyses of Moravian and Austrian mica schists, together with analyses of Early Medieval grinding stones, have already confirmed the Čučice area near Oslavany as a plausible source for at least part of this material (Ondráček 2014, 51; Ondráček, Přichystal 2017). Recent research has revealed a greater internal variability of the Čučice source than previously assumed, increasing the potential for identifying additional mica-schist grinding stones, and also micaceous fabrics as originating from this locality (Hlavica et al. 2023). Alternative sources based on regional geological occurrence of suitable lithologies are the Moravicum (e.g. the Lukov and Bílý Potok groups), the Jeseníky Mountains or the Tatric unit near Devín (Slovakia). A comparable non-local mica-tempered fabric has also been documented at Veselí (Petřík et al. 2015, 196).

As with micaceous pottery, no direct evidence exists for local production of graphite-tempered ceramics. Graphite pottery contains specific rock types, such as chlorite schists associated with graphite and mica, suggesting provenance from the Vranov-Olešnice group (Moravicum) or Desná group (Silesicum). A parallel study of graphite ceramics from nearby Veselí (containing graphite-bearing gneiss and metaquartzite) did not yield conclusive provenance results (Petřík et al. 2015, 103).

Forming

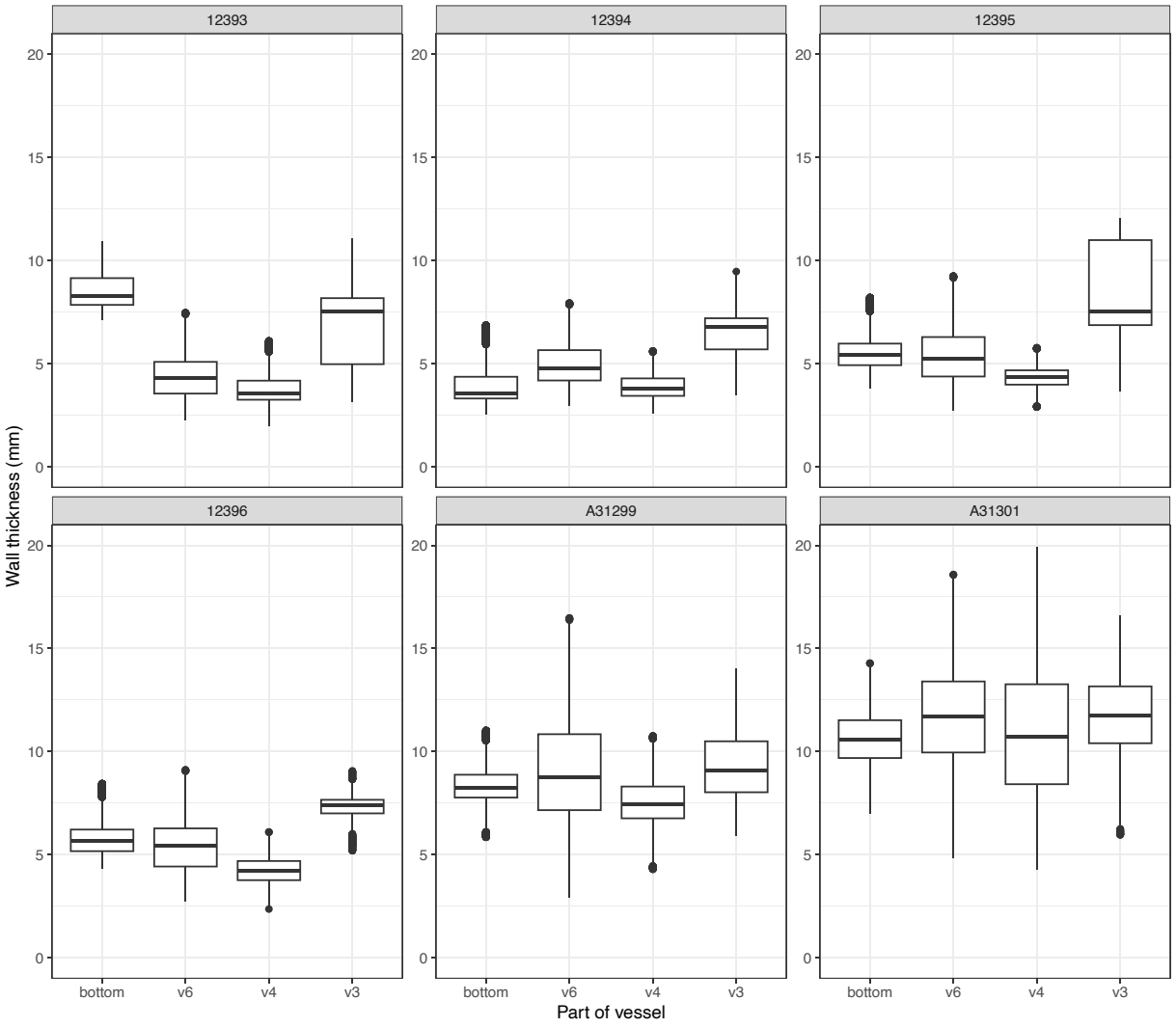
The vessel bodies from kiln 11 were constructed using coiling, most likely on a manually rotated turntable mounted on an axis, with kinetic energy employed primarily in shaping the neck and rim zones (method 1 according to Roux, Courty 1998, 752–753; 2019, 84, 188; cf. Richter 1982, 97–98; Čapek et al. 2018, 98–105). Typical features include uneven walls without traces of wheel forming (Fig. 114: 1b, 2b, 3b), somewhere with visible traces of slow wheel shaping near the bottom or around the rim (Fig. 115: 2b, 5b). Untrimmed coil joints are occasionally visible near the base or as gaps between coils in section (Fig. 115: 3b, 4; cf. Těsnohlídková 2022a, 71). The assumption that the vessels were coil-built is supported by the undulating alignment of particles visible in the section in samples 12 and 17 (Fig. 112: A). As a consequence of this forming technique, the vessels exhibit relatively thick walls, nearly always exceeding 5 mm – for example, 5.5–12 mm in the neck region. 3D wall-thickness analysis of two vessels confirms this observation. A high coefficient of variation in the lower vessel part (20.6% and 30%; Graph 19; Appendix 3-F) further illustrates irregular shaping. The imperfections of this forming method are also reflected in the vessel morphology, which is less globular compared to the High Medieval pottery from feature III/98.



Fig. 114. Staré Město near Uherské Hradiště –'Na Kostelíku', kiln 11. Pots formed from coils with typical uneven inner surface of walls, inv. No.: 1a–c – A31299; 2a–c – A31300; 3a–c – A31301; 1c – imprints of sand grains on the bottom; 2c, 3c – relief marks on the bottom. Photo by T. Chrástek; 1c – by R. Procházka.



Fig. 115. Staré Město near Uherské Hradiště – 'Na Kostelíku', kiln 11. Technological traces on vessels. inv. No.: 1 – A31268; 2 – A31270; 3 – A31251; 4 – A30989; 5 – A31263; 6 – A31024; 7 – A30995; 1b – uneven inner surface of the walls built by coiling; 1c – bottom with the relief mark; 2b, 3c – uneven inner surface of coiled wall; traces of the slow wheel throwing, joints of coils imperfectly adjusted; 3c – bottom with traces of dusting; 4 – uneven inner surface of the walls built from coils, joints of coils are imperfectly adjusted; 5 – traces of wall shaping of the upper part of the pot using the slow wheel throwing; 6 – part of the bottom with traces of cutting on the edge; 7 – fragment of the bottom with protruding ring around the circumference – trace of the the fixing clay strip or of an overhang of wall material outside the sanded area. Photo by R. Procházka; 5 – by T. Chrástek.



Graph 19. Staré Město near Uherské Hradiště. Boxplots showing variability in wall thickness visualising data obtained by 3D scanning of vessels from kilns (vessels 12393–6 – kiln 11, vessels A31299, A31301 – kiln III/98); indices of vessel parts: v6 – bottom to maximum belly diameter; v4 – maximum belly to the narrowest part of the neck; v3 – between the neck and the rim's edge). Author K. Slavíček.

The vessel bases are either smooth or bear traces of sand dusting (Fig. 114: 2c, 3c; 115: 1c); on some examples, cut-off marks left from separating the base from the turntable are visible (Fig. 115: 6). The presence of a peripheral ring on the underside of certain bases (Fig. 115: 7) may also indicate the use of a fixation strip during forming. Six bases from kiln 11 – three of them belonging to reconstructed vessels (two complete pots and one lower part) – carry an identical relief mark (Fig. 106: 1, 2; 107: 2; 114: 2c, 3c; 115: 1c). On three additional bases, different but unfortunately incomplete motifs were observed, the clearest of which depicts a star within a circular frame.

The different forming technique of the pottery from kiln III/98 is evident particularly on the inner vessel walls and bases. The inner surfaces are characterised by distinct undulations, consisting of alternating grooves and raised ridges, most pronounced below the maximum diameter, while the shoulder areas display these features less prominently (Fig 116: 1b, 2b, 3b; 117). These ridges are highly irregular, both in their horizontal course and in the variation of relief depth (e.g. 117: 8, 9), and in some cases they overlap (Fig. 117: 3, 7). Near the base, the inner contour often appears uneven, with signs of incomplete smoothing, such as minor distortions, bulges, pits, and voids, and occasionally a visible joint between coils (Fig. 117: 5, 6, 8, 10). Papillary impressions are common (Fig. 117: 2), and in some cases, tool marks in the form of narrow circumferential grooves with sharp edges running between the raised ridges can be observed (Fig. 117: 7). On the inner base surface, a spiral trace ('snail') caused by rotational movement is sometimes visible,



Fig. 116. Staré Město near Uherské Hradiště – 'Na Dvorku', kiln III/98. Technological traces on vessels, inv. No.: 1 – NV123942, 2 – NV123295, 3 – NV12396, pot with the mica on the surface; 1b, 2b, 3b – traces of wheel forming using the rotation kinetic energy – variety of rilling are visible on the inner surface of the walls; 1c, 2c, 2d – imprints of the fine and middle grains of sand (dusting); 2c, 3c – traces of cutting along the edge. Photo by R. Procházka.

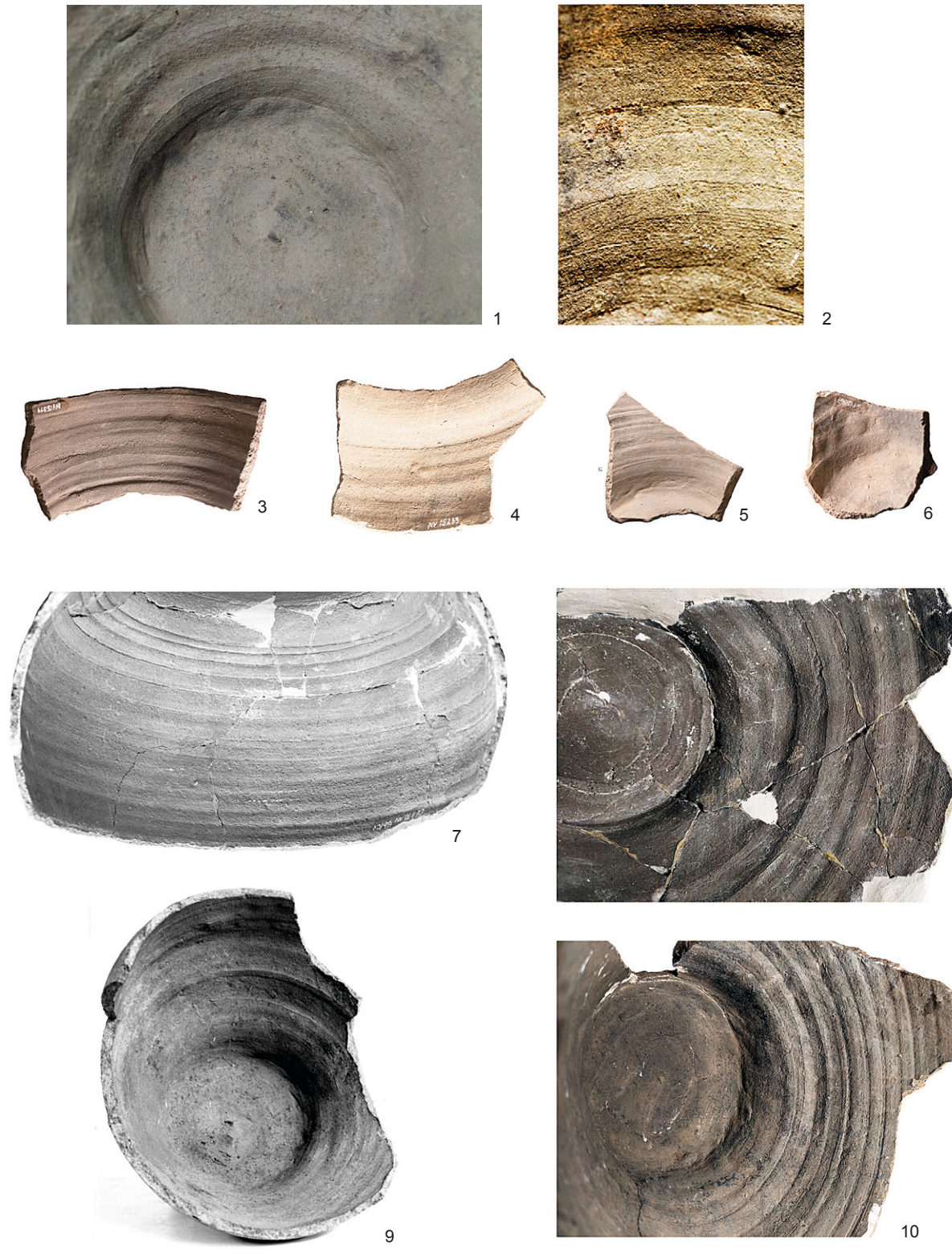
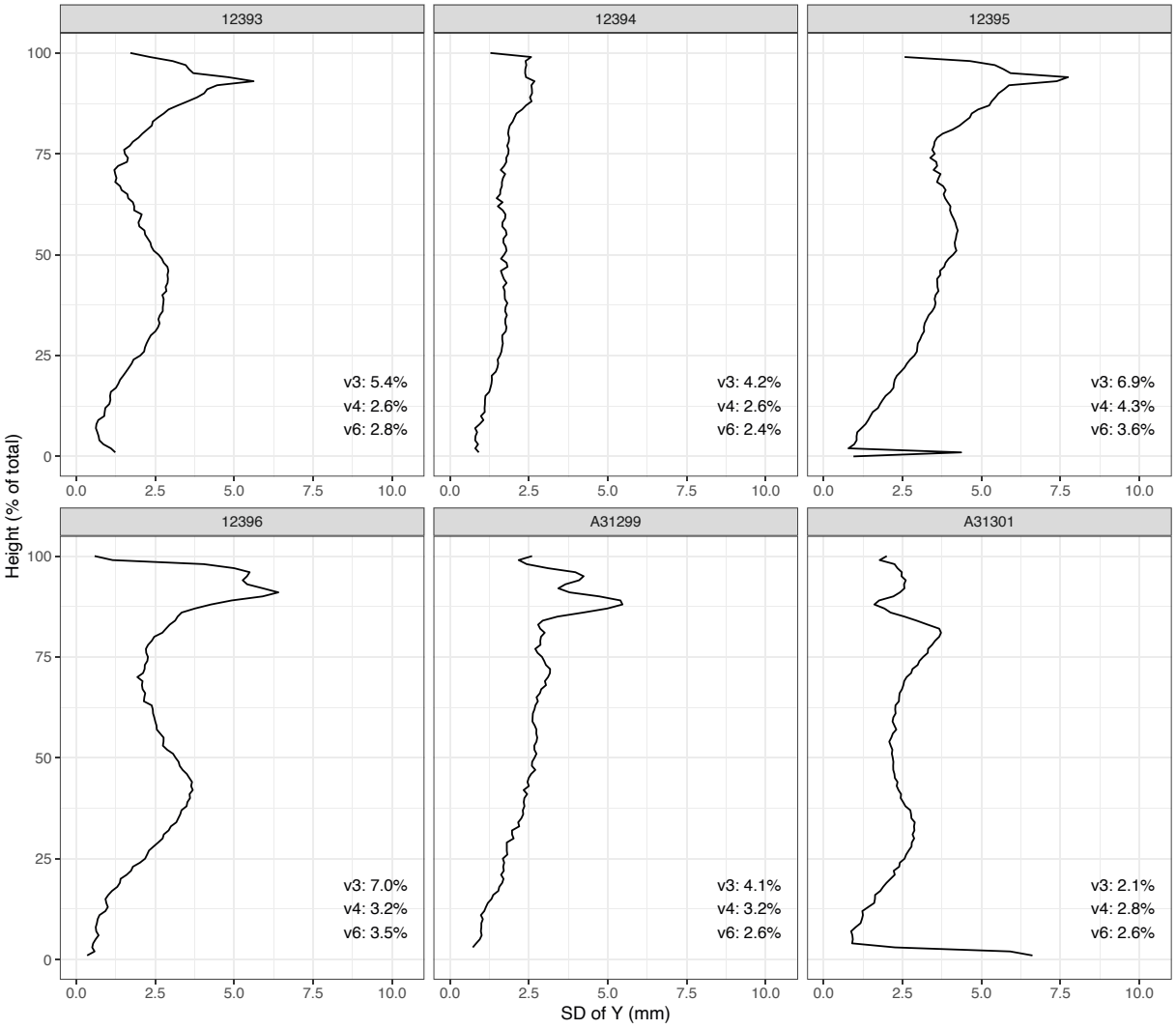


Fig. 117. Staré Město near Uherské Hradiště – 'Na Dvorku', kiln III/98. Technological traces of the forming of pots, inv. No.: 1 – NV15314, unregular undulating on the inner surface of the fragment of the lower part of the vessel; 2 – NV12405, trace of the first coil of the bottom; 3 – 12402, traces of papilary lines, 4 – NV15233, ridges and grooves visible on the inner surface of the upper part of the pot-wall; 5 – NV 15901, traces of compression over the bottom unintentionally created as considerable result of overturning of the clay; 6 – NV15867, traces of vertical pulling, squeezing on a fragment of the lower part of the pot; 7 – NV12410, dense rilling revealing the effect of shaping by rapid rotation, in the upper part visible thin groove after using the tool (the so called blade?); 8 – NV12400; 9 – NV12405; 10 – NV12402: variant traces of vessel wall formation on the inner wall-surfaces in the lower part of pots using the kinetic energy rotation. Photo by M. Košťál (1, 3–6), R. Procházka (2, 7–10).



Graph 20. Staré Město near Uherské Hradiště. Diagram showing the standard deviation of the outer surface from the rotational axis across vessel height of vessels from kilns (vessels 12393–6 – kiln 11, vessels A31299, A31301 – kiln III/98). Vessel part indices (v3, v4, and v6) are indicated, along with the corresponding coefficients of variation for each respective vessel part. Author K. Slavíček.

occasionally accentuated by a tool mark (Fig. 117: 8). The centre of the spiral is not always located precisely at the middle of the base. 3D scanning of four pots (Graph 19) revealed a consistent, slightly decreasing wall thickness from the base to the point of maximum diameter (v6) and from there to the neck (v4), with average values of 4.3–5.5 mm (v6) and 3.7–4.3 mm (v4). The coefficient of variation of wall thickness ranges between 19.8–23.5% (v6) and 12.9–17.3% (v4) – considerably lower than in the vessels from Kiln no. 11. The rims (v3) show thicker walls, reflecting their morphological type, with average values of 6.4–8.6 mm and a coefficient of variation of 8–25%.

Distinct striations caused by the movement of sand grains are often visible. The outer surfaces of the bases display traces of sand dusting (Fig. 116: 1c, 2c, 3c). Peripheral ridges occasionally occur and may represent the attachment of a clay strip used to secure the vessel during rotation, while short diagonal grooves along the base's rim sometimes indicate final cutting off (Fig. 116: 2c). Depressions or bulges occasionally observed were produced by the potter's fingers when lifting the vessel from the turntable or board. The outer base surface is flat (Fig. 108: 4, 9) or mostly slightly concave (e.g. Fig. 108: 1, 11). 3D section profiles likewise show a clear irregularity of rotation within a single vessel, frequently with thickening, broad coil or ridge, above the base.

The rotational symmetry of the pots from kiln 11 shows a decreasing trend from the base upwards (Graph 20; Fig. 118), reflected in the increasing coefficients of variation of the distance from the rotational axis: 2.6% (v6), 2.8–3.2% (v4), and

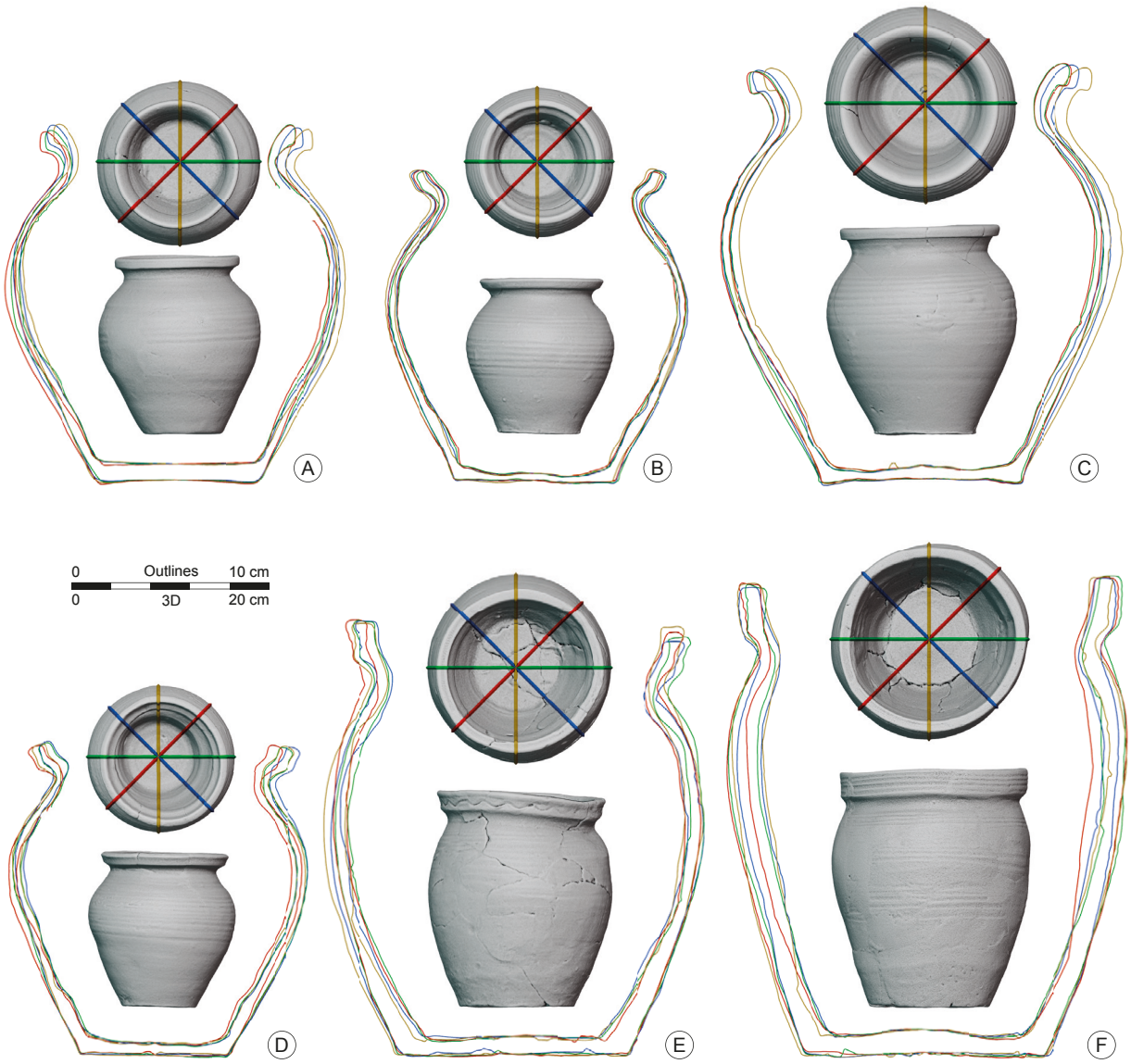
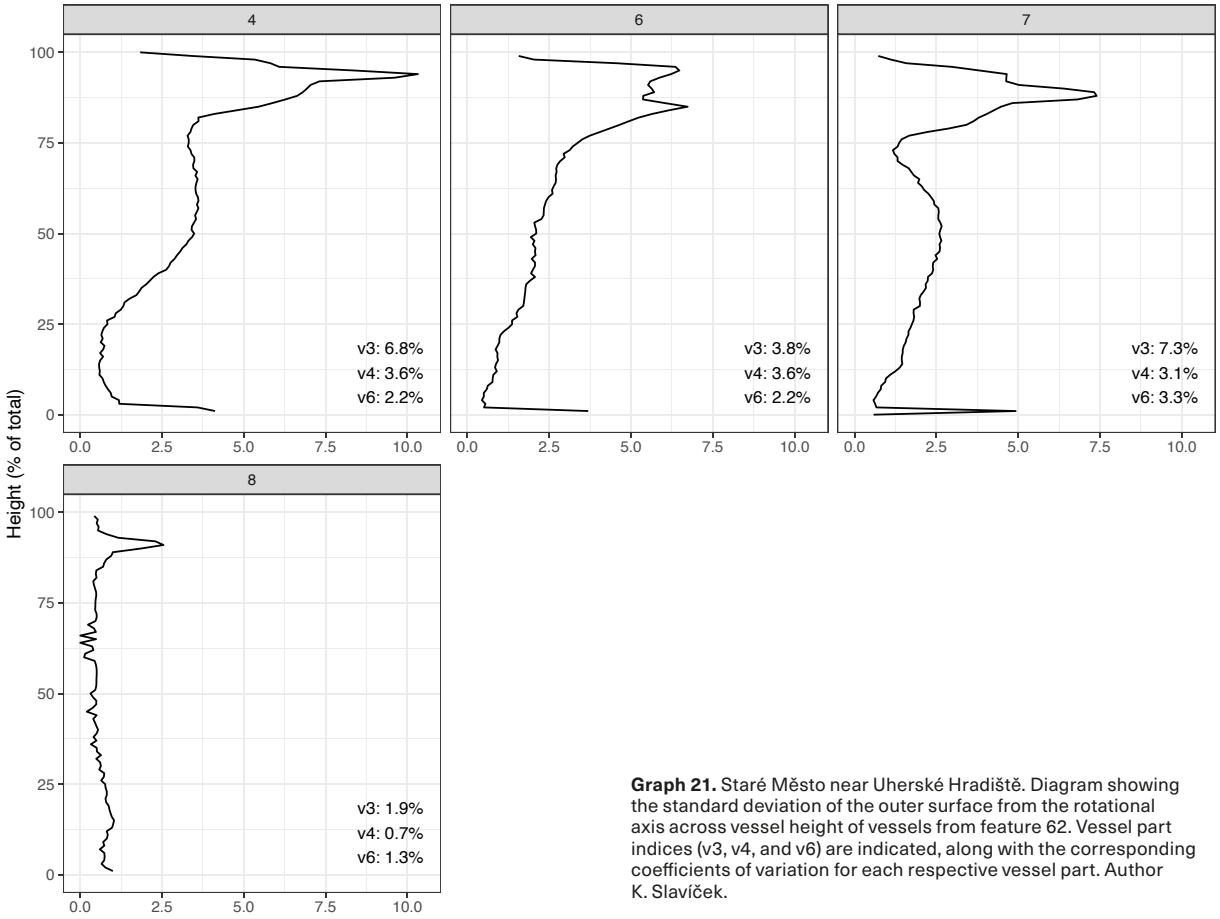


Fig. 118. Staré Město near Uherské Hradiště. 3D models and vertical cross-sections showing degree of vessel symmetry of pots from kilns, inv. No.: kiln III/98: A – 12393; B – 12394; C – 12395; D – 12396; kiln 11: E – A31299; F – A31301. Author M. Košťál.

2.1–4.1% (v3). In contrast, the pots from kiln III/98 exhibit a different pattern: the variability increases towards the maximum diameter (2.3–3.6%), then declines towards the neck (average 2.6–4.3% for v4), followed by a renewed increase at the rim (2.5–7%).

The pots from feature 62 show values comparable to those from kiln III/98 (Graph 21; Fig. 119), with the exception of vessel 8, which is remarkably axisymmetric. Across all its parts, including the rim, the coefficient of variation for the distance of the outer surface from the rotational axis remains below 2% (Appendix 3-F). The other vessels, however, display increasing asymmetry towards the maximum diameter, followed by a decline towards the neck and a marked increase at the rim. The coefficients of variation by vessel segment are 1.3–2.2% (v6), 0.7–3.6% (v4), and 1.9–7.3% (v3).

The more effective use of kinetic energy accounts for the distinctive features that differentiate the pots from kiln III/98 from those of feature 11. The faster rotation contributed to the thinning of vessel walls, which now reach minimum thicknesses between 3 and 5 mm, and enabled the formation of more globular shoulders, with the maximum diameter consistently exceeding that at the rim. These traits suggest that the vessel bodies were constructed from coils and subsequently shaped through rapid but irregular rotation, a technique consistent with transitional hand-wheel production (cf. Těsnohlídková 2022a, 68, 70–71).



Graph 21. Staré Město near Uherské Hradiště. Diagram showing the standard deviation of the outer surface from the rotational axis across vessel height of vessels from feature 62. Vessel part indices (v3, v4, and v6) are indicated, along with the corresponding coefficients of variation for each respective vessel part. Author K. Slavíček.

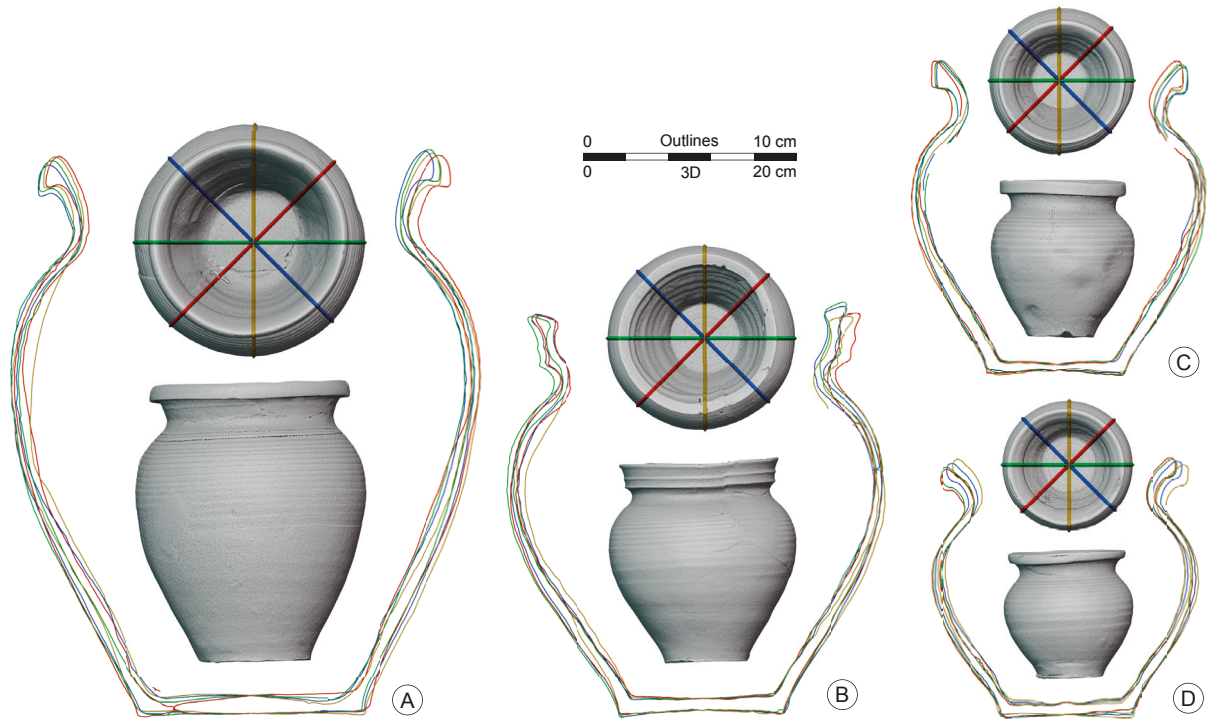


Fig. 119. Staré Město near Uherské Hradiště. 3D models and vertical cross-sections showing degree of vessel symmetry of pots from ceramic hoard 62: A – 4; B – 6; C – 7; D – 8. Author M. Košťál.

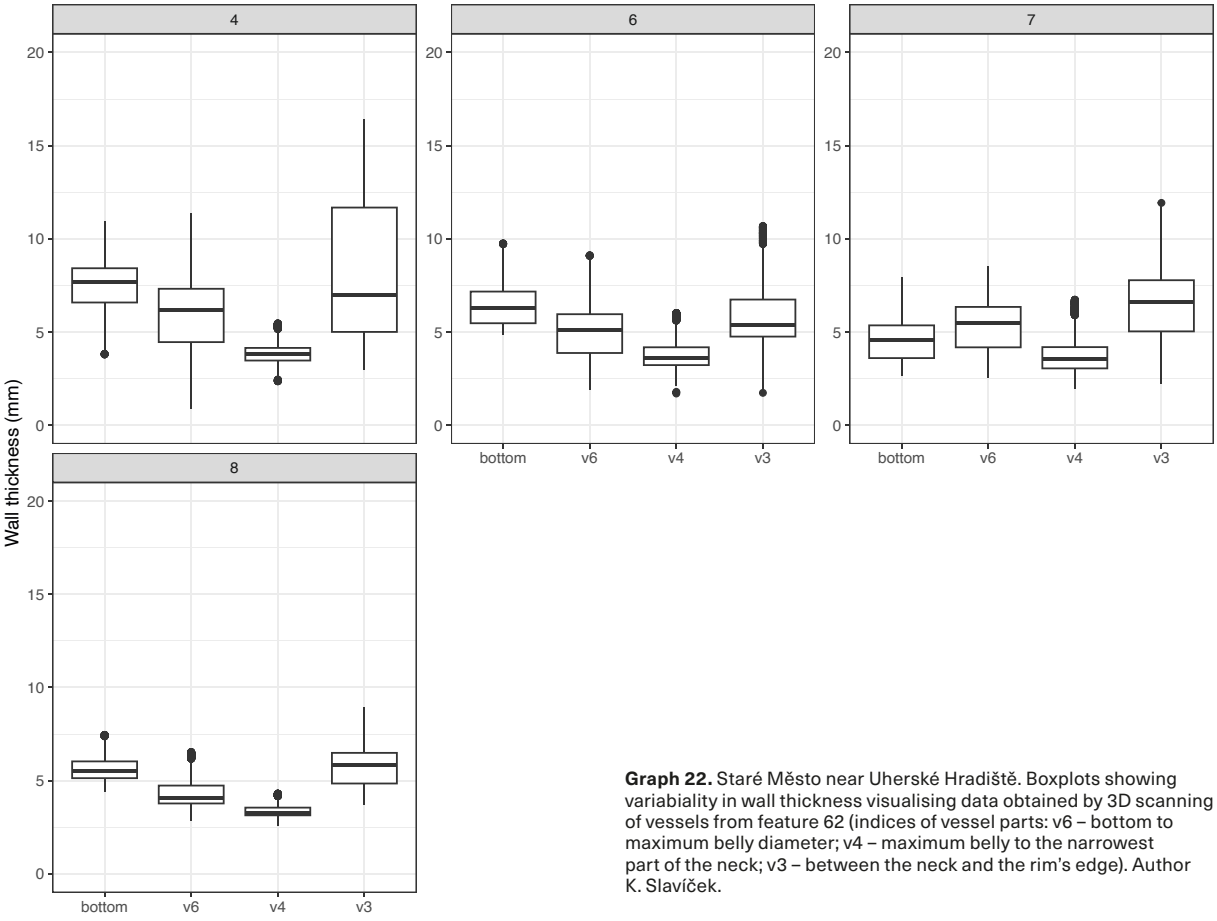
The ceramics from hoard 62 show no fundamental differences from the assemblage of feature III/98. On the inner walls of pots and particularly of goblet-shaped jugs (Fig. 120: 1b, 1c, 2b, 3b; 121: 5), horizontal ridges are again visible – although in some vessels they are less pronounced, which is reflected in the greater variability of wall thickness (Fig. 120; 121: 4–10; Graph 22). Compression folds above the base still occur occasionally (Fig. 121: 9). Rotational traces are also visible on the inner surfaces of the bases (Fig. 121: 10), whose outer sides still bear traces of sand dusting (Fig. 120: 1d, 2c, 3c; 121: 1). For some vessels with only faint marks on the inner walls, the possibility of throwing from a single lump of clay can be considered, albeit with caution. Among the lid knobs, some exhibit a rough, uneven surface (Fig. 121: 3), while others bear traces of cutting from the potter's wheel (Fig, 121: 2).



Fig. 120. Staré Město near Uherské Hradiště. Ceramics hoard, feature 62. 1, 2 – pots; 3 – jug; technological traces of fashioning of coiled walls by using the rapid rotation; 1d, 2c, 3c – bottoms with traces of dusting. Vessels without inv. No. Photo by R. Procházka.



Fig. 121. Staré Město near Uherské Hradiště. Ceramics hoard, feature 62, traces of vessel-forming: 1 – bottom of the cup-type jug with traces of dusting; 2 – lid-handle with spiral cut trace; 3 – lid handle with imprints of sandy grains; 4 – inner surface of the upper part of the pot – wall with fain undulation on the inner surface; 5 – inner surface of the cup-wall with significant ridges and grooves; below, above the bottom, probably traces of compression of the clay mass; 6 – bottom of a pot with sandy grains imprints and the trace of slight turning; 7 – traces of forming a pot by rapid rotation using a tool that leaves narrow grooves; 8 – traces of faint undulation on the bottom part of the inner surface of the pot-wall; 9, 10 – significant, unregular traces of wheel turning on the bottom parts of the pot, on the wall of the pot No. 9 visible narrow compression grooves. Photo by R. Procházka.



Graph 22. Staré Město near Uherské Hradiště. Boxplots showing variability in wall thickness visualising data obtained by 3D scanning of vessels from feature 62 (indices of vessel parts: v6 – bottom to maximum belly diameter; v4 – maximum belly to the narrowest part of the neck; v3 – between the neck and the rim's edge). Author K. Slavíček.

Firing

If we exclude intrusive sherds, three out of fifteen samples from the pottery assemblage of the stoking pit of kiln 11 show evidence of a distinctly oxidising firing atmosphere, while two samples were clearly reduced; four samples can be characterised as weakly oxidising, and the remaining ones as mixed. From a macroscopic perspective, the assemblage from kiln 11 overall exhibits a predominantly mixed firing atmosphere, with only a small portion being entirely oxidised. The colouration ranges from grey to brown and orange hues, often variable even within a single sherd. However, grey tones prevail on the surfaces, which may indicate an intentional attempt to achieve a reducing effect (Čapek et al. 2018, 62–64).

Heat-deformed ceramics, represented by the reconstructed fragments of three different vessels (sample 18), are grey in colour, consistent with temperatures exceeding 1000°C – conditions under which the firing atmosphere is typically reducing (Fig. 110: 18; 122). In this context, a comparison with ordinary settlement pottery, which was also present in the stoking pit, was suitable. Comparison with a contemporaneous assemblage of early medieaval technological tradition from waste pit 90 at 'Za Zahradou' would be interesting; here, oxidised surfaces are far more pronounced, possibly reflecting open firing rather than use of a kiln, since no advanced firing structures were identified nearby.

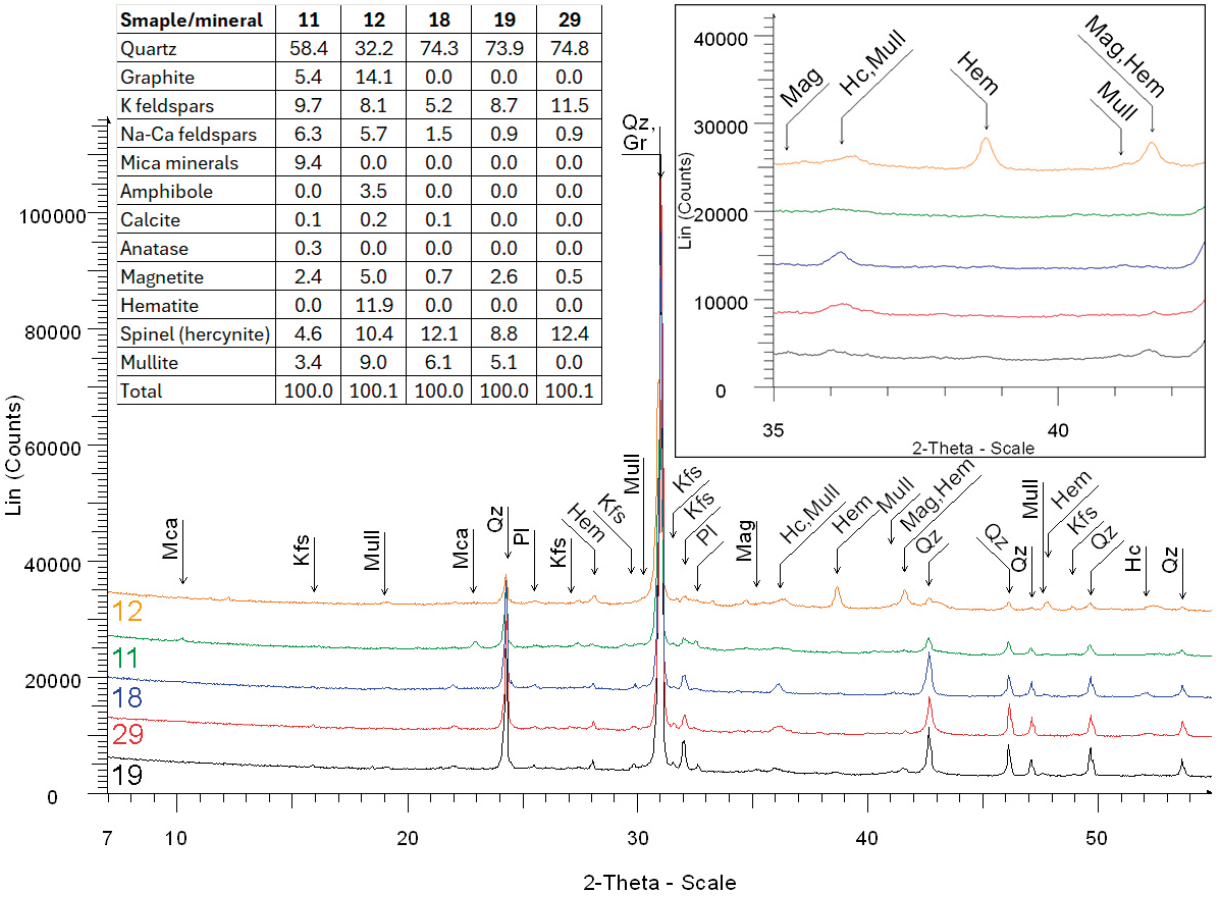


Fig. 122. Staré Město near Uherské Hradiště – 'Na Kostelíku', kiln 11. Fragment of a heat-deformed pot, inv. No. A31273. Photo by R. Procházka.

Temperature assessments were based on pleochroism of biotite, colour changes in green amphiboles, matrix optical activity, and XRD. The analysed samples indicate relatively high firing temperatures, typically around or slightly below 900°C. Exceptionally high temperatures (1000–1100°C) were inferred in aforementioned sample 18. The main indicator of firing temperature aside from melted matrix (Fig. 112: D, E) is the presence of mullite in XRD (Graph 23). Other high fired samples are of graphitic fabric (SM3). Sample 11 has an optically inactive matrix in the core, and together with the non-pleochroic biotite and presence of spinel (of structure close to hercynite), this indicates a firing temperature of 950–1000°C. The core remained reduced, while the margins were slightly oxidised. The firing temperature of sample 12 was higher than in sample 11, reaching 1000–1050°C, as evidenced by the increased volume of mullite. Micaceous sample 5 (fabric SM4) showed a locally optically inactive matrix, though biotite flakes exhibited medium to weak pleochroism, suggesting a firing temperature between 800 and 900°C. The sherd shows signs of a reducing firing, with a thin oxidised layer along the outer margin.

Among the 22 analysed samples from feature III/98, four were distinctly reduced, seven were clearly oxidised, and another seven were weakly oxidised, while the remaining samples showed evidence of a mixed firing atmosphere. The majority of the pottery from feature III/98 displays a grey surface colour, although a noticeable number of sherds exhibit signs of oxidation. Nevertheless, the assemblage cannot be described as consistently reduced-fired, even though a clear effort to achieve reduction firing can be observed. A single deformed rim was recorded, though not as a result of firing failure. A comparison with ordinary settlement pottery may help to clarify whether partially oxidised vessels were included in the distribution or rather discarded as substandard products. The majority of the analysed samples were fired below 900°C, and in some cases possibly even

Smaple/mineral	11	12	18	19	29
Quartz	58.4	32.2	74.3	73.9	74.8
Graphite	5.4	14.1	0.0	0.0	0.0
K feldspars	9.7	8.1	5.2	8.7	11.5
Na-Ca feldspars	6.3	5.7	1.5	0.9	0.9
Mica minerals	9.4	0.0	0.0	0.0	0.0
Amphibole	0.0	3.5	0.0	0.0	0.0
Calcite	0.1	0.2	0.1	0.0	0.0
Anatase	0.3	0.0	0.0	0.0	0.0
Magnetite	2.4	5.0	0.7	2.6	0.5
Hematite	0.0	11.9	0.0	0.0	0.0
Spinel (hercynite)	4.6	10.4	12.1	8.8	12.4
Mullite	3.4	9.0	6.1	5.1	0.0
Total	100.0	100.1	100.0	100.0	100.1



Graph 23. Staré Město near Uherské Hradiště. Diffractograms (angular range 7–55 °2θ) of samples 11, 12, 18 (kiln III/98), 19, and 29 (kiln 11) and results of quantitative phase analysis of crystalline fractions of the samples. The inset in the upper right corner shows an enlarged area of the record containing well-defined reflections of phases indicating firing conditions; Al-Si Spl = Al-Si spinel, Gr = graphite, Hc = spinel close to hercynite, Kfs = K-feldspars, Mag = magnetite, Mull = mullite, Pl = Na-Ca feldspars, Qz = quartz. Author D. Všianský.

at temperatures around 750°C. However, several samples exhibit optical characteristics and mineralogical compositions – identical to those observed in specimens from feature 11 – that indicate higher firing temperatures exceeding 1000°C but remaining below 1100°C. The highest firing temperature was recorded in sample 19, which contains neoformed spinel and mullite (Graph 23). Sample 29 does not contain mullite, yet the presence of spinel still suggests firing temperatures of around 1000°C.

The comparative ceramic assemblage from the hoard (feature 62) shows evidence of slightly higher firing temperatures compared to the ceramics from features 11 and III/98. In approximately half of the samples in the feature 62, the matrix is optically inactive in core and locally vitrified. The firing temperatures for these samples are estimated at approximately 900–950°C. The firing atmosphere was generally mixed. More specifically, some cores exhibited oxidising conditions, while others were reduced. Similarly, the layers below the surface displayed varying atmospheres, ranging from weakly reducing and weakly oxidising to fully oxidised. In about half of the samples, traces of smoke-darkening were observed on the vessel surfaces, indicating limited exposure to reducing gases during the final stage of firing. The ceramics in the hoard were produced using a basically uniform technology.

5

Late medieval pottery production in St. Pölten: Roßmarkt 11 and 12 in the context of Lower Austria

5.1 Town of St. Pölten in the Middle Ages

In the first half of the 2nd century AD, the *municipium Aelium Cetium* was founded on the site of the medieval town of St. Pölten. The *municipium* was abandoned by the Roman administration during the 5th century. After Charlemagne's wars against the Avars, a monastery dedicated to St. Hippolytus was probably founded in the 8th century by the Benedictine monastery of Tegernsee in Bavaria, within the area of the abandoned *municipium*. Around the same period, or shortly thereafter, the settlement of *Treisma* was established by the Diocese of Passau. The monastery and the settlement were the nuclei of the future town of St. Pölten, whose development was largely determined by the Diocese of Passau until the late 15th century. The town was first granted municipal rights in 1159, which were renewed in 1338. The construction of the city wall began around 1250, enclosing an area of approximately 38.22 ha (Fig. 123: 1, 2). After 1490, St. Pölten became a princely city (Risy 2011a; Weigl 2009; Fuchsberger, Schicht 2022, 382–387).

From the late 1980s until recently, numerous archaeological excavations have been carried out in the city centre of St. Pölten, corresponding to the extent of the medieval city. These include large-scale investigations at Rathausplatz and Domplatz, as well as numerous archaeological excavations accompanying construction work in the west and south of the medieval city's area.

5.2 Written sources on ceramic production

Only since the 16th century have more extensive written sources on ceramics production and the pottery guild in St. Pölten been preserved. The lack of written sources from the Middle Ages is partly due to the fact that the tendency to put things in written form was not yet as widespread as it became in modern times (Otruba 1952, IV). On the other hand, there are records of several major fires in St. Pölten, which are known to have destroyed written documents. In 1474, for example, a fire broke out in the house located at the corner of Rathausplatz (town hall square) and Heß Street, destroying large parts of the town, including sections of the town wall and the buildings in the *Hafnergazzen*.[1] The fact that the city archives were also likely to have been severely damaged can be deduced from the fact that only 17 original documents have been preserved from the period before 1474 (Kaska 2019, 6–7). A fire in 1512 caused damage on a similar scale (Gutkas 1989, 24–25; 1993, 86).

Early references to potters in St. Pölten can be found in the Passau Urbaria (land registers). The mentioning of pottery craft in the 1324 land register is the earliest known reference to it in Lower Austria. Three master potters are mentioned in St. Pölten for both 1324 and 1391 (Otruba 1952, XI, LIII), with at least one in 1367 (*Luencz Figulus* in the area of the Rathausplatz; Maidhof ed. 1933, 744) and in 1420, and again at least three in 1459. Between one and four pottery masters can be traced in the archives

1 Hafner Street, most of which is called Roßmarkt today. 'Hafner' is a term commonly used in southern Germany and Austria as a synonym for 'potter'.

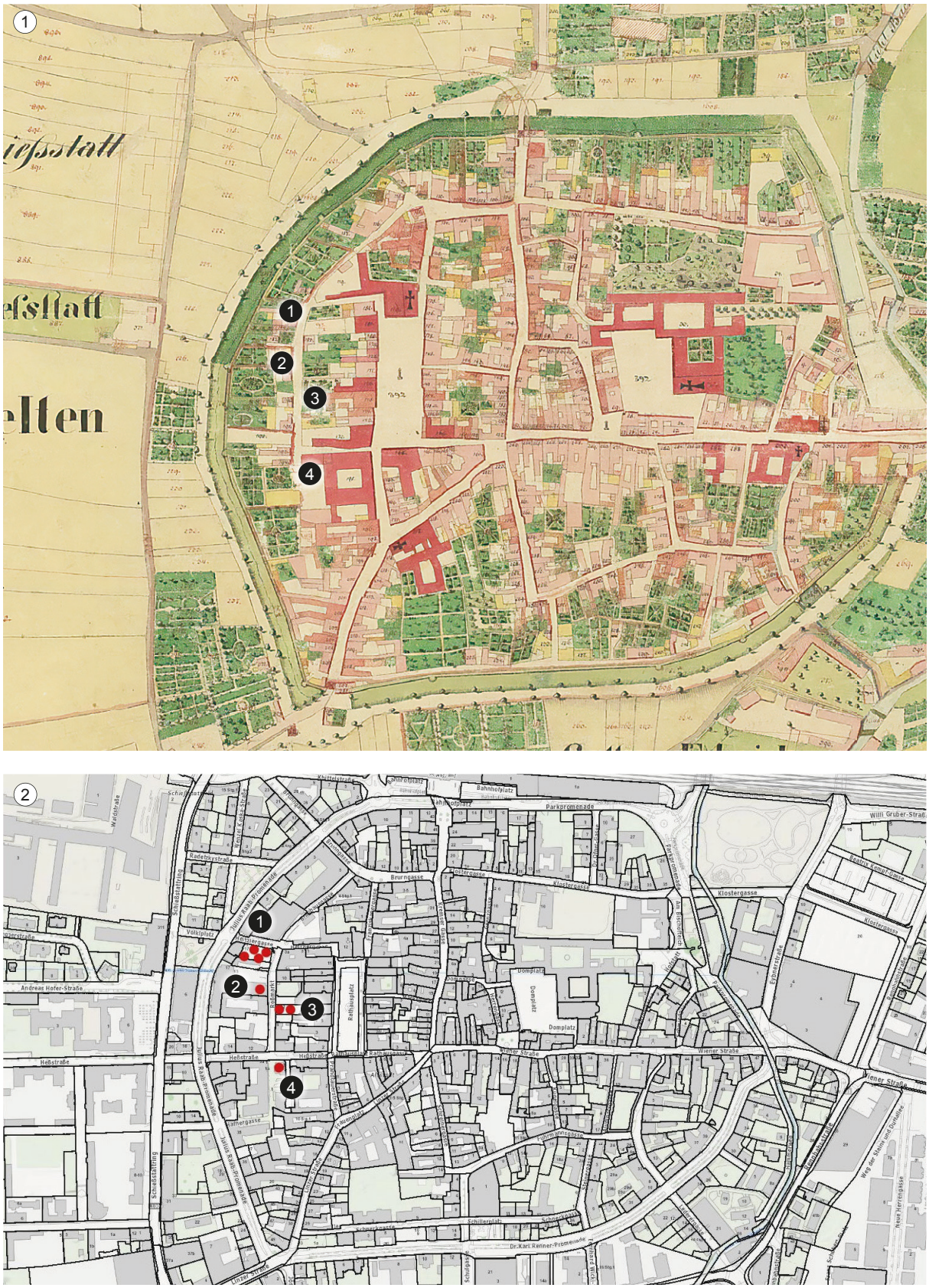


Fig. 123. St. Pölten. 1 – detail from the Franziscean cadastral map from 1821 (Arcanum maps); 2 – cadastral map with location of the medieval pottery kilns (basic data from NÖGIS - geographic information system of Lower Austria; 1 – Roßmarkt 19; 2 – Roßmarkt 11; 3 – Roßmarkt 12; 4 – Heß Street 5 / Hafner Street. Graphics by G. Scharrer-Liška.

per year, as in medieval Moravia (see Chapter 2), and in many towns in Lower Austria. Presumably, this number of workshops mainly supplied the local market, which is also likely to have been the case in St. Pölten. The Passau Urbarium of 1324 already mentions the *Hafnergazzen* (Maidhof ed. 1933, 473) with the reference to potter master *Stephanus*. In the Urbaria of 1367 and 1391, the name of the street is recorded in its Latin form as *strata figulorum* (Maidhof ed. 1933, 473, 834). This street was also mentioned in the context of the fire of 1474. Other towns and markets in Lower Austria and Upper Austria also had *Hafnergassen* or similar street names. Examples can be found in Horn (*Hafnergasse*), Vienna (*Hafnersteig*), Wels (Wiesinger 1937, 95) etc. However, due to gaps in the research there is often a lack of archaeological evidence to confirm the presence of pottery crafts associated with these street names, e.g. in Gars am Kamp, Klein-Pöchlarn and Gänserndorf.

Given the limited number of written sources, reference should be made to some remarkable ceramic finds from the vicinity of the pottery kiln documented in St. Pölten in 2017–2019 at the corner of Heß Street / Hafner Street on parcel 103/8 (Thaler 2021, 180). The ceramic fragments refer to a master who is mentioned by name. These are fragments of earthenware fired in an oxidising atmosphere with graphite tempering, as well as grey-coloured earthenware fired in a reducing atmosphere, which were stamped with inscriptions in Gothic minuscule letters. The inscriptions refer to *Steffan hafner uonsannd polten* and, based on paleographic criteria, can be dated to the period between 1475 and 1525 (Zajic, Zenz 2021, 159–163). Thus, at least one potter is known by name for this period. However, as already mentioned, it is not possible to identify the potter with certainty due to a lack of written sources (Kaska 2019, 6–7; Zajic, Zenz 2021, 161).

The organisation of craftsmen into guilds was a development that began in earnest in the 13th century, when Central Europe experienced a boom in urbanisation. The social changes and new economic conditions associated with this development remained decisive for the centuries that followed. The earliest written reference to the existence of an organised potters' guild relates to Vienna and can be found in the words die *dâ drænt ûz tahen heven unde krüge* in the 'Reimchronik' of Ottokar von der Gaal (*Otacher oûz der Geul*) from the early 14th century (Seemüller ed. 1893, 870). During the same period, as outlined above, *Passau Urbaria* also attest to the existence of potters in St. Pölten. However, these written sources do not allow any conclusions to be drawn about the extent of the organisation or the rules followed by the guilds.

The first explicit mention of a potters' guild in Lower Austria in 1471 refers to Klosterneuburg. Preserved potter's regulations date back to the 16th century, with those from St. Pölten from 1516, confirmed by the town council and judge (Horawitz 1876, 309–310; Otruba 1952, 88–89), representing the oldest preserved regulations in Lower Austria (Otruba 1952, 403). Similar early potter's regulations have also been preserved in Lower Austria for Krems and Stein from 1547 and Stockerau from 1585 (Otruba 1952, 391, 403). The potter's regulations for St. Pölten were renewed and confirmed by the town's council in 1591 and 1603. In 1719, Emperor Charles VI granted the potters of St. Pölten a new guild charter (Karner 1949, 49). Potters' guild charters, including those from St. Pölten, contain regulations regarding certification as a master craftsman, production guidelines, and rules regarding working hours and sales times. The regulations of the Vienna pottery guild were adopted in the Lower Austrian craft guild regulations, reflecting the common practice of integrating provincial masters into the main guild of the capital city.

One indication of a guild's prestige was its position in the Corpus Christi procession. The closer the representatives of a craftsmen's guild were to the Blessed Sacrament – carried at the end of the procession – the more prestigious the guild was. However, the order of the Corpus Christi procession was apparently not the same everywhere, and the age of the guild probably played a role. In Vienna, potters were positioned relatively far back in the procession, which indicates their high status. In St. Pölten, by contrast, they occupied the leading position in the procession (Horawitz 1876, 310; Otruba 1966, 41), while in Olomouc in Moravia, they were in the eight position (Veselý, Zaoral 2008, 54; see Chapter 2).

5.3 Archaeological evidence of pottery production: Medieval pottery kilns in St. Pölten

5.3.1 Pottery kilns discovered in 1909 (Roßmarkt 11) and 1991 (Roßmarkt 12)

In the west of the medieval town of St. Pölten, between the town wall and the Rathausplatz, there was a pottery district around today's Roßmarkt (Horse Marketplace) and its extension, Hafnergasse

(*Hafnergazzen*; Maidhof ed. 1933, 473). Numerous pottery kilns and workshop waste pits have been repeatedly documented archaeologically here from 1909 up to the recent past. The number of identified kilns has risen significantly, especially in recent years (Fig. 123). So far, eight late medieval pottery kilns have been verified in St. Pölten (see below Tab. 28).

In 1909, during the demolition of a potter's house at Roßmarkt 11, a medieval pottery kiln with an extensive pottery hoard was discovered (Otruba 1966, 52). This comprises 43 ceramic objects (Fig. 123: 2). No contemporary documentation of the find is known or has been preserved. A guide to the St. Pölten City Museum contains the oldest known written notes on the find (Neugebauer 1976, 370).

It is uncertain whether all 43 ceramic objects assigned to the pottery kiln in fact originated from the kiln, or whether the find complex might also contain pottery waste from the surrounding area (Krenn 1992, 203). The finds can be dated to around 1300. A piece of the kiln wall made of fired clay and traces of wattle and daub, which is in the collections of the St. Pölten City Museum, does not allow any detailed conclusions regarding the kiln's construction.

In 1991, archaeological excavations were carried out during construction activity in the vicinity of Roßmarkt 11 (parcels No. 84, 86/1, 2, 187, 188, 247/10, 415, and 1259; today parcel 86/2, Julius Raab-Promenade 19; Fig. 123: 3). In addition to the counter wall of the medieval town wall, workshop waste pits, clay pits, a well filled with medieval ceramics, and a late medieval pottery kiln was uncovered. The kiln was embedded in the bedrock and had an approximately oval floor plan, with the stoking channel area located on the eastern narrow side. The western end of the kiln had been destroyed by a modern water pipe and was missing. The original width of the kiln was 1.2 m, and a preserved length of 3.5 m. The pots stood upside down on a clay floor. They formed a central spoon-shaped firing floor. Eight of the pots were still in situ. Ceramic and brick fragments, as well as red-fired clay, were found between the vessels (Riegler 1992). Due to time constraints during the excavation, it was decided to recover the kiln as a single block. Recovery, transport, and storage of the block outdoors – albeit covered with sheets – resulted in further (frost) damage to the find (Fig. 124: 1–5). In February 1993, the kiln was examined in more detail and documented (Scharrer-Liška, Scherrer 2010, 87–88).

After removing loose material that was no longer in situ, a compact arch of fired clay was revealed. It contained five pots positioned upside down *in situ*, as well as the imprints of two more pots that had already been visible before the block was recovered (Fig. 124: 3). The pots were arranged nearly parallel to each other, with one located at the apex of the clay arch. The clay arch measured approximately 0.6 m in width and 0.25 m in height, and its lower end merged into a nearly horizontal floor made of fired clay (Fig. 124: 1, 4). A cross-section (Fig. 124: 5) through this construction showed that the pots had been placed directly on the subsoil, the gaps filled with clay and partly with brick fragments, and carefully coated with clay on the outside. Starting from this arch, a floor screed was then applied approximately horizontally across the subsoil. At the apex of the arch, the floor screed sloped downwards towards the southeast, in the direction of the presumed fireplace area, resulting in a difference in level within the kiln. Based on its design and comparative analysis, the kiln could be identified as a diagonal flame draft kiln. Based on the ceramic finds, especially the pots used as construction elements, the kiln can be dated to the mid or second half of the 14th century.

5.3.2 Pottery kilns discovered in 2017–2021

During archaeological excavations carried out alongside construction work between 2017 and 2019 at the corner of Heß Street and Hafner Street (parcel No. 103/8), another pottery kiln was unearthed (Fig. 123: 4). The kiln had been damaged by the construction of an early modern lime pit, so that only part of the central spoon-shaped firing floor, the western fire tunnel, and the kiln wall remained intact. The complete eastern part of the kiln, however, had been destroyed. Nevertheless, this kiln could also be identified as a diagonal flame kiln. The oldest finds from the kiln's backfill date to the Late Middle Ages (Thaler 2020, 36; 2021, 180).

In 2020, another kiln of the same type was documented at Roßmarkt 19 (parcel No. 184, 185, 81) during archaeological investigations accompanying construction work. The kiln measured approximately 3 × 2 m, had a central spoon-shaped firing floor and two firing openings at the western end. A working pit in front of it was also identified (Fig. 123: 1; 125: 2). Another kiln with a central spoon-shaped firing floor and a lightly limed kiln floor was partially documented. To the west of this was a shallow pit approximately 3.5 m in diameter, with four postholes set in the corners. This may also have served a working pit, this time covered. Both kilns had ceramic vessels built into the kiln walls to support the

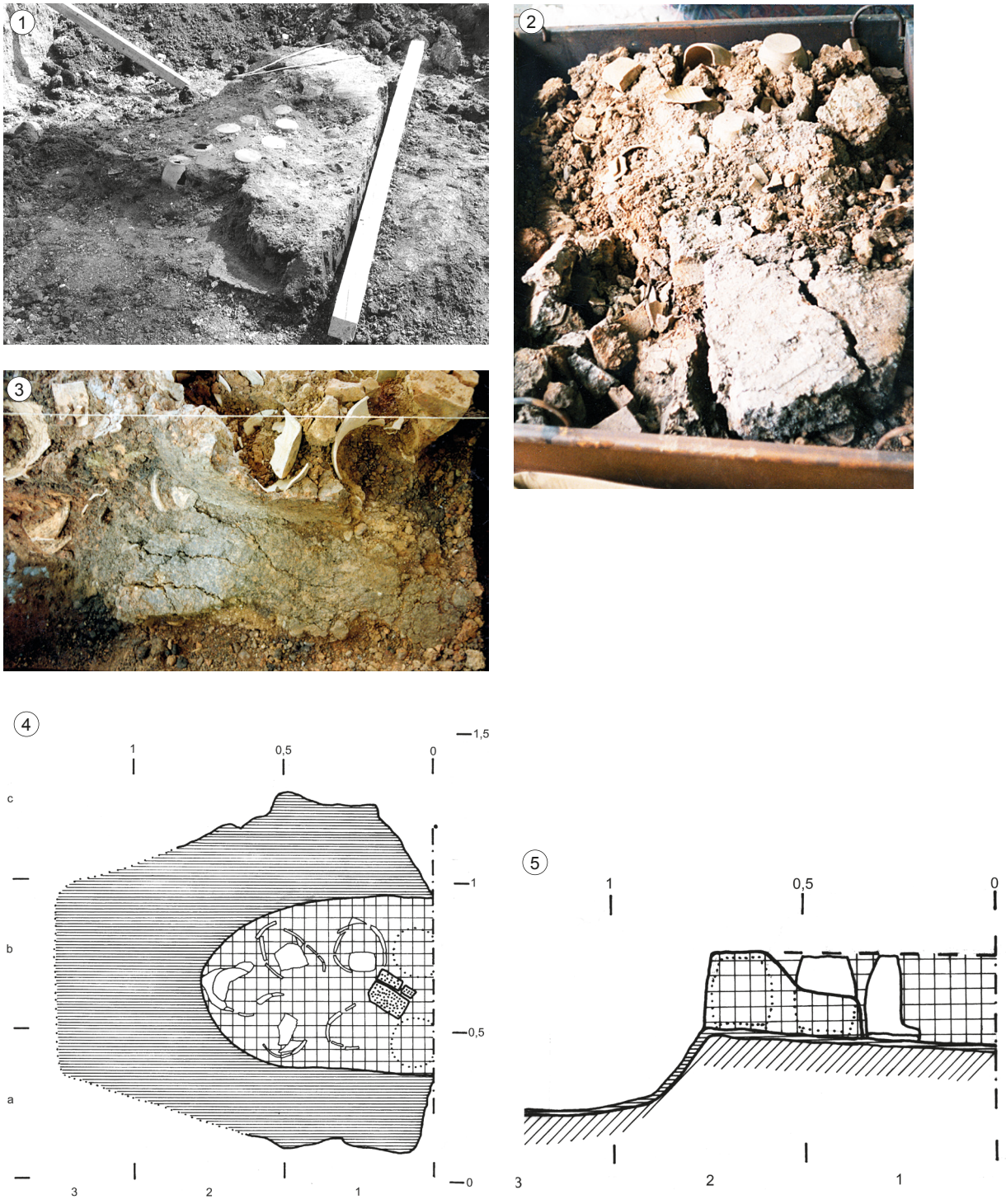


Fig. 124. St. Pölten – Roßmarkt 12. 1 – pottery kiln excavated in 1991 in situ; 2 – pottery kiln excavated in 1991 after taken out of the ground in a block complete with the surrounding earth and its content to be excavated later indoors; 3 – pottery kiln from 1991, view from above on the central spoon-shaped firing floor; 4 – plan of the rest of the kiln from 1991; 5 – pottery kiln from 1991. Section through the central spoon-shaped firing floor; 1 – photo by C. Riegler (Österreichisches Archäologisches Institut), 2, 3 – photo by G. Scharrer-Liška; 4–5 after Scharrer-Liška, Scherrer 2010, 89, Abb. 76–77. Graphics by G. Scharrer-Liška, M. Filip.

structure, most of which were positioned with their openings facing downwards. The ceramics from the kiln backfill and working pits can mostly be dated to the 14th century. Two more kilns were discovered in the excavation area, but were not examined in detail (Boulasikis, Zeger 2022, 223).

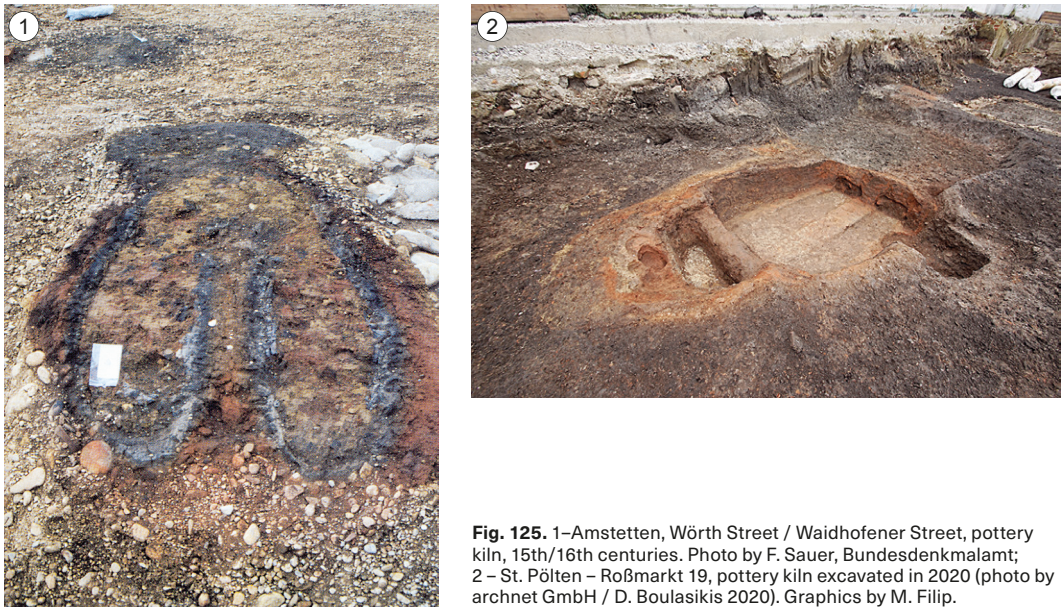


Fig. 125. 1–Amstetten, Wörth Street / Waidhofener Street, pottery kiln, 15th/16th centuries. Photo by F. Sauer, Bundesdenkmalamt; 2 – St. Pölten – Roßmarkt 19, pottery kiln excavated in 2020 (photo by archnet GmbH / D. Boulasikis 2020). Graphics by M. Filip.

In 2021, renovation work at Roßmarkt 12 (parcel No. 176) required archaeological investigations, which uncovered, among other features, the remains of a pottery kiln (Fig. 123: 3). The kiln, measuring approximately 3 × 1.4 m, had a central spoon-shaped firing floor. Its structure consisted partly of ceramic vessels (mainly pots), with the spaces between them filled with clay. The firing opening with a working pit in front of the kiln were located on the eastern side of the kiln. The ceramic vessels used in the kiln construction and the finds from the kiln backfill date to the Late Middle Ages (Boulasikis, Kögler, Rieß 2024, 278).

5.3.3 Workshop waste pits in St. Pölten

Clay pits and workshop waste pits were also discovered in the vicinity of the pottery kiln found at St. Pölten – Roßmarkt 12 (Riegler 1992). Due to the unfavourable circumstances during construction work, it was not possible to document the features in detail. Only a sample of the relatively homogeneous ceramic backfill material could be collected. However, based on the surrounding structures and the backfill material, which consisted of heavily fragmented misfired pottery (Scharrer-Liška, Scherrer 2010, 90–91), the interpretation of the features as workshop waste pits can be confirmed.

Further workshop pits containing misfired uniform vessel batches were documented in the vicinity of the kiln finds at Roßmarkt in 2021 (Boulasikis, Zeger 2022, 223). The workshop waste pits excavated in the potters' district of Tulln are also worth mentioning (Kreitner et al. 2006; Muschal 2013).

Due to a lack of financial and human resources, neither the workshop waste pits in St. Pölten nor those in Tulln have been examined in detail to date. In general, there is a lack of systematic analysis of such deposits. A. Kaltenberger has published a selection of samples of potters' waste from Upper Austria (Kaltenberger 2008; 2009a, 420–422, 434–446). In Germany, several notable examples of workshop waste deposits have been studied, including the sherd piles from Aulgasse in Siegburg in the Rhineland (Beckmann 1975; Weiser 2003). The workshop waste pits in Regensburg-Prebrunn (Endres, Loers 1981), Straubing (Endres 1984; 1985; 1986; 1990; 1991; 1994), and Einbeck (Heege 1993; 1998, 11) should be mentioned as well. In most cases, the detailed analysis and publication of such archaeological material has not been conducted due to the usually unmanageable amount of material found and the personnel required for the analysis.

5.3.4 Pottery kilns in St. Pölten in a regional and supraregional context

Additional to old finds from the first decades of the 20th century, numerous new discoveries of pottery kilns have been documented in Lower Austria, particularly in the first two decades of the 21st century. Kilns discovered up until the early 1990s – including findings from Hainburg, Neunkirchen, Amstetten, Vienna, Horn, Mautern, and St. Pölten – have been published with varying levels of detail (Scharrer-Liška, Scherrer 2010 with other references). Since the early 2000s, extensive excavations have been carried out, primarily in St. Pölten (see above),

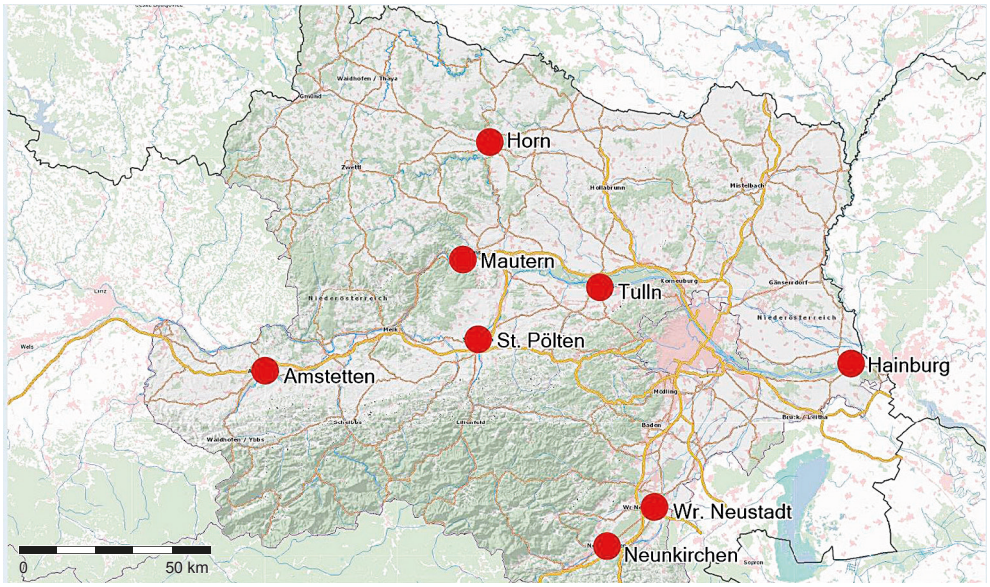


Fig. 126. Lower Austria. Map of sites with late medieval pottery kilns. Basic data from NÖGIS. Graphics by G. Scharrer-Liška.

Tulln (Kreitner et al. 2006; Sabeditsch, Scholz 2013), but also in Amstetten (Sauer 2001) and Wiener Neustadt (Geigenberger 2021, 199), numerous new findings of medieval pottery kilns have been discovered (Fig. 126; see below Tab. 28). Almost all these kilns belong to of the diagonal flame draft type.

The classification of pottery kilns often proves challenging, largely due to the varying states of preservation. As a result, several systems have been developed in archaeological research to address this issue. These classifications were first compiled in a comprehensive overview published in 2007 by A. Heege. He classified kiln types according to the type of kiln operation (continuous or discontinuous firing), the type of flame direction (vertical or horizontal), the number of chambers or kiln sections, and the spatial arrangement of the fireplace area and firing chamber (Heege 2007, 15–18). In their overview of pottery kilns in Bohemia, L. Čapek and M. Preusz also argued in favour of using the type of flame direction as a differentiation criterion, since classification according to the number of chambers is often complicated by the structures' state of preservation (Čapek, Preusz 2019). For many decades, pottery kilns were typically classified based on the arrangement of the fireplace area and firing chamber. A distinction is made between updraught kilns respectively kilns with vertical draft, in which the fireplace area and firing chamber are arranged one above the other and separated by a suspended floor perforated with circular vents, and kilns with horizontal draught, in which the fireplace area and firing chamber are arranged one behind the other. The latter group includes the vast majority of late medieval kiln finds in Lower Austria. This is indicated not at least by the (preserved) lengths of the kilns in St. Pölten, many of which exceed 3 m.

5.3.5 Finds of pottery kilns in Lower Austria

All medieval pottery kilns in Lower Austria (Tab. 28) that have been archaeologically verified up to 1990 date to the Late Middle Ages and can basically be attributed to the urban guild craft. In addition to the kiln in St. Pölten – Roßmarkt 11, these include features from Horn, Mautern, Neunkirchen, and Hainburg (Fig. 126). Due to a lack of archaeological features and documentation, a kiln in Vienna, Griechen Street 4–6 (Huber 1992), will not be discussed in detail here. All these pottery kilns share the feature that they were discovered and subsequently destroyed during construction work. Due to the circumstances of their discovery, they were poorly documented. However, a few conclusions can be drawn from the limited details of the features that have been preserved in notes and/or photographs.

In 1955, during construction work in **Horn**, Thurnhof Street 32 (formerly *Hafnergasse*), a medieval pottery workshop was discovered. The kilns themselves had been so badly damaged by the construction work that it was impossible to determine their design. Based on the ceramic finds, the site was dated to the 14th and 15th century (Cech 1985).

In 1963, a pottery kiln in **Mautern** was also destroyed by excavation work. According to the excavation report, some pots were standing upside down on their rims (Kainz 1974), which is reminiscent of

No.	Town	Kiln type	Explanatory note
1	Amstetten – Wörth Street12	Diag. fl. draft kiln	Central spoon-shaped firing floor constructed of pots?
2	Amstetten – Wörth Street/ Waidhofener Street(Fig. 125: 1)	Diag. fl. draft kiln	Central spoon-shaped firing floor
3	Amstetten – Wörth Street /Waidhofener Street	Diag. fl. draft kiln	Central spoon-shaped firing floor
4	Amstetten – Wörth Street/Waidhofener Street	Diag. fl. draft kiln	Central spoon-shaped firing floor
5	Hainburg	Diag. fl. draft kiln?	Central spoon-shaped firing floor constructed of pots?
6	Horn – Thurnhof Street 32	?	?
7	Mautern	Diag. fl. draft kiln?	Central spoon-shaped firing floor constructed of pots upside down
8	Neunkirchen, Schießstätt Street 33	Unknown	Unknown
9	St. Pölten – Heß Street 5/Hafner Street	Diag. fl. draft kiln	Central spoon-shaped firing floor
10	St. Pölten – Roßmarkt 11	Unknown	–
11	St. Pölten – Roßmarkt 12	Diag. fl. draft kiln	Central spoon-shaped firing floor constructed of pots upside down
12	St. Pölten – Roßmarkt 12 (Fig. 124)	Diag. fl. draft kiln	Central spoon-shaped firing floor constructed of pots upside down
13	St. Pölten – Roßmarkt 19 (Fig. 125: 2)	Diag. fl. draft kiln	Central spoon-shaped firing floor
14	St. Pölten – Roßmarkt 19	Diag. fl. draft kiln	Central spoon-shaped firing floor
15	St. Pölten – Roßmarkt 19	Diag. fl. draft kiln	Not examined in detail
16	St. Pölten – Roßmarkt 19	Diag. fl. draft kiln	Not examined in detail
17	Tulln – Hauptplatz, Rosenarcade (Fig. 127: 5)	Diag. fl. draft kiln	Central spoon-shaped firing floor constructed of pots upside down
18	Tulln – Schießstatt Street	Diag. fl. draft kiln	Kiln walls and central spoon-shaped firing floor consisting of pebbles, ceramic fragments and clay
19	Tulln – Schießstatt Street	Diag. fl. draft kiln	Kiln walls and central spoon-shaped firing floor consisting of pebbles, ceramic fragments and clay
20	Tulln – Schießstatt Street	Diag. fl. draft kiln	Kiln walls and central spoon-shaped firing floor consisting of pebbles, ceramic fragments and clay
21	Tulln – Schießstatt Street	Diag. fl. draft kiln	Central spoon-shaped firing floor constructed of clay
22	Tulln – Schießstatt Street	Diag. fl. draft kiln	Central spoon-shaped firing floor constructed of clay
23	Tulln – Schießstatt Street	Diag. fl. draft kiln	Central spoon-shaped firing floor constructed of clay
24	Tulln – Schießstatt Street	Diag. fl. draft kiln	Central spoon-shaped firing floor constructed of clay
25	Tulln – Schießstatt Street, feature 10 (Fig. 127: 2, 3)	Diag. fl. draft kiln	Central spoon-shaped firing floor constructed of pots upside down
26	Tulln – Schießstatt Street, feature 450 (Fig. 127: 1)	Diag. fl. draft kiln	Kiln walls and central spoon-shaped firing floor consisting of pebbles, ceramic fragments, and clay
27	Tulln – Brüder Street, Stadtoase	Diag. fl. draft kiln	Central spoon-shaped firing floor
28	Tulln – Brüder Street, Stadtoase (Fig. 127: 4)	Diag. fl. draft kiln	Central spoon-shaped firing floor, made of bricks, stones, ceramic fragments, and clay; kiln wall consisted at least partly of a row of ceramic jugs standing on their rim
29	Wiener Neustadt	Diag. fl. draft kiln	?
30	Wiener Neustadt	Updraft kiln	?

Tab. 28. Archaeological evidence of pottery kilns in Lower Austria. Diag. fl. draft kiln – diagonal flame draft kiln.

some kilns in St. Pölten. In this case, too, it can be assumed that the pottery kiln belong to of the diagonal flame draft type with a central spoon-shaped firing floor.

During construction work in 1978 also in **Neunkirchen**, Schießstätt Street 33, the remains of a late medieval pottery workshop, including a kiln, were discovered. No further information is available about the kiln itself. The misfired pieces of ceramic found were dated to the 15th century according to preliminary reports (Haider 1979; Haider-Berky 1982). The site is in a district south of the centre outside the settlement's wall (Fuchsberger, Schicht 2022, 324–329) and is separated from it by a tributary of the River Schwarza.

As early as 1924, at least one, but probably several, pottery kilns were discovered during construction work in **Hainburg**. Originally described as updraft kilns with suspended floor perforated with circular vents, the published illustrations (Beninger 1930, Tab. XXI, XXII, XXIV) show pots standing upside down on their rims, which were not recognised as part of the kiln. However, this is likely to be another kiln with a with a central spoon-shaped firing floor constructed of pots standing on their rims. The pots displayed suggest a dating to the 14th and early 15th centuries likely (Scharrer 2001, 42).

In 1991, during construction work in **Amstetten**, Wörth Street 12, on the southwestern edge of the medieval market settlement, a pottery kiln was

(Preserved) length / width	Dating	Reference
Unknown	2nd half of the 15th century / 1st half of the 16th century	Scharrer 1994
?	2nd half of the 15th century / 1st half of the 16th century	Sauer 2001
?	2nd half of the 15th century / 1st half of the 16th century	Sauer 2001
?	2nd half of the 15th century / 1st half of the 16th century	Sauer 2001
?	14th/15th century	Beninger 1930
Unknown	14th/15th century	Cech 1985
Unknown	Late Middle Ages	Kainz 1961–65
Unknown	15th century	Haider 1978; Haider-Berky 1982
	Late Middle Ages	Thaler 2020; Thaler 2021
Unknown	Around 1300	Krenn 1992
3.5 m / 1.20 m	2nd half of the 14th century	Scharrer-Liška, Scherrer 2010
3 m / 1.40 m	Late Middle Ages	Boulasikis, Kögler, Rieß 2024
3 m / 2 m	14th century	Boulasikis, Zeger 2022
?	14th century	Boulasikis, Zeger 2022
?	Late Middle Ages	Boulasikis, Zeger 2022
?	Late Middle Ages	Boulasikis, Zeger 2022
Approx. 2.4 m / 1.70 m	15th century	Scholz et al. 2007, 14
?	End of 14th/beginning of 15th centuries	Breibert et al. 2007
?	End of 14th/beginning of 15th centuries	Breibert et al. 2007
?	End of 14th/beginning of 15th centuries	Breibert et al. 2007
?	Late Middle Ages	Sabeditsch, Scholz 2013
?	Late Middle Ages	Sabeditsch, Scholz 2013
?	Late Middle Ages	Sabeditsch, Scholz 2013
?	Late Middle Ages	Sabeditsch, Scholz 2013
?	End of 14th/beginning of 15th centuries	Breibert et al. 2007
Approx. 3.50 m	End of 14th/beginning of 15th centuries	Breibert et al. 2007
?	Late Middle Ages	Muschal 2013
Approx. 3 m or more	15th century	Muschal 2013
?	2nd half of the 13th century	Geigenberger 2021
?	2nd half of the 13th century	Geigenberger 2021

found and destroyed. Thanks to the efforts of a local historian, the ceramics were recovered and a few notes on the features were made. Accordingly, two pots standing close together at their mouths suggest the existence of a central spoon-shaped firing floor constructed of pots, as in the case of the kilns in St. Pölten, Mautern, and Hainburg. Furthermore, ceramic pipes with thick layers of red-fired clay were found, which were probably also structural elements of the kiln. The pipes were located, at least in part, around the kiln that appeared to form the conjunction between the fireplace area and the firing chamber. It cannot be excluded that the pipes were part of the vaulted structure of the kiln. The few indications point to a diagonal flame draft type kiln. Based on the quality of the sherds, the production techniques, stamp marks, and formal analogies, the pottery can be dated to the end of the 15th or the first half of the 16th centuries (Scharrer 1994; Scharrer 2001, 41).

In 2000, archaeological investigations were carried out in Amstetten in the Wörth Street / Waidhofener Street area during construction work. The site was in the immediate vicinity of the pottery kiln that had been destroyed in 1991. There as well, three kilns with central spoon-shaped firing floors were documented (Fig. 125: 1). The ceramics recovered from the three kilns also allow the features to be dated to the second half of the 15th century and first half of the 16th century (Sauer 2001).



Fig. 127. Tulln. 1 – Schießstatt Street, kiln with central spoon-shaped firing floor (photo by Verein ASINOE); 2, 3 – Schießstatt Street, central spoon-shaped firing floor constructed of ceramic pots (photo by Bundesdenkmalamt, T. Kreitner); 4 – Stadtoase, Brüder Street 1–3; central spoon-shaped firing floor constructed of ceramic fragments, pebbles and clay of a late medieval pottery kiln (photo by B. Muschal / Verein ASINOE); 5 – EKZ Rosenarcade, Hauptplatz 12–14 (Main Square), central spoon-shaped firing floor constructed of ceramic pots and fragments, pebbles and clay of a late medieval pottery kiln; items to be fired in the fire chamber (photo by Bundesdenkmalamt /U. Scholz). Graphics by M. Filip.

Medieval pottery kilns are now as numerous in **Tulln** as they are in St. Pölten. In 2005, five pottery kilns were excavated and documented outside the city, in the western suburbs, in Schießstatt Street. These discoveries prove that pottery was produced west of the city, near the Danube. The kilns belong to of the diagonal flame draft type with a central spoon-shaped firing floor and oriented south–north. The kiln walls consisted of ceramic fragments, pebbles, and clay. In four cases, the central spoon-shaped firing floors consisted of pebbles, ceramic fragments (some from large graphite-tempered, oxidised storage vessels), and clay, similar in composition to the kiln walls (Fig. 127: 1–3). The kiln feature 10 had

a central spoon-shaped firing floor constructed from two parallel rows of pots standing upside down on their mouths and were neatly coated with clay on the outside. The ceramic finds in the kilns and their surroundings can be dated to the end of the 14th and beginning of the 15th centuries. Several workshop waste pits were also found in the vicinity of the kilns. Further archaeological excavations on neighbouring areas between 2006 and 2008 uncovered four more kilns with central spoon-shaped firing floor constructed of clay (Breibert et al. 2007, 613–616; Scholz 2013, 203; Scholz et al. 2007, 10; Sabeditsch, Scholz 2013, 29–30).

A pottery kiln dating back to the late 15th century was documented during archaeological excavations in 2006 and 2007 in the rear parts of the plots of the recent houses No. 12–14, in the southwest part of the Hauptplatz (Main Square) of Tulln (today the shopping center Rosenarcade). In contrast to the kilns in Schießstatt Street, this one was located within the city walls. The kiln had probably collapsed during a firing process; the kiln batch was still in the firing chamber (Fig. 127: 5). In this case, it was also a kiln with a central spoon-shaped firing floor constructed of pots standing upside down (Scholz 2013, 203; Scholz et al. 2007, 14).

Two further pottery kiln finds (kilns 4 and 9) were documented in 2012 in Tulln, northwest of the Hauptplatz (Main Square), in the Brüder Street 1–3 (residential complex 'Stadtoase', parcel No. 550/1, 551, 552), also within the medieval city walls. Both kilns were similar in shape and construction, but differed in dimensions and details, belonging to the type of the diagonal flame draft kilns with a central spoon-shaped firing floor. Kiln 4 had an oval shape and a broad central spoon-shaped firing floor made of bricks, stones, ceramic fragments, and clay (Fig. 127: 4). The kiln wall, which consisted at least partly of a row of ceramic jugs standing on their rim, was still preserved in the southern part of the kiln. The kiln shows signs of having been built in more than one phase and was apparently modified and downsized during its lifetime. Based on the ceramic material used for construction, the kiln can be dated to the end of the Late Middle Ages (Muschal 2013, 237–238). The Tulln kiln finds from 2012 (Schmitsberger 2012), as well as those from 2006 and 2007, indicate that the pottery production originally located in the suburbs was relocated within the city walls during the 15th century.

Two pottery kilns in **Wiener Neustadt** (parcel No. 54/1, 757/1–2, 5419) date back to the second half of the 13th century. One was a diagonal flame draft kiln, while the other was an updraft kiln. The kilns were located on the southwestern periphery of the city, within the city walls (Gröninger 2018, 4; Geigenberger 2021, 199).

5.4 Product range of medieval ceramics

5.4.1 Repertoire of ceramic forms

The ceramic repertoire (terminology according to Gaisbauer 2022) of the consumer milieu of late medieval St. Pölten consists mainly of pots. Additionally, there are also typical large-format storage pots (Fig. 128) as well as handled cups, bowls/pans (flat pans with straight handle, tripod pans with straight handle), funnels, jugs, ewers with stirrup handles, lids (disc lids, flat lids, bell-shaped lids), beakers and goblets, kettles, money boxes, and lighting devices (lamps, tinder holders). Moreover, there are figural objects, some of uncertain functions and aquamaniles (Fig. 129–132). Different types of stove tiles such as vessel tiles with rectangular



Fig. 128. St. Pölten, Lederer Street. Storage pot made of graphite tempered oxidising fired earthenware, 14th/15th centuries. Photo by N. Gail, Österreichische Akademie der Wissenschaften – Österreichisches Archäologisches Institut (ÖAW-ÖAI).

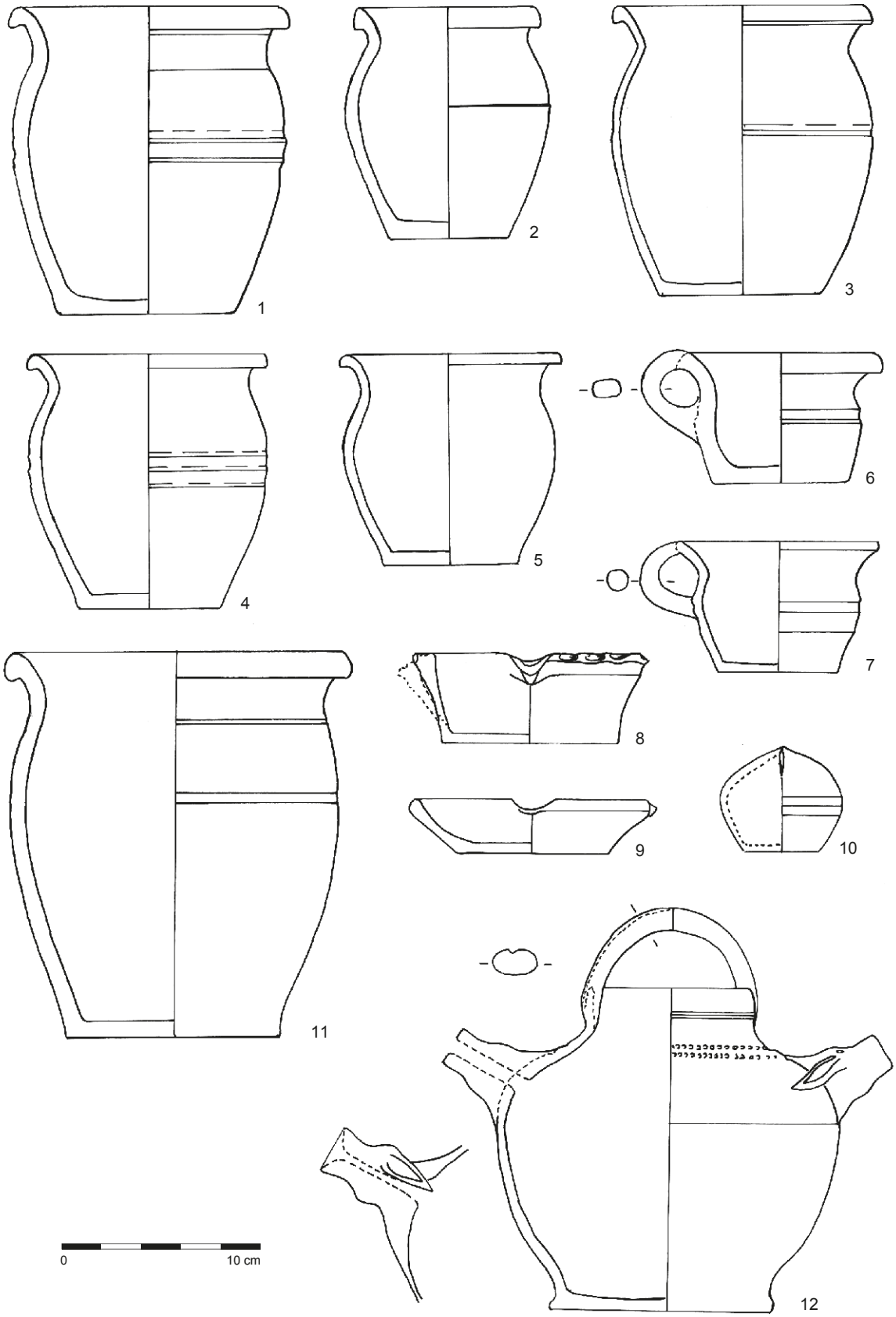


Fig. 129. St. Pölten – Roßmarkt 11, pottery kiln. Types of tableware ceramics: 1–5, 11 – pots; 1 – inv. No. 3; 2 – inv. No. 61; 3 – inv. No 65; 4 – inv. No. 75; 5 – inv. No. – 100; 6 – inv. No. 19, handled pot; 7 – inv. No. 119, handled pot; 8 – inv. No 50B, bowl or lamp; 9 – inv. No. 97, lamp; 10 – inv. No. 78, money box; 11 – inv. No. 150; 12 – inv. No. 99, ewer with stirrup handle. Based on the drawings after Krenn 1992, Taf. 1: A1, A3, A6; 2: A8, A10, A11; 3: B1, B3, B8; 4: B8, B9, B10; 5: C1, C3, D1, D2, E1; 6: F1, F3, F4, F6; 7: G5; 8: H1. Drawings by L. Dvořáková, graphics by G. Scharrer Liška, R. Procházka.

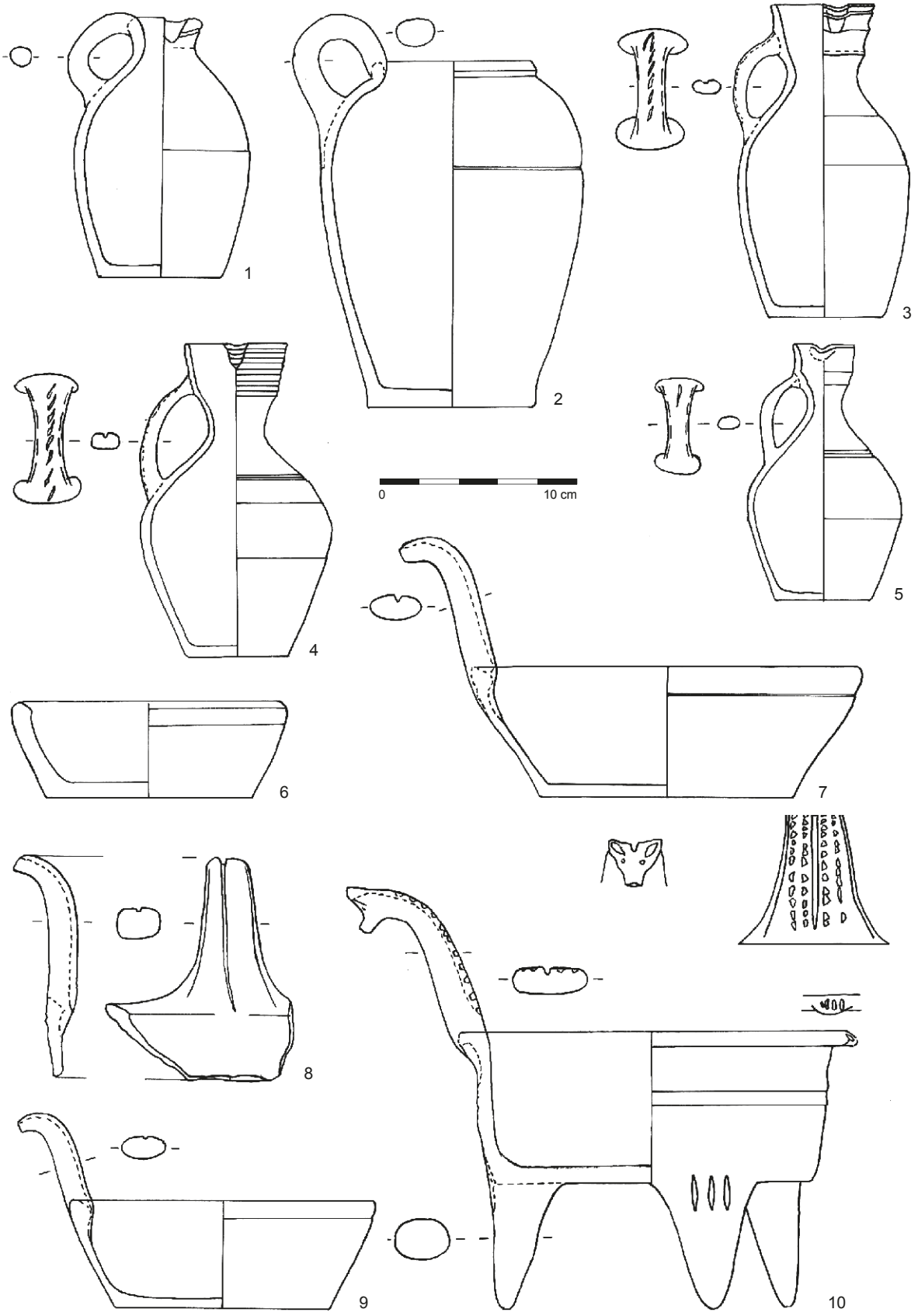


Fig. 130. St. Pölten – Roßmarkt 11, pottery kiln. Types of tableware ceramics: 1–5 – jugs; 1 – inv. No. 6; 2 – inv. No. 7; 3 – inv. No. 124; 4 – inv. No. 2; 5 – inv. No. 122; 6 – flat pan or bowl, inv. No. 87; 7 – inv. No. 83, flat pan; 8 – inv. No. 90, handle of a flat pan; 9 – inv. No. 69, flat pan; 10 – inv. No. 89, tripod pan. Based on the drawings after Krenn 1992, Taf. 3: B1, B3; 4: B8, B9, B10; 5: F1, F2, F3; 6: F4, F6; 7: G5; drawings by L. Dvořáková, graphics by G. Scharrer-Liška, R. Procházka.



Fig. 131. St. Pölten. Selection of ceramic finds. 1–6, 8 – Roßmarkt 11; 1 – stirrup handled ewer with two zoomorphic spouts in the form of hare's heads; 2 – jug with pulled spout, narrow neck and bulbous vessel body; 3 – flat pan with a straight handle and inside thickened rim; 4 – tripod pan with a straight handle with zoomorphic end; 5 – lamp; 6 – flat saucer-shaped lid with a spool-shaped knob; 8 – figural object in the form of a hybrid of fish and bird; 7 – Grenz Street; head fragment of an aquamanile in the form of an equestrian; 9 – Dome Square; figural illumination device in form of a witch. Stadtmuseum St. Pölten. Photo by N. Gail / ÖAW-ÖAI, graphics by M. Filip.

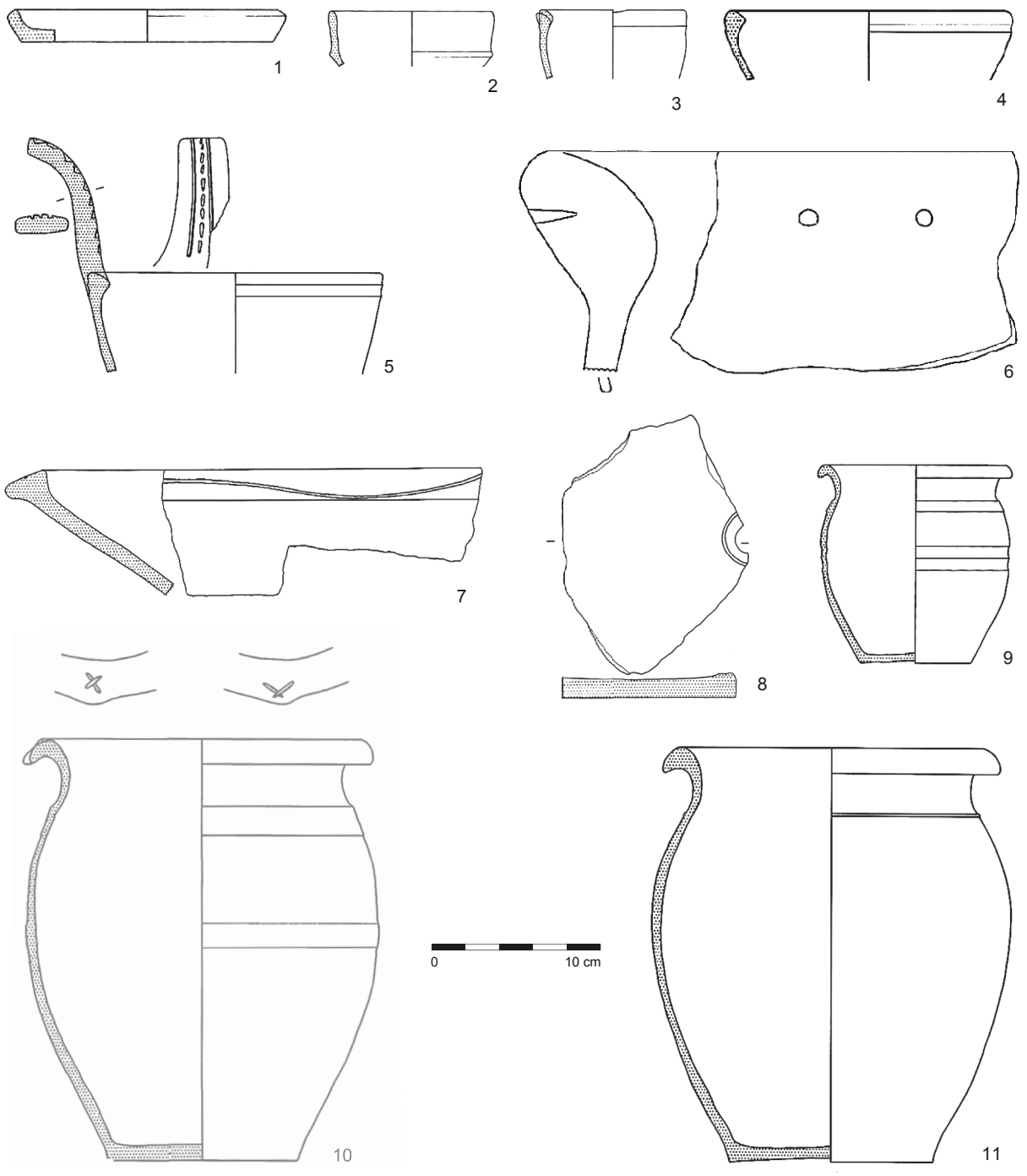


Fig. 132. St. Pölten – Roßmarkt 12. Pottery from the kiln, inv. No.: 1 – flat lid, T36/A2; 2 – rim of a jug, T1/A32; 3 – rim of a jug, T1/A45; 4 – bowl, T83/A7; 5 – flat pan, T17/12; 6 – rim of a storage vessel, T1/A2; 7 – rim of a funnel, T64/A1; 8 – fragment of a sieve bowl, T60/A14; 9–11 – pots, T28/A2, T2/A2, T28/A2. After Scharrer–Liška, Scherrer 2010, Taf. 53, 56, 58, 75–78; graphics by M. Filip.

opening, beaker tiles, and niche tiles also exist. This ceramic repertoire corresponds partly to that of Brno (Procházka 1995, 113–122).

Characteristics of 13th century **pots** include their bulbous shape and a (slightly undercut) rim in form of a collar or even brim – similar to those in Brno, Dominikánská or Česká streets (Procházka, Peška 2007, obr. 25–28; here Fig. 129: 1–5, 7). Decoration is relatively rare, though horizontal grooves are common. Sometimes roulette stamped decoration or Roman numbers' decoration can be found (Scharrer-Liška, Scherrer 2010, 26). In this deposit, the slightly undercut rim in form of a collar as well as in form of a brim are represented. These pots are

decorated with horizontal grooves (Tab. 28, No. 10; Krenn 1992, 209–210; Fig. 129: 1–4, 11).

As the Late Middle Ages progressed, the pots' shapes became more slender. In the 14th century pots have ellipsoid or egg-shaped vessel bodies, the shoulder can have an edge, the neck is high, the rim can still have the form of a slightly undercut collar but mostly that of a slightly then more undercut brim (Fig. 129: 11). The vessel's shoulder and body can be decorated with strips and horizontal grooves, which both are decorations that are promoted using a fast-rotating potter's wheel. Examples of pots of the second half of the 14th century in St. Pölten include 21 completely preserved which served either as structural elements (sample 10) or as part of the pots to be fired (Fig. 132: 9–11), found in the kiln at Roßmarkt 12 (Tab. 28, No. 11; Scharrer-Liška, Scherrer 2010, 104). They as well as the samples from the waste pits from Roßmarkt 12 (1991) belong to fabric A according to K. Slavíček's results (see Subchapter 5.5.2) and are made of high-quality clay rich of kaolin. It should be emphasised that the dating was based on parallels and not on absolutely dated strata.

In the late 15th century, the vessels finally became barrel-shaped, with a mostly stepped shoulder and a shorter neck. The rims became more bulbous, and the centre of the rim, which had initially been in the middle, moved to the inside of the mouth toward the end of the century. In many cases, the pots are marked with incised marks and/or, especially from the 15th century onwards, with stamp marks.

Similar features to pots in terms of the rim shape and the decorations on the shoulder have stocky **handled cups** (Krenn 1992, 222–223; Fig. 129: 6, 7).

Large **storage pots** have appeared as a special type of vessel in St. Pölten and other places in Lower Austria, as well as in Moravia, since the 11th century. They are made of thick-walled, graphite-tempered ceramic and have rectangular profiled or club-shaped (profiled) rims. The former rim shape is typical for Moravian vessels and occurs only very rarely in St. Pölten. On the other hand, storage pots made of dark grey fired graphite-tempered ceramics with club-shaped profiled rims are more common in St. Pölten. This form represents the autochthonous ceramic tradition of the Danube region. The rounded, club-shaped rims of the late High Middle Ages in particular are associated with graphite-tempered, oxidatively fired vessels and were used until well into the Late Middle Ages (Scharrer-Liška 2003). Fragments of this type have also been found in the pottery kiln from Roßmarkt 12 (Fig. 132: 6). Typical of the club-shaped rims of the Late Middle Ages are punctures at regular intervals, which were decorative in nature but were probably added primarily for technical reasons related to firing. This rim form is rarely found in Moravia. Due to their size, storage pots were difficult to transport. It can be assumed that, due to their use in storage, they were also deposited in one place permanently (cf. Sedláčková 2021a, 22). An impressive, almost completely preserved example of this type of vessel was documented in St. Pölten, Lederer Street (Scharrer-Liška, Scherrer 2010, 27–28; Fig. 128).

Like Brno (Procházka 1995, 113) **beakers** are rarely found among the ceramic finds excavated in St. Pölten. These include footed **goblets** or spouted goblets. (Scharrer-Liška, Scherrer 2010, 28).

High medieval **double-handled jugs** and, above all, their functional successors, **ewers with a stirrup handle**, are well represented in St. Pölten. This type of spouted vessel has been known since the 12th century. Characteristic features include a bulbous vessel shape, a handle extending over the rim, and usually two spouts on the shoulder. Especially in St. Pölten, but also in Vienna, spouts in various zoomorphic shapes are represented, most of which can be dated to the late 13th and early 14th centuries (Huber 2011). But we know these types, mostly made of glazed earthenware, also from Brno (Sedláčková 2020, 93–95). The pottery kiln complex discovered in in St. Pölten – Roßmarkt 11 contains a completely preserved specimen with spouts in the shape of hare heads (Fig. 129: 12; 131: 1), as well as the spout of another vessel.

Jugs, which can be regarded as the functional successors to double-handled jugs and ewers with a stirrup handle, appear in many different forms in St. Pölten, as demonstrated by the finds from Roßmarkt 11. Seven complete vessels and five fragmentary ones have been preserved here. Early jug shapes are characterised by a bulbous body, a sharply indented neck, and a funnel-shaped rim with a simple rounded edge (Fig. 130: 3–5). They can be found with or without a spout. The handle is usually attached at an obtuse angle to the spout, which makes it easier to handle when pouring. During the 14th and 15th centuries, the profile of the funnel-shaped rims became more pronounced, the neck and mouth widened, and the body of the vessel more slender or ellipsoidal. As shown by the few pieces classified as jugs from the pottery kiln find from Roßmarkt 12, the rims or rim edges are now intensified on the

inside, like bowls and pans. Additionally, jug forms with either a very short neck or no neck at all and with rim-attached handles are also found.

Bowls and **flat pans** appeared in Lower Austria from the 11th century onwards. Pans from the High Middle Ages usually had a socket handle. From the 13th century onwards, flat pans with reinforced rims and straight handles are documented in St. Pölten (Fig. 130: 7–9; 132: 5). Flat pans with straight handles may also have feet and be shaped as a tripod pan, maybe with zoomorphic end of the handle (Fig. 130: 10). There are also examples of these from Roßmarkt 11. Objects formally comparable can be found in Brno, Kopečná Street; in this case, the tripod pan from the second half of the 14th and first half of the 15th centuries is also made of oxidised fired earthenware, but is glazed olive green on the inside (Sedláčková 2021b, 112).

Sieve bowls were found in the pottery kiln at Roßmarkt 12. They have a large rim diameter, a low conical body, and a base with multiple holes (Fig. 132: 8). Some of the rims feature a wavy decorative pattern on the outside and inside.

Funnels have a shape like that of sieve bowls. They usually have a large rim diameter and a low, conical body, but lack a base. The rim is thickened on both sides; the lower rim is thickened on the outside and cut off horizontally (Fig. 132: 7). Due to their characteristic rim shape, often with a wavy line decoration on the rim's outside, as well as a characteristic wavy line decoration on the inside of the vessel body, even fragments can be identified with relative certainty (Scharrer-Liška, Scherrer 2010, 32–33). Similar vessels are known from Brno (Sedláčková 2021b, 107). These objects were probably used in milk preparation and/or cheese production.

Lamps have also been found in St. Pölten. They occurred in large numbers at the Roßmarkt site, which can be attributed to the manufacturing milieu, as evidenced by two completely preserved pieces from the pottery kiln of Roßmarkt 11 (Fig. 129: 8, 9; 131: 5), as well as numerous fragmentary remains from workshop waste pits. These lamps are characterised by reinforced or simply rounded rims and a conical, low body. Protrusions on the rim into which the wick was placed are characteristic. The lamps date mainly from the 13th and 14th centuries and are made of typical late medieval earthenware, tempered with sand, and fired in a reducing or oxidising atmosphere. This very functional pottery type is also common in the Czech lands (Čapek et al. 2021, 127: Ji 17, 141: ČB 13; Sedláčková 2020, 100–101).

Typologically medieval later **flat lids** with turned-up rims appear in St. Pölten from the late High Middle Ages onwards, including the Late Middle Ages. The initially solid turned-up rim becomes increasingly finer and lower in shape over time. Spool-shaped knobs are the predominant type of handle. Initially, the knob was not raised in the middle, but from the 14th century onwards, it began to rise, becoming more pronounced in the Late Middle Ages. Other forms of handles include central or rim-standing handles. Flat lids with turned-up rims are widespread from Bavaria eastwards to Hungary. In Lower Austria, flat lids with turned-up rims can be traced back to the 12th century. Some of these early ones are made of graphite-tempered ceramic. These include finds from St. Pölten – Rathausplatz (Scharrer-Liška, Scherrer 2010, 34). Most flat lids with turned-up rims from eastern Austria are made of sand-tempered earthenware fired in a reducing or oxidising atmosphere, as numerous examples have been found in St. Pölten – Rossmarkt (Fig. 131: 6; 132: 1). They were common until the 15th century, when they were eventually replaced by bell-shaped lids in the modern era.

Bell-shaped lids have a more or less profiled conical shape. Knobs represent the most common type of handhold, with handles being less frequent. Early forms of hollow lids are relatively steep and strongly curved and have a wide knob. Later, hollow lids become lower and lose their profiled shape. Bell-shaped lids appear from the 13th century onwards. Until the end of the Middle Ages and the beginning of the early modern period, bell-shaped lids were used alongside flat lids, but eventually replaced them. In St. Pölten, bell-shaped lids have been found at numerous sites and consist of typical late medieval sand-tempered earthenware fired in a reducing or oxidising atmosphere. (Scharrer-Liška, Scherrer 2010, 33).

In addition to tableware ceramics, **money boxes** have also been discovered at several sites in St. Pölten. They are generally made of sand-tempered, oxidatively fired earthenware (Fig. 129: 10). Money boxes are closed, approximately spherical to mushroom-shaped hollow forms with a slot for coin insertion located approximately at the top and centre. As functional forms whose morphology has hardly changed, they are of limited chronological significance (Scharrer-Liška, Scherrer 2010, 35). We know this functional type made of (glazed) earthenware also from Brno (Sedláčková 2020, 99).

Finally, the diverse group of **figurative ceramics**, whose function is not always clearly identifiable, deserves to be mentioned. This includes an object from the pottery kiln complex in St. Pölten – Roßmarkt 11 that appears to be a hybrid between a bird and a fish. (Fig. 131: 8). Furthermore, in Grenz Street the fragment of a presumed equestrian aquamanile (Fig. 131: 7) was found and because of its style is supposed from the 14th century. A lighting device is worth mentioning, possibly a pinewood holder, in the form of a female figure excavated at the Dome Square. Its physiognomy is reminiscent of devil or witch depictions (Risy 2011b) and because of its style and fabric quality it is most likely to be dated into the 15th century (Fig. 131: 9). All the objects mentioned are made of late medieval sand-tempered earthenware, fired in a reducing or oxidising atmosphere.

5.4.2 Ceramic paste, forming and firing vessel formation from a macroscopic perspective and previous microscopic research

The ceramics of the High Middle Ages in St. Pölten can generally be classified into graphite-tempered, mica-tempered, and sand-tempered earthenware, which could be oxidised, variably fired, and occasionally reduced fired. In the case of graphite-tempered ceramics, natural graphite clays were used, which also contain graphite in the matrix and date back to the early High Middle Ages. Additionally, there are sherd qualities that indicate the mixing of graphite- and non-graphite-containing clays. Non-graphite-containing ceramics vary considerably in terms of tempering and firing atmosphere. Overall, the sherd quality presents a heterogeneous picture. This indicates the individual exploitation of small local mineral deposits by the potter(s). At the beginning of the High Middle Ages, traces of production still occasionally indicate that vessels were constructed by hand. As time progressed, there is increasing evidence of vessels being formed using the coil technique (see Subchapter 5.5.2) and the use of a turning device (initially slow, later fast).

From around 1300 ceramic finds from St. Pölten began to reveal a more standardised pattern. Graphite-tempered, oxidised earthenware continued to be present in the form of large storage pots throughout the Late Middle Ages. The reduced-fired graphite-tempered ceramics, known as 'iron clay ware' (*eisentachen, Eisentonware*), which were mainly used for kitchenware, are also represented. However, characteristic of the late medieval sherd repertoire of St. Pölten is a quartz-tempered, reduction-fired earthenware with a light grey core and a medium to dark grey surface made of clay with only a very low iron component. If the same clay is fired in an oxidising atmosphere, the shards are beige to light brown-orange in colour (Scharrer-Liška 2009, 184; Scharrer-Liška, Scherrer 2010, 12–14, 24). With the exception of large storage pots, the vessels were almost exclusively shaped using a fast-rotating potter's wheel. Firing temperatures generally ranged between 800–900°C, as previously proposed (Krenn 1992, 205), a finding that has since been confirmed by more recent analyses. In some cases, however, significantly higher firing temperatures of up to 1000–1100°C were achieved, as evidenced by the mineral phases (see Subchapter 5.5.2).

It has been suggested on several previous occasions that the late medieval oxidised earthenware, especially from the find from Roßmarkt 11, may have been (in parts) semi-finished products intended for glaze firing, or even misfires (Krenn 1992, 239–240; Kaltenberger 2009b, 176). However, objects of this sherd quality can be found in St. Pölten not only in the manufacturing context, but also in the consumer milieu. That means that this sherd quality also represented finished products. An alternative explanation may be that so-called 'second-choice' goods also entered circulation through trade, as is supported by evidence from other find complexes. (Huber, Scharrer-Liška 2005, 39).

5.4.3 Pottery production from the kiln from Roßmarkt 11

The range of types found in this complex is extensive. Beside pots (eleven pieces) with collar-shaped or brim-shaped rims (Fig. 129: 1–5), handled cups (three pieces) with the same rim shapes (Fig. 129: 6, 7), jugs (twelve pieces, Fig. 130: 1–5), conical bowls (Fig. 130: 6), lamps (two pieces, Fig. 129: 8, 9, 131: 5), flat pans (seven pieces, Fig. 130: 7, 9; 131: 3), tripod pans (five pieces, Fig. 130: 10; 131: 4), ewers with stirrup handles (two pieces, Fig. 129: 12; 130: 1), a money box (Fig. 129: 10), and a figural object (Fig. 131: 8) were found. Due to their morphology, the objects can be dated around 1300.

The completely preserved pots have slightly undercut collar-shaped or brim-shaped rims. The pots have a bulbous or ovoid body with a low-lying point of maximum diameter. Height ranges from 11.2 to 18.6 cm (average 13.3 cm, median 12.8 cm),

	No. of pots	W	H	D	Z
Index range	11	0.38–0.46	0.85–1.18	0.35–0.71	1.62–1.72
Mean	11	0.41	1.06	0.54	1.61
Median	11	0.42	1.06	0.53	1.62

Tab. 29. St. Pölten – Roßmarkt 11. Pot index values.

rim diameter ranges from 9.6 to 16.9 cm (average 12.7 cm, median 12.4 cm), the bottom diameter ranges from 6.1 to 10.4 cm (average 7.8 cm, median 7.4 cm). The pots' stocky shape is evident in the ratio of height to rim diameter of approx. 1 : 1. They are decorated with horizontal grooves (Krenn 1992, 209–210; Fig. 129: 1–5, 11).

For pots, indices were monitored that more closely specified the shape of their bodies. These are the W value determining the position of the bulge, the H value determining the bulbosity, the D value defining the convexity of the body and V examining the relationship between the largest diameter of the vessel and the diameter of the bottom, showing the degree of thinning of the lower part of the vessel (for more details, see Procházka, Peška 2007, 269 and also the Chapter 3 in this book).

The average values of the W index and the closely corresponding median indicate low-lying bulges (maximum body diameter) bordering on the medium degree. The mean value of the H bulbosity index, identical to the median, falls within the 'high' degree. The degree of body convexity expressed by the D index, again with closely matching mean and median values, can be described as low. The degree of narrowing of the lower part, represented by the Z index with nearly identical mean and median values, corresponds to a medium degree, close to the boundary of the 'low' category (Tab. 29).

The jugs have a bulbous shape, a strongly indented neck, and a funnel-shaped rim with a simple rounded edge (Fig. 130: 3–5; 131: 2). Their height ranges between 13.3 and 32.4 cm (average 22.5 cm), rim diameter ranges from 3.9 to 10.8 cm (average 7.2 cm), and the bottom diameter ranges between 6.1 and 12.3 cm (average 9.5 cm). The handle can be aligned to the rim or positioned supra-rim and have a round profile. More common are sub-marginal handles with an oval profile and a diagonal notch decoration which are also known from Brno (Sedláčková 2020, Fig. 55: 1). Flat pans and tripod pans have reinforced rims and straight handles which may have a zoomorphic end (Fig. 130: 7–10; 131: 3, 4). The handles usually are typically decorated with vertical, rarely horizontal cuts or cut-in patterns as decoration. Their height (without handle and feet) ranges from 4.8 to 8.6 cm (average 6.2 cm), the rim diameter ranges from 14.2 to 20.1 cm (average 17.35 cm) and the bottom diameter between 10.6 and 15.6 cm (average 12.5 cm). Ewers with stirrup handles generally display the same bulbous body shape as contemporary pots, a simply rounded rim edge, a handle with an oval profile spanning the rim, and usually two spouts in zoomorphic shapes on the shoulder. The one complete preserved specimen has a height of 16.2 cm (20.2 cm including the handle), a rim diameter of 7.6 cm, a bottom diameter of 11.3 cm and a maximum diameter of 16 cm (Fig. 129: 12; 131: 1). The lamps with a low bowl-shaped body usually have a reinforced rim with characteristic protrusions into which the wick was placed (Fig. 129: 8, 9; 131: 5). A money box should be mentioned, which has a closed, approximately spherical to mushroom-shaped hollow body with a slot for coin insertion located approximately at the top centre (Fig. 129: 10). Finally, a unique figural object must be noted. It appears to be a hybrid between a bird and a fish (Fig. 131: 8).

Contemporary documentation of the kiln is non-existent. Therefore, we have not any information about the kiln type. Only a piece of the kiln wall made of fired clay and traces of mesh, gives a slight hint about the cupola's construction.

5.4.4 Pottery production from the kilns and workshop waste pits at Roßmarkt 12

The find at Roßmarkt 12 includes 22 completely preserved pots dating from the second half of the 14th century. The increasingly slender shape of the vessels (Scharrer-Liška, Scherrer 2010, 127–128) is evident in the ratio of height to rim diameter, which rises from approximately 1 : 1 to 1 : 1.7, whereby the vessel heights range between 11.5 and 31.5 cm (average 20.7 cm, median 22.1 cm), the rim diameter between 12.5 and 25 cm (average 17,9 cm, median 20 cm), the maximum diameter range between 11.5 and 25.5 cm (average 17.7 cm, median 20 cm) and the bottom diameter range from 7.4 to 15 cm (average 10.8 cm, median 12 cm).

Ceramics that served as construction elements of the kiln as well as were presumably items to be fired can be attributed to the diagonal flame draft kiln. These ceramics consist mostly of pots with brim-shaped rims (Fig. 132: 9–11), some of which bear scratched mark forming a 'V' or a 'X' (Fig. 132: 10). Marks like these we know, e.g. from Jihlava (Novotný 1982, 5, 15, tab. 10: 3). Compared with the assemblage from the kiln of Roßmarkt 11, there is an increase in vessel volume, and the rims are more undercut. The pots from Roßmarkt 12 are also sparsely decorated. Beside a stepped shoulder, horizontal grooves as well as horizontal flat wide strips running around the vessel can be observed.

The samples from this workshop are similar in terms of manufacturing technique and morphology to those from the Moravian kilns of the second half of the 14th century, e.g. in Staré Město near Uherské Hradiště (Procházka et al. 2024), even though the Moravian products seem to be more decorated at first glance. Beside unornamented vessels, examples with dense wide grooves can be found in Brno, as well as wavy line or roller stamped decoration occur. It seems, that pots with a stepped shoulder to be absent in Brno but occur in Jihlava (Procházka 1995, 113; Novotný 1982, tab. 9: 2, 10: 5). Pots from a well backfill in Brno-Komárov from the second half of the 14th and the first half of the 15th centuries are similar in shape to those from the St. Pölten kiln from Roßmarkt 12, although differences in the decoration are apparent (cf. Kochan, Sedláčková, Vachůt 2015, obr. 5).

The close values of the mean and median of W index show that the vessels from St. Pölten belong to the category of vessels with a low bulge; only 27% of the vessels belong to the category with a medium bulge. The values of the H index indicate a prevailing high degree of bulbosity, to which the mean and median belong. The D index, determining the degree of curvature of the upper part of the vessel, places all vessels in the category of weakly convex forms, with more than one third classified as very weakly convex. The close values of the average and median show a uniform distribution within the frame of the given scale. The Z index is mostly in the medium range, with only two vessels in the high range (Tab. 30).

When comparing the mean and median values of the morphometric indices, no substantial differences are observed between the two assemblages. The values of index W are particularly similar – near the upper limit of the low degree. The degree of globularity falls into the high category, with the values for the younger assemblage (1991) being slightly higher than those for the older one (1909). The degree of convexity (bulging) is low, and in the case of the assemblage from Roßmarkt 12, it is slightly lower than in the pots from the older kiln at Roßmarkt 11. The degree of narrowing of the lower part of the vessels corresponds to a medium level; in the younger assemblage from the Roßmarkt 12 kiln, it is slightly higher than in the vessels from the Roßmarkt 11 kiln, which may reflect a more general trend (for a broader comparison, see Chapter 7).

Fragments of storage pots made of graphite-tempered fabric (Scharrer-Liška, Scherrer 2010, 130) could most likely be part of the kiln, as archaeological evidence in Tulln proves (see Subchapter 5.3.5). But it cannot be excluded that those fragments were intrusions from settlement features or strata.

In addition to countless undiagnostic wall sherds, fragments of pots and jugs were recovered from the workshop waste pits documented in 1991. The pots' morphology from the waste pits corresponds to that of the kiln. The jugs' morphology is younger than those of the kiln from Roßmarkt 11, meaning the profile of the funnel-shaped rims is more pronounced, the neck and mouth are wider, and the body of the vessel slimmer or ovoid. The rims or rim edges are now intensified on the inside (Fig. 132: 2, 3). Fragments of flat or tripod pans (Fig. 132: 5), funnels (Fig. 132: 7), sieve bowls (Fig. 132: 8), flat lids (Fig. 132: 1) and a bowl with inwardly sloping top (Fig. 132: 4) were also present among the ceramic finds.

	No. of pots	W	H	D	Z
Index range	23	0.38–0.46	1.04–1.25	0.17–0.61	1.48–2.06
Mean	23	0.42	1.16	0.40	1.72
Median	23	0.43	1.15	0.41	1.72

Tab. 30. St. Pölten – Roßmarkt 12. Pot index values.

5.5. Raw material sources and ceramic production technology in St. Pölten

5.5.1. Historical records about clay mining sites

Archaeometric analyses (thin section analyses, see below) conducted in the late 1980s and early 1990s on medieval ceramic finds from St. Pölten and on reference samples indicate the use of local small-scale deposits during the High Middle Ages and early Late Middle Ages, which, however, cannot yet be identified in detail. This hypothesis is supported by the new thin-section analyses of samples from the pottery kiln from Roßmarkt 11, which indicate a new, additional petrographic ceramic group (fabric B; see below). In contrast, samples from the 14th and 15th centuries, including those from the pottery kiln found in Roßmarkt 12, suggest the exploitation of high-quality clay deposits located 22 km north of St. Pölten in the Oberfucha/Tiefenfucha area and/or 7–10 km northwest of the town and south of the Danube in the Karlstetten area of the Dunkelsteiner Forest (petrographic ceramic group 9; Sauer 2010, 19–20).

These regions were under the feudal rule of the nearby Göttweig Abbey. According to written documents, clay mining was already important for the abbey in the 15th century. In the 18th century, it experienced a considerable increase, according to the *Tacha* protocols ('Tacha' is an old term used in southern Germany and Austria as a synonym for 'clay') from 1734 and 1751, which are still preserved today. Apparently, clay delivery contracts had been concluded with pottery guilds without respecting the rights of the landlords. In response, the Abbey imposed fines on the one hand, and on the other hand concluded new contracts on the basis of which clay was not only delivered to potters' guilds in Lower Austria, but also transported as far as Slovakia and Hungary. According to the contracts, the clay was often transported on the River Danube (Koller 1952).

As part of the project 'Emergence of medieval pottery – the pottery kilns and their batch', samples of additional pots from St. Pölten – Roßmarkt 12 and 11, were examined. The samples were analysed by K. Slavíček using thin-section analysis under a polarizing microscope. The new results confirm and supplement those obtained in the late 1980s and early 1990s in the form of fabric A (see below). The samples from fabric A originate from the pottery kiln (samples 10–14) and from the workshop waste pits (samples 1–7) found in Roßmarkt 12. In contrast, samples from the kiln found in Roßmarkt 11 (samples 8–9), which were examined archaeometrically for the first time, are assigned to fabric B.

The clay deposits in the Oberfucha/Tiefenfucha and Karlstetten regions are significant in size and have been mentioned in the scientific literature (Kirnbauer 1969, 94). These deposits were undoubtedly already being used in Roman times (Sauer 2010, 20–23). The clay was probably extracted in open-cast mines and presumably seasonally as secondary employment by the farming population (Kirnbauer 1969, 92), as suggested by the aforementioned *Tacha* protocols. The transport from the mining site to the shipping dock, from where the clay was shipped down the Danube to customers, was also carried out by peasants (Koller 1952, 5).

In general, horse-drawn or ox-drawn carts were used to transport clay from the mining site

ID	Cat. No.	Type of context	Vessel type	Ceramic class
1	G (?)	Waste pit	Pot?	Sand-tempered, reduced fired earthen ware
2		Waste pit	Pot?	Sand-tempered, reduced fired earthen ware
3		Waste pit	Jug?	Sand-tempered, reduced fired earthen ware
4		Waste pit	Pot?	Sand-tempered, reduced fired earthen ware
5	G (?)	Waste pit	Pot?	Sand-tempered, oxidised fired earthen ware
6		Waste pit	Pot?	Sand-tempered, reduced fired earthen ware
7		Waste pit	Pot?	Sand-tempered, reduced fired earthen ware
8		Kiln Roßmarkt 11	Pot?	Sand-tempered, oxidised fired earthen ware
9		Kiln Roßmarkt 11	Pot?	Sand-tempered, oxidised fired earthen ware
10	T83	Kiln Roßmarkt 12	Pot	Sand-tempered, oxidised fired earthen ware
11	T39	Kiln Roßmarkt 12	Pot	Sand-tempered, oxidised fired earthen ware
12		Kiln Roßmarkt 12	Pot?	Sand-tempered, oxidised fired earthen ware
13	T81	Kiln Roßmarkt 12	Pot	Sand-tempered, reduced fired earthen ware
14	T33	Kiln Roßmarkt 12	Pot	Sand-tempered, oxidised fired earthen ware

Tab. 31. St. Pölten. Samples selected for analyses.

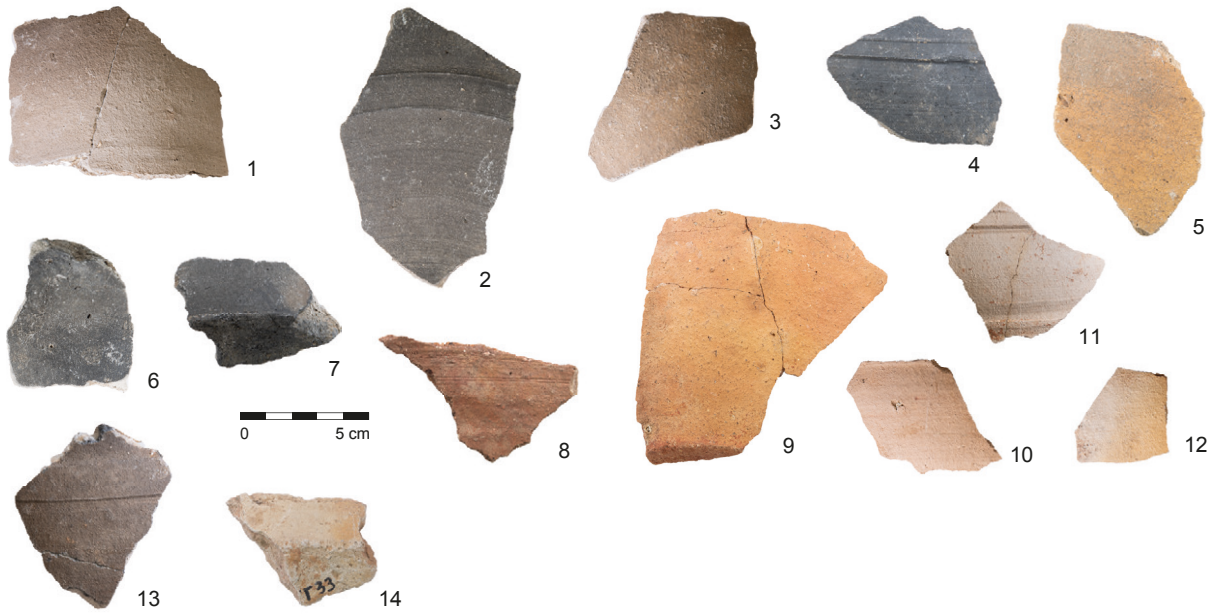


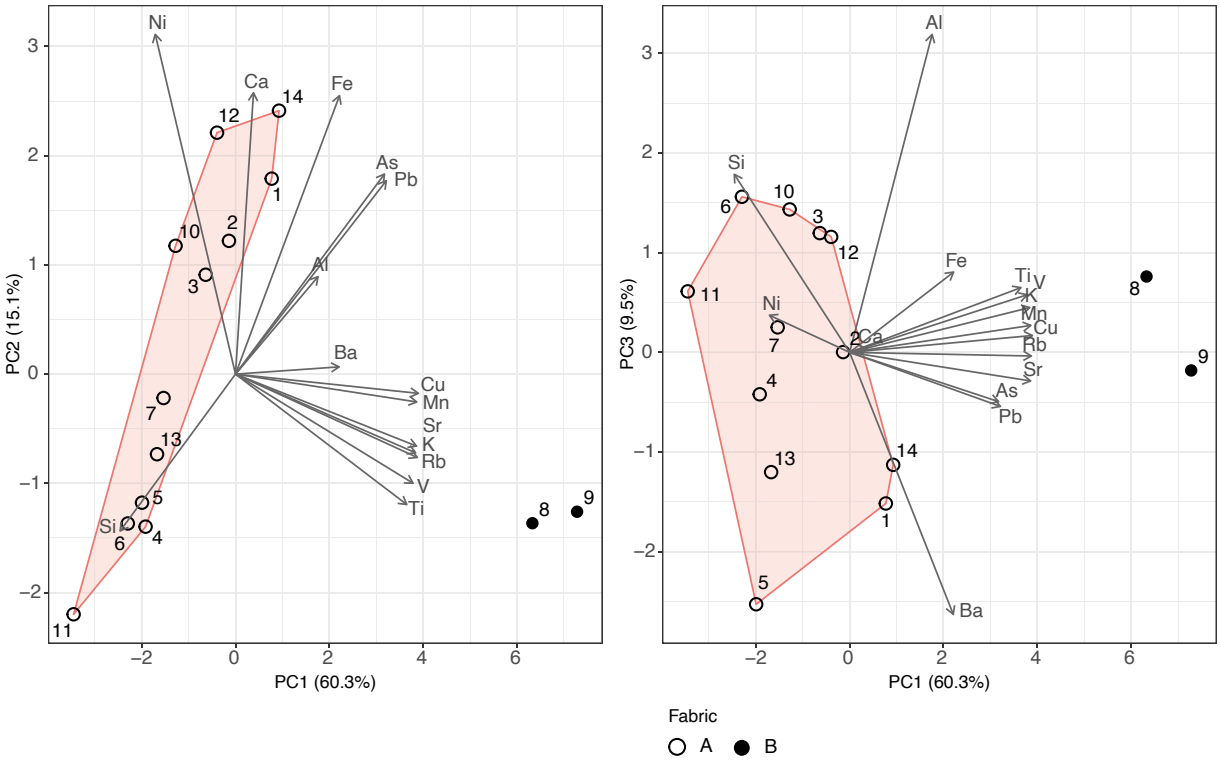
Fig. 133. St. Pölten. Analysed samples. Photo by M. Košťál.

Fabric	Sample Ids	Fabric description	Fabric features	Petrographic markers	Chemical markers	Possible sources
A	1–7, 10–14	Kaolinic clay with silt and sand, non tempered	Mostly unparallel microstructure, unimodal grain size distribution	Quartz, claystone (or clay pellets), kyanite, rutile, alkali feldspar, calcite, crystalline rocks, plagioclase, sandstone, muscovite, sillimanite, zircon	Representation of 'average' for the site	Source related to Karlstetten kaolin deposit
B	8, 9	Kaolinic clay with silt, sand tempered	Slightly parallel, bimodal grain size distribution, frequent Fe oxy-hydroxides	Quartz, alkali feldspar, serpentinite, muscovite, biotite, plagioclase, sillimanite, gneiss	Compared to fabric A: elevated Al, K, Ti, Fe, Cu, Rb, Sr, Ba	Clay: Peilach formation or redeposited Karlstetten kaolin; Temper: Melk sands

Tab. 32. St. Pölten. General description of fabrics.

	Fabric A				Fabric B			
	mean	sd	min	max	mean	sd	min	max
SiO_2	69.3	2.1	66.7	72.1	63.2	0.1	63.2	63.3
Al_2O_3	23.8	1.5	21.3	25.7	25.7	0.1	25.7	25.8
Fe_2O_3	3.5	0.6	2.4	4.3	3.9	0.1	3.8	4
K_2O	1.5	0.4	1.1	2.3	4.9	0.2	4.7	5
CaO	1.1	0.2	0.8	1.4	1	0	1	1
TiO_2	0.7	0.1	0.6	0.8	1.2	0	1.2	1.2
V	56	8	42	68	164	4	161	166
Mn	134	21	108	179	265	24	248	282
Ni	45	5	37	53	33	2	32	35
Cu	28	2	24	31	43	0	42	43
As	8	1	7	9	9	0	9	9
Rb	52	17	34	90	211	21	196	226
Sr	44	8	36	65	103	12	95	111
Ba	171	126	35	489	317	104	244	390
Pb	21	1	19	22	22	0	22	22

Tab. 33. St. Pölten. Summary of the chemical composition of fabrics (major oxides in wt %, trace elements in ppm).



Graph 24. St. Pölten. Principal component analysis of chemical composition – scatter plots of the first component against the second and third. Chemical differences between fabrics A and B serve as a compositional fingerprint for future comparative studies. Author K. Slavíček.

to St. Pölten. A horse can pull a weight of up to one tonne and is faster than an ox. However, until modern times, horses remained a status symbol of the clergy and secular nobility. It can therefore be assumed that clay was transported using ox carts (Ohler 1995, 35–41). Depending on the load capacity, the distance between St. Pölten and the mining areas could be travelled in a day or a few hours with an ox cart (Ohler 2009). It is also possible that the clay was transported with sledge dogs (Benecke 1994, 75).

5.5.2. Ceramic paste – archaeometric analyses

For archaeometric analyses 14 samples of pottery from various archaeological contexts, namely the pottery kiln at Roßmarkt 11 (samples 8 and 9) as well as the kiln (samples 10–14) and the waste pit (samples 1–7) at Roßmarkt 12 were examined (Tab. 31; Fig. 133). All studied samples were made of kaolinitic clay. Based on ceramic petrography, the analysed samples were divided into two fabrics (Tab. 32) – untempered (A) and tempered (B). In adition to difference in grain-size distribution, both show differences concerning mineralogical composition and detrital rock types (Appendix 1-G, Appendix 2-G). Elemental concentrations show differences mostly in elevated K, Ti and most of the trace elements in fabric B samples (Graph 24; Tab. 33). A previous analysis by R. Sauer, based on thin-section petrography and heavy mineral analysis, identified 14 ceramic groups (Scharrer-Liška, Scherrer 2010, 15–24).

Fabric A pottery (twelve samples, from two contexts – namely samples 1–7 from the waste pit and samples 10–14 from the kiln from Roßmarkt 12) was made of kaolin with variable amounts of silt- and sand-sized grains (Fig. 134: A, B). The inclusions are of natural origin and were likely not intentionally added as temper. The grain size distribution is unimodal. Most samples do not show a parallel alignment. Fabric A was probably produced using naturally coarse clay, which contained a sufficient amount of silt and sand. Fabric A corresponds to 'petrografische Keramikgruppe 9' according to the analysis of R. Sauer (Scharrer-Liška, Scherrer 2010, 19).

The aplastics mainly consisted of quartz grains. Alkaline feldspars were present only occasionally or in lower amounts, while plagioclases were rare. Micas were found only in sample 14, where highly weathered muscovite was identified. Key components for the petrographic definition of this fabric were kyanite, rutile, and calcite (Fig. 134: E–G). Kyanite was commonly present, rutile occurs occasionally, and calcite

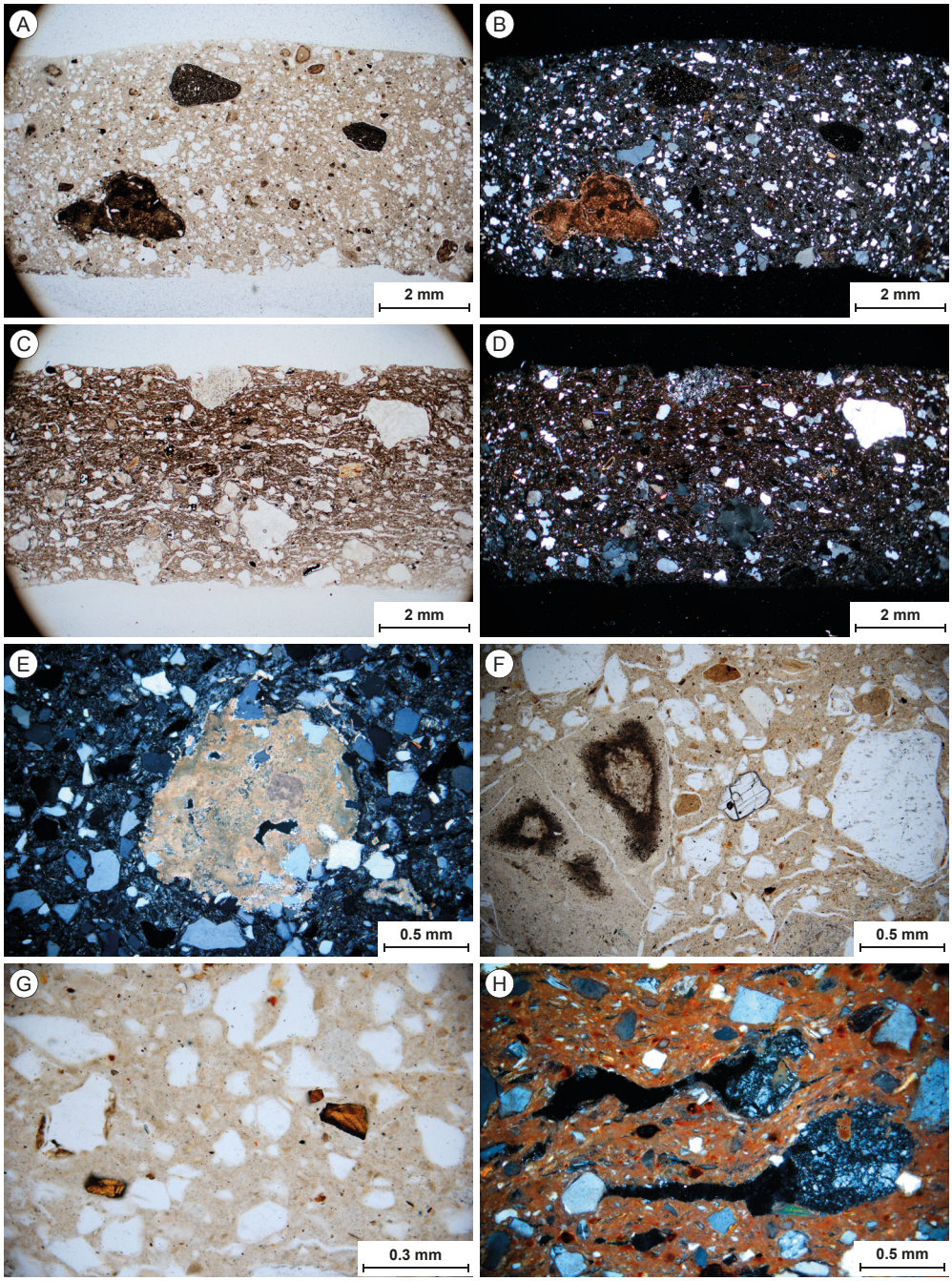


Fig. 134. St. Pölten. Photomicrographs: A, B – untempered kaoline fabric A (sample 1; PPL and XPL); C, D – tempered fabric B (sample 9; PPL and XPL); E – sandy limestone fragment within matrix rich in silt and sand quartz grains (sample 4; fabric A; XPL); F – kyanite grain in the center, clay lump on the left and frequent sub-angular quartz grains (sample 3; fabric A; PPL); G – rutile is a natural part of fabric A (sample 3; PPL); H – fragments of serpentinite as a part of temper used for fabric B (sample 9; XPL). Author K. Slavíček.

was found in almost all samples, though in varying amounts. The calcite grains were mostly sand-sized. Defining was also the presence of rounded clay or mudstone clasts, which are mostly abundant. Some samples contained sparse rock fragments composed of quartz and alkaline feldspars. Exceptionally, sample 13 showed a rare occurrence of sillimanite and a piece of an avian eggshell, and sample 14 contained frequent inclusions of sandstone and a fine sand-sized fragment of gneiss.

Regarding the pots used in the construction of the kiln, five samples were examined using thin-section analysis under a polarizing microscope. They consist of kaolin with variable amounts of silt- and sand-sized grains with not intentionally added temper, like other ceramic of fabric A.

Ceramic fabric B (samples 8 and 9 from the kiln Roßmarkt 11) was made of kaolinic clay containing silt-sized particles (specifically <30 µm). It was tempered with sand-sized grains (average size ~200 µm, max. size 1400 µm; Fig. 134: C, D). The microstructure showed a slightly parallel alignment. The temper consisted of mineral and rock fragments, mainly quartz, polycrystalline quartz, alkali feldspar (which is frequent), and serpentinite (Fig. 134: H). The clay also contained frequent iron oxyhydroxides and rare iron rich clay pellets. Micas were less common – muscovite occurred occasionally, and biotite was also occasional or rare. Plagioclases were also rare, as well as sillimanite and fragments of sillimanite gneiss. Occasional grains of rock composed of quartz and alkali feldspar were also observed. At this stage of research, it is not possible to attribute fabric B to any previously distinguished groups. It seems likely that it belongs to sandy pottery (groups 9–14), which appears to be more variable than originally thought (Scharrer-Liška, Scherrer 2010, 19–20).

St. Pölten is located within sediments of the autochthonous Molasse, which forms an approximately 10 km wide east–west belt between the crystalline units of the Bohemian Massif to the northwest and the thrust sedimentary units to the south – the Subalpine Molasse and Alpine Flysch. The Molasse zone comprises a sequence of detrital sediments ranging from the Late Eocene to the Middle Miocene. The Bohemian Massif in this area is represented by Moldanubian units; the closest unit to St. Pölten is the variegated series composed of granulite with areas of ultrabasic rocks and serpentinite. To the southwest, this unit is bordered by garnet- and pyroxene-bearing amphibolite, migmatite, calc-silicate gneiss, quartzite, and marble. Further northwest, the bedrock is composed of Gföhl gneiss, which typically contains accessory garnet, sillimanite, and kyanite. The Flysch zone comprises Cretaceous to Paleogene sediments, predominantly marls and sandstones. The city itself is situated in the valley of the River Traisen, a tributary of the Danube, which transports flysch-derived sediments from the south. The river terrace sediments underlying the city are flanked to the east and west by loess and loess loam. In the bedrock and to the north of the city, Molasse zone rocks outcrop directly above the crystalline basement, which is composed of granulite, locally kaolinized to depths of up to 10 m. The Molasse sequence in this region includes sediments of Egerian, Ottnangian, and Eggenburgian age. Of particular interest as a ceramic raw material are the refractory Eger clays of the Pielach Formation. Overlying these clays are Melk sands, with high content of feldspars, capped by 'Schlier' – calcareous clays containing carbonate concretions. In the Ottnangian, transgressive Robulus Schlier clays were deposited (Janoschek, Matura 1980; Müller, Schermann, Schwaighofer 1983; Geologische Bundesanstalt 2002; Roetzel 2002).

Fabric A was manufactured from kaolinitic clay containing carbonate fragments and numerous clay or mudstone pellets. The nearest known kaolinite deposit lies about 1 km east of Karlstetten, a village approximately 7 km northwest of St. Pölten. The Karlstetten kaolin was formed by weathering of Moldanubian crystalline rocks, mostly granulite. The presence of carbonate pellets suggests a secondary depositional environment for the kaolin, with carbonate admixtures introduced during transport. This mode of origin has been documented at the Karlstetten deposit (Müller, Schermann, Schwaighofer 1983), though no carbonates were reported there. However, the presence of kyanite and rutile grains in fabric A supports derivation from an amphibolite or granulite-facies metamorphic, indicating a likely genetic relationship with the Karlstetten deposit. Fabric B was tempered with sand rich in frequent alkali feldspar, quartz, and serpentinite grains, along with accessory sillimanite. This sandy material can be attributed to the Melk sands. The clay used for fabric B likely originated either from Pielach Formation or from redeposited material derived from the Karlstetten deposit.

5.5.3 Forming

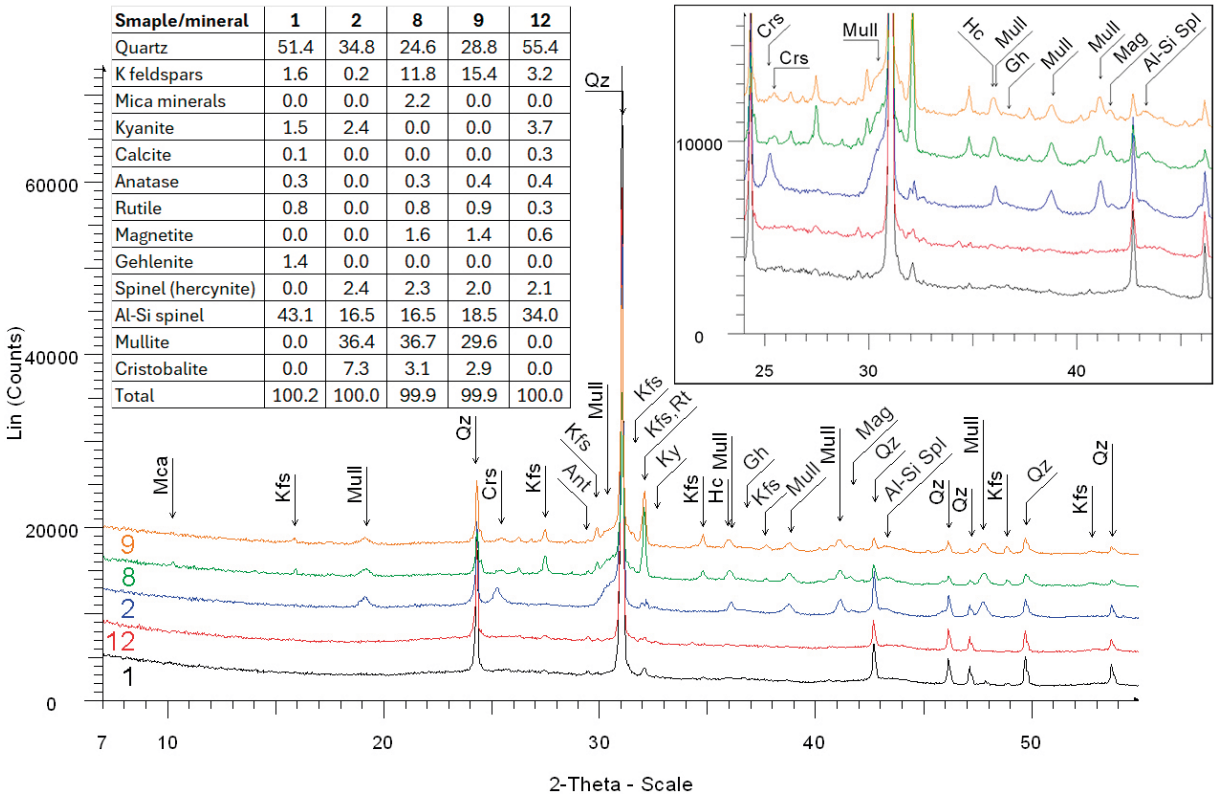
The vessels from the kiln at Roßmarkt 11 were most likely constructed using the coil-building technique as indicated by the uneven surface, particularly inside the lower part of the pots and a rounded wall thickening (relic of the lowest coil) just above the bottom. Marks of wheel throwing manifested as undulations with rings and depressions inside the vessel suggest they were thrown on potter's wheel utilizing kinetic energy. On the bottom surfaces, marks left by the separating agents (ash, fine sand) on the potter's wheel can be seen, and sometimes also the so-called swelling rim. Occasionally, there are traces of so-called rough bottoms left behind when the vessel was lifted from the base. The vessel surfaces are well smoothed. Spiral patterns can also be seen on the inside of the bases.

The vessels from the kiln at Roßmarkt 12 display similar manufacturing characteristics to those found in Roßmarkt 11. The lower parts of the pots show



Fig. 135. St. Pölten – Roßmarkt 12. Description of technological marks on pottery from kiln: 1 – pot with the fain waviness of the lower part of the wall (inv. No. 62); 2 – sand dust and clamp marks around the bottom perimeter (inv. No. 62); 3 – the rings in inner wall (inv. No. 62); 4 – the faint depression in low part of the pot and rings in upper part (inv. No. 11); 5 – sand dust and clamp marks around the bottom perimeter (inv. No. 11); 6 – shape deformation caused by handling the pot after production (inv. No. 63); 7 – pressing the spout into the body of the vessel (inv. No 50); 8 – marks of the coils under the neck of the jug (inv. No. G/A121); 9 – marks of the coils under the neck of the jug (inv. No. G/A6); 10 – the depressions and the rings (inv. No. T70/A1); 11 – the depressions and the rings (inv. No. T60/A8); 12 – the rings and the compression of clay (inv. No. G/A77); 13 – the rings and the incisions (inv. No. G/A169). Photo by M. Košťál; graphics by K. Těsnohlídková.

Smaple/mineral	1	2	8	9	12
Quartz	51.4	34.8	24.6	28.8	55.4
K feldspars	1.6	0.2	11.8	15.4	3.2
Mica minerals	0.0	0.0	2.2	0.0	0.0
Kyanite	1.5	2.4	0.0	0.0	3.7
Calcite	0.1	0.0	0.0	0.0	0.3
Anatase	0.3	0.0	0.3	0.4	0.4
Rutile	0.8	0.0	0.8	0.9	0.3
Magnetite	0.0	0.0	1.6	1.4	0.6
Gehlenite	1.4	0.0	0.0	0.0	0.0
Spinel (hercynite)	0.0	2.4	2.3	2.0	2.1
Al-Si spinel	43.1	16.5	16.5	18.5	34.0
Mullite	0.0	36.4	36.7	29.6	0.0
Cristobalite	0.0	7.3	3.1	2.9	0.0
Total	100.2	100.0	99.9	99.9	100.0



Graph 25. St. Pölten. Diffractograms of samples 1, 2, 8, 9, and 12 (angular range 7–55° 2θ) and results of quantitative phase analysis of crystalline fractions of the samples. The inset in the upper right corner shows an enlarged area of the record containing well-defined reflections of phases indicating firing conditions; Al-Si Spl = Al-Si spinel, Ant = anatase, Crs = cristobalite, Gh = gehlenite, Hc = spinel (close to hercynite), Kfs = K-feldspars, Ky = kyanite, Mag = magnetite, Mca = mica minerals, Mull = mullite, Qz = quartz, Rt = rutile. Author D. Všianský.

partly hints to the coil-building technique (sample 13), typical undulation inside the vessel, traces of separating agents on the bottom and so-called swelling rims. On the inner side of the walls of some vessels, e.g. on the necks of jugs, traces of insufficient smoothing of the joints between the coils have been preserved. But the rotational grooves are mostly finer and more regular. Compared to the earthenware from the older kiln, the wheel throwing seems to have been perfected (see Fig. 135 for details).

In fabric A were identified traces of coiling by the archaeometric analyses in samples 2 and 13. In these samples, elongated pores are aligned with the axis of the former coil.

5.5.4 Firing

Most fabric A samples from the kiln from Roßmarkt 12 indicate predominantly reducing firing, resulting in light grey body colors. Samples 10, 12, and 14 display slight oxidation, evidenced by weak ochre tones. Several vessels show darker outer layers caused by smoke-blackening (e.g. samples 4, 6, 7, 13). Firing intensity is reflected by the partial or complete loss of matrix optical activity in several samples (1, 2, 12). Another indicator of firing temperature for samples 1 and 12 is the high content of Al–Si spinel and the absence of mullite. It can be assumed that the maximum firing temperature was around 900–950°C. The soaking period was probably short as evidenced by the incomplete decomposition of calcite grains. Decomposition of calcite allowed to form gehlenite, which was identified in sample 1 (Graph 25). Sample 2 firing temperature was above 1050°C based on presence of cristobalite and high content of mullite. However the temperature did not exceed this limit for long period of time given by the low crystallinity of mullite (manifested by broad diffraction lines). For the remaining samples, maximum firing temperature was estimated between 800–900°C. Unfortunately, this estimate could not be corroborated through changes in the optical properties of iron-bearing minerals (e.g. biotite, green amphibole), as these minerals were absent. It is worth mentioning that the raw material of fabric A, which presumably comes from the clay deposits in the Tiefenfucha/Oberfucha and Karlstetten region,

is suitable for producing stoneware and therefore appropriate for high firing temperatures.

Fabric B (the kiln at Roßmarkt 11) shows signs of oxidation. This is evidenced not only by the ochre color of the entire sherd but also by the oxidised iron oxyhydroxides in the ceramic body. During firing, these clasts underwent significant shrinkage. The firing temperature was above 1050°C based on the similar content of neoformed minerals as in sample 2 of fabric A (Graph 25). Biotite flakes are black and non-pleochroic. The matrix is optically inactive, likely partially vitrified. In parts, the vessels are overfired. Occasional gray spots indicate local reduction.

5.6 St. Pölten and late medieval pottery production in Lower Austria: Concluding remarks

Currently, archaeological research into high medieval ceramic production in Lower Austria and St. Pölten can only rely on the ceramics themselves, as pottery kilns or firing facilities from this period have not yet been found. This lack of high medieval evidence may be due to the organisation of the pottery production in the High Middle Ages (Scharrer 2000; 2001). A similar lack of production units is evident in Moravia (Procházka 2015, 215).

From the 13th century onwards, with the establishment of guilds for urban craftsmen, pottery kilns became archaeologically verifiable in Lower Austria. In St. Pölten, as elsewhere, particularly in Tulln (Tab. 28), the diagonal flame draft kiln represented the predominant type in Lower Austria in the Late Middle Ages. Numerous archaeological remains of this type have now been identified. This observation also corresponds with those in Bohemia (Čapek, Preusz 2019, 355) In horizontal kilns, the firing chamber and heating chamber of the oven are arranged one behind the other. Due to frequent damage to the features, the original length of the kilns can rarely be determined. However, lengths of 3–3.5 m have been documented in St. Pölten and Tulln. These dimensions are like those of cross-draft kilns in Moravia, where lengths of more than 2 m and maximum values of 4 m were documented from the 14th century onwards. (Procházka 2015, 219, 222). It should be noted, that kilns with a minor length seemed to be common in rural settlements as indicated by examples in Mstěnice (Nekuda 2000, 110–112). The size of the kilns goes hand in hand with increasing production amount and higher consumer demand.

All the diagonal flame draft kilns in Lower Austria were provided with central spoon-shaped firing floors (Tab. 28). This fact can be proved despite the often poor documentation of kilns discovered before 1990. Numerous new evidences of the last 35 years support this hypothesis. The central spoon-shaped firing floors were often constructed of stones, brick and ceramic fragments, and clay, in contrast to similar constructions in the Czech lands. Also, in Moravia kilns with central spoon-shaped firing floors represent the dominant type in the Late Middle Ages as examples from Mstěnice or Staré Město near Uherské Hradiště indicate (Procházka 2015, 219; Procházka et al. 2024, obr. 8; see Chapter 4 in this volume).

There exists also a special type of central spoon-shaped firing floors. This type consisted of two parallel rows of pots standing upside down. The gaps between these pots were partially filled with ceramic fragments and clay, which was neatly smoothed onto the outside of the central spoon-shaped firing floor. This construction technique has been verified for kilns in St. Pölten, Mautern, Tulln, and Hainburg. These evidences date into the 14th, and possibly even into the 15th centuries and currently represent a special group of pottery kilns of the diagonal flame draft type. Outside Lower Austria, a central spoon-shaped firing floor constructed in this way has be documented only once in Bavaria (Gumberger 2000). A. Heege postulated this special type of horizontal kilns in his interpretation kilns respectively central spoon-shaped firing floors in his overview of pottery kilns in German-speaking countries, the Netherlands, and Belgium, based on finds in St. Pölten and Tulln known at this time. He also referred to features in Moravia (Heege 2007, 73). However, R. Procházka corrected, that central spoon-shaped firing floors constructed from pots upside down only occur in Lower Austria, but not yet in Moravia (Procházka 2015, 219).

The problem with interpreting the pottery kilns in St. Pölten and elsewhere in Lower Austria, and with reconstructing the kiln type, is – as with many other finds – that they are incomplete and in more or less poor condition. It is maybe conceivable that the two channels created by the central central spoon-shaped firing floor were bridged, for example, by flat stones or a clay construction (De Groote 1993, Fig. 21; Heege 2007, 73; Procházka 2015, 218).

Apparently, ceramic vessels were also used at least occasionally in the construction of the kiln wall, as evidenced by findings from 2020 and 2021

in St. Pölten. However, the possibility of a kiln wall made of wickerwork coated with clay cannot be excluded, as suggested by the remains of the kiln found in St. Pölten – Roßmarkt 11 (Scharrer-Liška, Scherrer 2010, 86). The building material for the pottery kilns probably obtained from the immediate vicinity. This assumption is supported by archaeometric analyses of the kiln clay from the kiln found in St. Pölten – Roßmarkt 12. According to these analyses, the clay came from the immediate vicinity (Scharrer-Liška, Scherrer 2010, 20).

Regarding the location of pottery workshops in the respective towns and markets, it should be noted that, despite the fire hazard they posed, many workshops were located within the city walls. This was the case in Wiener Neustadt, St. Pölten, Tulln, and Amstetten. It is noteworthy that the pottery workshops were located on the south-western or western outskirts within the city walls. In Tulln, late medieval pottery kilns were initially found in the western suburbs before the pottery district was apparently relocated within the city walls. The question arises as to whether this pattern had a specific reason. Given that the prevailing wind direction in Lower Austria is westerly, this means that in the event of a fire, there was an increased risk of the flames spreading to the adjoining urban area. This risk may have been reduced by varying building densities. According to pictorial sources, it appears that at least in St. Pölten, the southwestern part of the city within the city walls had a low building density in the Late Middle Ages and early modern period. In Neunkirchen, on the other hand, there was a pottery workshop in the district south of the centre (like the situation in Kostelec near Jihlava; cf. Zimola 2021, 104), which was separated by a tributary of the River Schwarza, thus at least reducing the fire hazard posed by the pottery kilns. In Horn, the situation is different again: here, the pottery kilns that have been found so far were located on the eastern outskirts of the town.

Both archaeological evidence (such as in St. Pölten, Tulln, and Amstetten) and street names (e.g. 'Hafnergassen' in St. Pölten and Horn, 'Hafnersteig' in Vienna) indicate that the pottery craft was concentrated in certain streets. At the same time, large-scale excavations such as those in Tulln also prove that pottery districts could be relocated over time. Today, there are also Hafnergassen in other Lower Austrian towns or markets, such as Gars am Kamp, Klein-Pöchlarn, and Gänserndorf. In these cases, however, there is a lack of archaeological evidence, which is primarily due to investigation gaps.

Particularly the finds from St. Pölten – Roßmarkt 11, but also those from Tulln from the last 20 years, testify to the variety of objects produced in these kilns, ranging from sophisticated tableware to figurative objects, some of whose functions are unknown, and stove tiles. The pottery kilns and the objects connotated from 1909 (Roßmarkt 11) and 1991 (Roßmarkt 12) in St. Pölten may also indicate a change in the used raw material sources. (The evaluation of the findings from the last two decades is still outstanding.) The archaeometrically examined samples from the complex from Roßmarkt 11, which dates back to around 1300, were assigned to the petrographic ceramic group fabric B, which indicates more extensive processing of the clay. In contrast, the samples from the kiln find dating to the middle or second half of the 14th century, and the workshop waste pits from Roßmarkt 12 could be assigned to fabric A. Fabric A, in turn, suggests the use of high-quality clay deposits in the Karlstetten and Oberfucha/Tiefenfucha area. Written sources from the 18th century attest to the organised extraction of raw materials and their sale to various potters' guilds. However, the results of archaeological and archaeometric investigations indicate that a similar situation already existed as early as the 14th century.

In final, it should be noted that all pottery kilns identified in St. Pölten and the rest of Lower Austria were suitable for firing ceramic objects of manageable dimensions (ceramic vessels, figural objects, stove tiles, etc.) due to their size. Large storage pots made of graphite-tempered, oxidatively fired sherds, typical in the Austrian Danube region and Moravia in the Late Middle Ages, could not be fired in the pottery kilns found in archaeological contexts to date due to their size. Rather, it can be assumed that these storage pots were burnt by pit firing or open firing (Macků 2021).

6

Experimental medieval pottery production

The chapters of this book that are devoted to experimental archaeology are based on experiments carried out as part of the co-author's doctoral thesis from 2013 to 2019 (Těsnohlídková 2021). From 2020 to 2024, further experiments were conducted with a focus on the technology of high and late medieval pottery production, reflecting and complementing the results of previous experiments.

The initial aim of this extensive experimental project was to verify the technological procedures that are assumed to have been used in medieval pottery, to explain various macroscopic traces on the pottery, and to provide new insights into various topics that have been addressed hitherto in only a more traditional manner. Gradually, the most significant part of the project focused on ceramics in the Bohemian-Moravian Highlands and pottery production in the 13th century to the first half of the 14th century, primarily in regard to the processing of pottery kiln finds and kiln batches. The implemented experiments provide an additional source for the study of medieval and late medieval pottery production, and partially also for the research of ceramics of other periods.

As with the previous sections, the structure of this part of the thesis is divided into topics as they progress along the operational chain of pottery production. The first section deals with the issue of sources for the production of ceramic fabric and the properties of ceramic fabric with different types of inclusions. The second section focuses on the formation of vessels with an emphasis on the technology of wheel coiling, which was predominant in the vessels from the kilns under study, and its comparison with the wheel-throwing of vessels from a single piece of fabric. The third section focuses on the technology of firing ceramics with the use of different firing strategies so the characteristics of the final product would correspond to medieval goods. This part consists of three sub-chapters focusing on the construction of pottery kilns, the firing of ceramics, and the properties of ceramic fabrics during firing.

6.1 Ceramic pastes

The aim of the experiments was to obtain a sufficient base of raw materials for solving general issues concerning the technology of high and late medieval pottery production. Suitable regional raw materials were sought out mainly in the area of interest, i.e. the Bohemian-Moravian Highlands. At the same time, purchased, pre-prepared materials were used in the experiments. We came to this compromise due to the poor availability and complex processing of natural clays, although we acknowledge the fact that properties of current industrially-produced clays do not match the material used to produce medieval pottery.

In terms of natural clays, we encounter issues concerning their processing and appropriate treatment. This is the part of pottery production that has deviated the most from historical tradition and has been completely abandoned. We know the procedures for the processing and treatment of clay partly from ethnography, and the manual extraction and preparation of clay is the most physically and time-consuming part of the entire production process. Regions with a rich presence of loess or loess loam, which are suitable for the production of medieval pottery and relatively easy to process, have a certain

advantage in terms of ceramic fabric. However, these sediments are found only in the peripheral parts of the Bohemian-Moravian Highlands, and mostly so-called brickmaking (non-loess) clays (Zaoralová, Slavíček 2021). In addition to the basic clays, various types of inclusions were also sought out and tested, especially graphite. For comparison, both the industrially-processed fabrics and high-quality natural pottery clays from neighbouring areas were used for the experiments.

6.1.1 Historical sources of pottery and brickmaking clays in the Bohemian-Moravian Highlands

Information concerning the sources of clay for historical pottery can be obtained from written sources or place names. In addition to the abundance of wood there, it was also primarily a source of high-quality clay, on which the development of pottery in the region depended. The relationship between pottery workshops and sources of primarily loess or loess loam has been observed recently by L. Čapek (2024, 13–18). Demands on the quality of the clay have increased for some of the more recent branches of pottery. An example of this is faience, the production of which was centred in Velká Bíteš (Svoboda 1927, 240; Černohorský 1941, 14–17).

Historically, we know sources from which one of the last potters in the Vysočina Region František Čurda from Knínice in the Telčsko Region (Hladík 1988) drew clay. Toponyms present or preserved on old mappings may also refer to sources of clay, e.g. the place name 'U bílé hlíny' (which means "by white clay") near Mohelno and Dalešice (Kuča 2013, 32). It is also possible to locate preserved clay deposits by means of airborne laser scanning (LiDAR) in combination with field survey, and possibly also via place names and written sources. This is how clay deposits can be traced, for example, near Ledeč nad Sázavou or Svratka, two important modern-era pottery centres. At Ledeč nad Sázavou, where pottery was gradually replaced by stove production, we have evidence of clay extraction along the road towards Kožlí (Chvátal et al. 2013, 184–200). In Svratka, there were rich clay deposits in Borovina by the road to Hlinsko and in other places. Significant relics are still visible in the terrain today (Bálek 1989, 57). In the case of another pottery centre in Nové Veselí, the sources of pottery clay were in close proximity to the village, e.g. around the present-day Veselský rybník (Veselský Pond) or in the vicinity of the Chapel of St Roch (Landsmannová 2020, 31).

In archival sources, we most often encounter records concerning the sources of pottery clay in cases where there was a dispute over its extraction, e.g. we know of such a case from 1865 in Nové Veselí (Těsnohlídková 2021, 9). The extraction of pottery clay was permitted by the sovereign for a fee in some places and free of charge in others (Černohorský 1941, 14–17).

Brickyards are another type of historical monument that can guide us to the sources of pottery clay. Brickyards served as a source for the production of fired and air-dried bricks, which were used more frequently in rural construction from the 20th century onwards (Kuča 2013, 30). However, sufficient brickmaking required a much lower quality of clay than was the case for pottery. The use of clays from old brickyards is often limited by the fact that in growing towns, these brickyards usually ended up underneath the built-up area or flooded with water, e.g. in Žďár nad Sázavou (Lopaur 2012, 145–146), Nové Město na Moravě (Cihelský rybník [Cihelský Pond]; the brickyards building burnt down in 1929; Marková 2009, 78–79), Havlíčkův Brod (Cihlář Pond, residential built-up area), or Jihlava (today's Na Hliništi Street).

Sites of clay sources can also be found in the vicinity of late-modern pottery production centres. In the Highlands, this included, e.g. Svratka, Velká Bíteš, Nové Veselí, or Knínice near Telč. These centres were in operation until the second half of the 19th century, and in some cases until the first half of the 20th century. The last pottery workshops probably operated in Jihlava, Telč and Knínice until the 1940s or early 1950s. Among the last to operate a workshop in Knínice near Telč was František Čurda, who officially terminated his trade in 1944. As late as the 1950s, J. Pelikán still occasionally fired smoked goods in Ostrov nad Oslavou (for details, see Scheufler 1972, 136–138; Válka 1994, 12–13; Landsfeld 1950, 307–309; Hladík 1988, 171–172; oral testimony from the chronicler of the village of Ostrov nad Oslavou, J. Doupal).

6.1.2 Ceramic fabrics used in conducted experiments

Over the course of the experiments, several different sets of samples were produced in succession to address questions concerning the behaviour of ceramic fabrics with varying properties during forming and experimental firing. The samples were continually supplemented to include new materials, and the main type of raw material, i.e. non-loess

brickmaking clay, has very similar properties across the region. For forming, fabrics were continuously processed and stored so that they were available for use when needed and also to allow for the monitoring of changing properties throughout the course of processing and maturation (for a precise description of the processing procedure, see Těsnohlídková 2021, 110–111, Appendices 1–5; Fig. 136).

In an ideal case, ceramic fabrics obtained from the vicinity of the sites with pottery kiln finds (which are the focus of this publication) could be used for experiments. So far, similar research has only been carried out in the case of the kiln from Žďár nad Sázavou – 'Staré Město', primarily in order to determine the provenance of the pottery produced. Unfortunately, even here there was no directly available source that would provide a sufficient quality of clay for processing in the experiments. Sample collection was complicated by the current built-up area in the area surrounding the kilns. Possibilities of probing for potential sources were continuously monitored and planned in the framework of further research. For this reason, materials that had already been prepared during previous research projects, i.e. from 2015 to 2019, were preferred for the experiments in this project. This was also due to the time-consuming nature of preparing the clays.

The clays used for the forming experiments were mainly clays from modern brickyards and clay deposits, loess from Šlapanice and Bukovsko and brickmaking clays from the sites of Luka nad Jihlavou (brickyards), Panská Lhota (brickyards), and Kejžlice, a modern clay deposit and clay from a pottery storage site from the archaeological research of a potter's house in Telč No. 48 (hitherto unevaluated research by Archaia Brno). Part of the clay was enriched to include finely ground graphite with a coarseness of up to 1 mm, a portion of which was put through a sieve to achieve a finer coarseness (up to 2 mm). Clays from other sources have only been used on a small scale for testing.

6.1.3 Phase analysis of the composition of the used natural sources of pottery clays

Selected clay samples were subjected to a series of analyses: powder X-ray diffraction (XRD) and thermal analysis. This was performed by Dalibor Všianský from the Institute of Geological Sciences, Faculty of Science, Masaryk University. The aim was to determine the quality of the clays and their suitability for use as a ceramic raw material. For this purpose, kaolinite and clay mineral content was monitored. Fabrics from medieval brickyards in the Bohemian-Moravian Highlands assumed to be of the same quality as medieval pottery were selected. These were supplemented with several comparative samples possessing different properties.

Powder X-ray diffraction analysis was performed using a Panalytical X'Pert PRO MPD apparatus with a Co anode ($\lambda K\alpha$ = 0.17902 nm), an RTMS detector (X'Celerator), and fixed divergence slits in a conventional reflection geometry. Step size: 0.033 °2θ, time per step: 240 s, angular range: 5–100 °2θ, total scan time: 5345 s. The data were processed using Malvern Panalytical HighScore 5.2 plus and Bruker AXS DIFFRAC plus Topas 4 software. (Semi) quantitative phase analysis was performed using the Rietveld method. Only the crystalline phases were quantified.

Thermal analysis by differential scanning calorimetry (DSC) and thermogravimetry (TG) was carried out using a Setaram Setsys EVO 1700 instrument. The experiment was conducted in a dynamic air atmosphere during heating in the range of 40–1000°C with a heating rate of 10°C/min. The data were processed using Setaram Processing software.

All seven samples of five selected fabrics from brickyards had very similar kaolinite contents and other clay minerals. The proportion of kaolinite ranged from 7 to 12%. Clay minerals with illite accounted for 21–31% of the fabric. Thus, all the analysed samples can be considered usable for the production of ceramics, and we refer to them in this work as 'brickmaking' non-loess clays or non-loess clays 'of a brickmaking quality'. Furthermore, fabric from the modern-era clay storage in the potter's house in Telč was analysed, which in quality was equivalent to the brickmaking clays mentioned above. The content of clay minerals was roughly twice as high in two analysed loess clays from Horní Skrýchov (Jindřichův Hradec District) and Pilsen. As expected, fabric from Chřesťovice (Písek District), composed of more than 50% kaolin, stood out strongly (Tab. 34; Všianský 2020).

6.1.4 Properties of experimentally prepared ceramic fabrics with regard to the technique of forming and firing medieval pottery

The forming experiment targeted the technique of wheel coiling and the ways it differed from wheel-throwing, which is also reflected in the ideal composition of the ceramic fabric. Experiences from experimental production and the analysis of archaeological pottery finds show that the demands on clay



Fig. 136. Storage and processing of brickmaking clays: A – storage of clays in a moist state in plastic tubs; B – drying clays on wooden boards to the desired moisture content before processing; C – coarse crushing of clay for easier levigation; D – levigation to refine the material; E – detail of coarse impurities on the sieve during levigation; F – kneading the material into 'loaf' shapes on wooden boards. Photo by K. Těsnohlídková.

Locality	Kaolinite content (wt. %)	Clay minerals and mica content (wt. %)	Brief description
Luka nad Jihlavou			Brickyard
Luka nad Jihlavou			Brickyard, material refined to 2 mm
Panská Lhota			Brickyard
Panská Lhota			Brickyard
Cihlář – Havlíčkův Brod			Brickyard
Cihlář – Havlíčkův Brod	19	44.43	Brickyard
Havlíčkův Brod, U Prchalů		34.5	Clay from modern-era pottery storage
Nové Veselí, pond			Presumed modern-era source for pottery production
Svratka			Clay pit for pottery production 19th centrury
Kožlí			Clay pit for pottery production 19th centrury
Jehnědno/Chřestovice	51.7	68	Kaolin
Telč			Clay from pottery storage 18th century
Horní Skrýchov	20	Non measured	Loess
Plzeň		40.5	Loess

Tab. 34. Kaolinite and clay mineral content in selected clays used in experimental ceramic production. Mica and illite cannot be distinguished by used method, so the actual clay mineral content is somewhat lower than the stated value; material from Svratka and Kožlí was used since 2020; results of the analysis were incorporated into the work for comparison. After Všianský 2020.

quality are lower for techniques using coiling for the production of vessel bodies (regardless of the type of rotation involved), and the range of usable fabrics is wider than for wheel-thrown pottery. This is also related to the higher requirements for mastering the production technology via the given technique; this is discussed in the section on vessel forming. Industrially prepared fabrics display different forming behaviour, especially when forming via coilsand during the subsequent coiling process, and working with them is inefficient.

Working with natural clays has shown that plasticity improves with gradual maturation, aging, and repeated kneading of the material. In the past, the attempt to improve the properties of pottery clay for forming was evidently reflected in the addition of various inclusions – mainly graphite, organic inclusions, or mica. Mica was mostly present in the fabric of vessels from the studied pottery kilns in small to medium quantities as a natural inclusion in the raw material, and thus its presence was not related to a change in the properties of the fabric. Another inclusion sometimes mentioned is sand, which was always present in regional clays in a sufficient amount, and thus its further addition would have been ineffective.

Some of the vessels from the pottery kilns contained a significant inclusion of graphite, and therefore its behaviour during forming and firing was also studied via experiments (on the current state of knowledge concerning graphite in ceramics, see the new works of P. Macků 2021, 66; 2023, 167–175). No clay with a natural source of graphite was available, so it was artificially added to the clay in all cases. Over the course of adding graphite, its ability to absorb moisture and adjust the fabric to reach an ideal consistency for vessel formation proved to be crucial (for similar works, see, e.g. Rzeźnik, Stoksik 2004, 321–336). A similar property has been documented for organic temper by J. Skibo et his colleagues (Skibo, Schiffer, Reid 1989, 136). In the case of lesser-quality clays or clays that were too wet for the production of a vessel, it was possible to improve their properties for immediate use by incorporating graphite. If we add too much graphite, the clay begins to lose its plasticity, dries out, and needs to be moistened. During his experiments, P. Macků observed the main contribution of graphite in that it served as a fabric temper, i.e. it reduced shrinkage during drying and the first stage of firing (Macků 2023, 173–175). However, this function could have been fulfilled by another temper that in most cases was more available, e.g. sand.

After the first firings and realizing that industrial clays were insufficient for the experiments, samples of natural clays or prepared mixtures gradually began to be fired in order to determine their behaviour at certain temperatures or types of firing. We aimed to obtain suitable materials for firing strategies assumed to have been applied in the High and Late Middle Ages, which range from simple bonfire-like clamp firings with the assumption of large jumps in temperature to more gradual firings in various types of kilns, especially for smoked pottery. It was important to monitor graphite combustion in order to find an efficient method of firing graphite ceramics.

The results of sample firings pointed to the unsuitability of using non-loess brickmaking materials for high-temperature firings or longer durations at higher temperatures. On the contrary, their resistance to large temperature jumps and therefore their key role for experiments with rapid firings was demonstrated. Loess as well as purchased fine and grog mixtures proved to be unsuitable for firings whose course could not be controlled, such as single firings without adding additional fuel, such as in pits, fireplaces, or simple bonfire-like clamp devices. The inclusion of graphite had no great impact on this fact. In addition, the use of graphite requires a specific type of firing if it is not to be completely combusted, which would increase the permeability of the vessels. These findings served as the basis for further experiments focusing on studied pottery production from the researched pottery kilns.

6.2 Pottery forming with a focus on the technique of wheel coiling

Most of the vessels produced during this experimental project were made by throwing via a rapidly rotating wheel. This is also the most efficient and fastest technique for producing vessels, allowing us to effectively create the load for firing. Using this technique, experiments verified, e.g. inner wall corrugation and its forms, various manufacturing defects on the walls and bottoms, as well as the suitability of the technique for different types of clays and inclusions.

Primary attention was paid to the technique (or group of techniques) of wheel coiling while considering the fact that the majority of ceramics preserved in the analysed kilns had been made using coils, but also with the use of a certain degree of rapid rotation. The theoretical part of the experiment was supported by a detailed analysis of wheel coiling that was ethnographically preserved in the Balkan Peninsula in small, mountainous areas of Bosnia and Herzegovina, Croatia, and Serbia up to the second half of the 20th century (e.g. Djordjević 2007; 2011; Carlton-RJC films). Its aim was to point out preserved techniques, their variability, and the possibilities of their use in reconstructing processes for forming medieval ceramics. The practical section then built upon this research by verifying these procedures as being analogous to Czech medieval pottery production.

The technique of wheel coiling in Czech medieval pottery was first thoroughly described by M. Richter using material from Hradišťko u Davle (Richter 1982, 95–103). The question of pottery production techniques using coils has been dealt with by J. Macháček and more recently by M. Mazuch (Macháček 2001, 22; Mazuch 2013, 43–44, 60) for the early medieval period. Ceramics technology is more fully reflected in the recent works of R. Procházka (Procházka, Peška 2007, 228; Procházka 2022, Procházka et al. 2024). It has been dealt with in more detail in previous works by the authors of this chapter (Těsnohlídková 2021; 2022b; Slavíček et al. 2023). Generally, the research of pottery shaping techniques is based primarily on ethnographic studies in the Eastern European milieu (Hołubowicz 1965; Bobrinskij 1978; Carlton JRC films; Djordjević 2011; Djordjević, Carlton 2013; Bikić 2014; Djordjević 2016; Jenjić 2018) and in cultural anthropology (Rye 1981; Rice 1987), as evidence of ceramics technology in archaeological material most often comes from ethnographic analogies or experimental archaeology (Orton, Tyers, Vince 1993; Courty, Roux 1995; Rzeźnik 1992; Rogier 2015; Thér, Květina, Neumannová 2019; Roux 2019, 72–90; Gunnarssone et al. 2021).

Two schemes exist for classifying wheel coiling techniques. Both stem from the method by which fast rotation is attained; at the same time, however, they are based on different fundaments. Using Eastern European ethnographic material, A. Bobrinskij defined seven stages of pottery production using a rotating wheel or potter's wheel: 1) a wheel is used as a rotating table while forming by hand; 2) a wheel is used to smooth the surface of a hand-formed vessel; 3) a vessel is formed by hand, and a wheel is used to smooth the surface and finish shaping the rim; 4) the body of a vessel is formed as a coiling roll by hand, and the wheel is used to partially or completely form the body – the mouth, shoulders and body; 5) the wheel is used to balance, shape, and partially draw out the walls of the vessel shaped by hand via coiling; 6) the wheel is partially used to shape the coiled base and draw out the walls of the vessel, but the vessel is attached to the surface of the wheel by hand or the use of other techniques; 7) the wheel is used to draw out the walls from a single piece of clay (Bobrinskij 1978, 27). Techniques 3 to 6 can be considered to be wheel coiling, provided that the initial cylinder is formed from coils, which can range from thin coils to whole pieces of clay pressed against the foundation as walls.

The second typology is offered by the French systematic concept of *chaîne opératoire*, which is based on the general possibilities of pottery

formation and developed by V. Roux. It involves four possibilities based on which stages of production involve the use of rotational kinetic energy and whether centrifugal force is used: 1) coils are created, joined and thinned by means of discontinuous pressure (i.e. without the help of rotational kinetic energy); the shape is created by means of rotational kinetic energy; 2) coilsare created and connected by means of discontinuous pressure (i.e. without the help of rotational kinetic energy), coils are then thinned, and the shape is created by means of rotational kinetic energy; 3) coils are created using discontinuous pressure (i.e. without the help of rotational kinetic energy), and the joining, thinning, and shaping carried out with the help of rotational kinetic energy; 4) all stages of production are carried out using rotational kinetic energy – in this method, coils are coiled up on the wheel, then thinned and shaped using rotational kinetic energy; the symmetrical base is adjusted, and then another coiling roll is attached using rotational kinetic energy (Roux, Courty 1998, 748–750; Roux 2009, 197–198).

6.2.1 Wheel forming pottery on the Balkan Peninsula

For the experimental part of this work, we sought out ethnographically preserved patterns that might be used to create a model for pottery production via wheel coiling in the Middle Ages. Consideration was given to the works of V. Hołubowicz and A. Bobrinskij, who documented traditional pottery production in Eastern Europe (Hołubowicz 1965; Bobrinskij 1978). For an even longer period of time, i.e. until the 1990s, the tradition of pottery was preserved on the Balkan Peninsula in the mountainous regions of Bosnia, Serbia, and Croatia. The analysis of surviving detailed forming procedures and video recordings of them forms the main part of this chapter, and it aims to highlight the variability of this technology and possible parallels to medieval pottery production via wheel coiling.

Richard Carlton, who also documented the production methods of traditional potters on film, is strongly credited with mapping the Balkan tradition for foreign research. The first research took place from 1987 to 1989. During these three seasons, he captured potters who were still active in several sites, potters still occasionally making pottery to augment their retirement income, or potters who were no longer active but were still willing to present their craft (Carlton 1987; 1988; 2008, 209; Carlton-RJC films).

Wheel forming pottery received attention in domestic ethnography, which was probably formed more in the second half of the 20th century (Tomić 1966; Sanski Most 1974). It evidently began to enter ethnographic museum collections more from the 1980s onwards (see, e.g. Jenjić 2018, 41–49). This tradition has been the subject of research by domestic researchers especially in recent years and has received interest thanks to the developing field of ethnoarchaeology, primarily due to the researcher B. Djordjević (e.g. Djordjević 2011; 2013, 49–52; Bikić 2014, 221–234; Jenjić 2018). The most prominent project is research into pottery in Zlakusa implemented by the National Museum in Belgrade titled Intangible Heritage: Ethnoarchaeological research on traditional pottery-making techniques (Djordjević 2013, 49–52).

The long retention of wheel forming pottery is probably due to a combination of factors and the remoteness of the areas in question. The fabric from which this pottery was made is unsuitable for throwing on a fast wheel. However, it is resistant when used in an open fire, giving the pottery the properties required by the consumer. The kick-wheel potter's wheel and double chamber kiln spread to the area with immigrants from Austria-Hungary in the late 19th century. Initially, the kick-wheel spread mainly in cities, but since the 20th century it can also be found in the countryside. Wheel-thrown pottery was cheaper and, thanks to kiln firing, often involved glazed ware with better utilitarian properties. Wheel forming pottery continued to persist only in remote mountainous areas and was greatly affected by the war in the 1990s (Carlton 2008, 209; Djordjević 2011, 47–48, 57).

In addition, a degradation of the original production methods can be observed in recent production activities targeting tourism. Traditional pottery from Zlakusa in Serbia was added to the UNESCO Intangible Cultural Heritage List in 2020 (Fig. 137; Jenjić 2018, 41–49; Djordjević 2007, 89; 2013, 49–52; Djordjević, Carlton 2013).

Available findings on film for the analysis of wheel-forming pottery production technology on the Balkan Peninsula come from villages in three countries: from six settlements in Bosnia and Herzegovina, from three in Croatia, and from several workshops in Zlakusa, Serbia.

- The oldest published film footage of wheel forming pottery production was taken in 1974 in present-day Bosnia and Herzegovina at the Sanski Most site (Sanski Most 1974). Other potters were



Fig. 137. Traditional hand-wheel pottery production in the municipality of Zlakusa, Serbia (Zlakusa 1); A – turntable with the potter's personal engraved mark and the bottom of the vessel; B – thick coils used to build the walls of the vessels; C – building the vessel wall; D – completion of wall construction; E – shaping the rim and adjusting the bulge; F – smoothing the vessel's surface; G – removing the vessel from the turntable; H – drying the vessels. Reproduced from the section *Istorija grnčarskog zanata u Zlakusi* on the official municipal website of Zlakusa, Serbia. Published with the kind permission of Ethno Park 'Terzica avlija' and the Ethno Association 'Zavičaj'.



Fig. 138. Traditional hand-wheel pottery in the municipality of Potravlje; A – building the bottom; B – base of the wall; C – smoothing the surface; D – finishing the vessel. Reproduced from the section *Traditional Hand-Wheel Pottery in Potravlje* on the official tourism website of the City of Sinj, Croatia.

documented here by R. Carlton in Malešiči in 1990 and again in 2018 (Carlton-RJC film 5; Carlton 1987; Carlton 1989, 66). In 1990, potters in the villages of Liješevo, Višnjica, Pulac and Ularice were also captured on film (Carlton-RJC film 3; Carlton-RJC film 4; Carlton 1987).

- In Croatia, production was documented at the Lika, Veli and Potravlje sites in the early 1990s (Carlton-RJC film 1; Carlton-RJC film 2; Carlton-RJC film 7; Lika 1; Lika 2). Production in Potravlje was documented as recently as 2015 (Knezević-video; Fig. 138).

- The tradition of wheel-forming pottery resonates most strongly in Serbia thanks to traditional Zlakusa pottery's entry into UNESCO's cultural heritage list. The production processes here were documented in 1994 and 2000 by R. Carlton; after 2000, other materials were created as evidence of the cultural tradition, especially for the tourism industry (Carlton-RJC film 8; Zlakusa 1 – Zlakusa 5; Knezević-video; Fig. 139).

Fabric used for the production of pottery in the sites where ceramics were produced using clay coils on the Balkan Peninsula was most often obtained locally, or it may have been imported from several kilometres away, as was the case with the temper. Depending on availability, calcite or quartz was used for tempering and was finely ground using a stone grinder, which was part of the pottery workshop's equipment, in order to obtain the proper ratio. The ratio of clay to temper was most often 50 : 50 or 40 : 60. The fabric seems to be crucial in the production of ceramics produced via coiling. The described type of fabric is not suitable for wheel-throwing pottery, which may be the reason why in some villages there was a long tradition of coiling and wheel-thrown pottery side by side. Ceramics with a coarser temper have been shown to be more durable for use as cooking vessels (Djordjević 2011, 47–48).

Several types of throwing wheels have been documented at the investigated sites. The most common type was a wooden turntable connected by four spokes with a wooden cross, i.e. the type that is known from medieval iconography and documented in Germany



Fig. 139. Traditional hand-wheel pottery production in he municipality of Zlakusa; A – dusting; B – building the wall; C – smoothing the surface; D – open firing. Reproduced from the UNESCO Representative List of the Intangible Cultural Heritage of Humanity entry *Zlakusa pottery making, hand-wheel pottery making in the village of Zlakusa*" (Zlakusa 2). Published with the kind permission of Ethno Park 'Terzica avlija' and the Ethno Association 'Zavičaj'.

in the 15th–16th centuries (Rogier 2015, 17–18; Těsnohlídková 2021, 24). The structure was usually mounted on a wooden (or in more modern versions metal) axis fixed in a wooden or stone foundation or directly in the ground. A similar design could also be found with a fixed axis that was fitted into a hole in the ground, although its rotation was significantly lower. Less frequent were devices of a mushroom cap-like or hemispherical shape with a flat turntable on top. Here it was more common for a hole to have been drilled into the bottom of the turntable in order to place it on a shaft, which was then fixed into a wooden or stone (Carlton 1988, 57–59). By the end of the 20th century, modern electric throwing wheels were already being constructed using, e.g. motors from washing machines. Adaptation of the foot-powered kick wheel to the coiling technique was also observed sporadically, probably with regard to the properties of the ceramic fabric and requirements of customers.

A special feature is the presence of engraved marks in the centre of the throwing wheels, which are explained as being the personal mark of the potter and which resemble the marks on medieval pottery (Blagojević 1974, 336). A thin wooden plate of a circular or square shape was sometimes attached to the throwing wheel itself and could be removed from the surface of the turntable at the same time as the finished vessel. The vessel was then removed from it, presumably after it had partially dried and became unstuck from the surface.

Another characteristic observed was the use of dusting, which was employed by most potters. It was usually the same material as the inclusion that was used – i.e. ground calcite or quartz. The dusting was

placed directly on the wheel's turntable or poured onto a clay plate that was then placed on the wheel and fixed around the turntable's circumference. Finally, the vessels were pulled off the turntable horizontally by hand; in some cases, they were trimmed with a wooden blade around their outer edges, or cuts were made around the bottom and excess material was removed from the outer sides. If no dusting was applied, a replaceable board was used, which was probably fixed with a piece of clay to the turntable and removed from the wheel along with the finished vessel; the vessel would stand on it until it dried and became unstuck, or it could be removed from the plate. One of the potters also adapted a string to remove vessels from the wheel and did not subsequently use dusting.

The variability of possibilities can also be observed in the initial stage of vessel bottom formation. A lump of clay was placed on the plate of the wheel and flattened out with the back of the hand and fingers into a flat surface or disk, which was then fixed to the turntable around the base circumference. Then, using slow rotation, the bottom was marked. A wooden blade was used to trim it, or it was merely marked with a groove made using the finger. Excess fabric was then removed and worked into the first coiling roll or squeezed onto the bottom as a base for the wall and also to hold the bottom more firmly to the turntable.

A unique procedure was documented at the Sanski Most site in 1974, where, by applying pressure with the fingers, the primary fabric placed on the turntable appears to produce the ring of the body and simultaneously a central cone between the future centre and bottom edge (Sanski Most 1974). After the body's wall has been formed, this cone is pushed downwards using the fingers, spreading it out at the bottom. If necessary, any excess material is then removed. This procedure has been captured only in a rather fragmentary manner; it is also possible that the central cone is inserted into the middle only secondarily, although its attachment to the plate would in this case be rather problematic. The procedure offers an interesting analogy to the question of so-called 'secondarily attached bottoms' in medieval pottery.

The base of the body could have been created in several basic ways or via a combination of methods. In the first and more frequent, fabric was drawn from the centre to the edge using the fingers during slow rotation, or a grooves was created in the centre by adding pressure during medium rotation and the fabric was pushed towards the edge, where it formed the basic ring of the body. In this case, the potter would purposely make the initial bottom thicker in order to have enough fabric available. The first clay coils could also be immediately attached around the bottom. The advantage of forming the base of the wall from the fabric of the bottom what that it reinforced one of the most high-risk places on the vessel, i.e. the transition between bottom and body. This place may have been strengthened by an additional coiling roll on the inner wall; however, it is not clear whether this was a regular practice or whether it was only applied when there was a weaker spot there. In Potravlje, this seems to have been part of the standard production procedure.

The form, coiling method, and incorporation of clay coils was also observed. Thicker coils are predominant in all sites, and in the case of Zlakusa, they are more like whole chunks of fabric. Sometimes they are placed from the inside and 'twisted' from the inside of the vessel (attached with the back side of the fingers and hand so that they turn). After they are attached, the outer juncture is not usually visible, even after this primary attachment. At other times, the coils are laid down and pressed on top of one another, and the outer juncture is visible after primary attachment, although it is usually faint. It is then smoothed out by hand. In other cases, the coilss are only placed on top of one another and then smoothed out using medium rotation using the hand, a cloth or blade. The coils are most often placed from the inside, or from the top in an oblique direction from the inside and less frequently from the top onto the previous one. In rare cases, they are placed from the top in an oblique direction from the outside – this is done in cases where their placement contributes to the final shape of the vessel. In Potravlje, they are laid from the inside so that no change is visible from the outside at first. The coiling roll is then pushed and spread into the wall as it rotates while the shape grows in height.

The shaping of the vessel's body is most often carried out after the base is formed from coils to a cylinder and after the final shaping of the vessels is completed using wheel shaping by applying pressure with the hands, with a wooden tool or using a wet cloth. In other cases, the desired body shape is built from coils, which are slightly adjusted during the process or at the end especially at the bottom with a wooden blade. Final shaping with a wet cloth is applied only to the neck and rim.

The neck and rim are sometimes formed from a finished shape, while in other cases the shape of the coils is tapered at the top into a neck. However, a wet cloth is always used for the final shaping and smoothing.

In some cases, the walls of the vessels are thinned by trimming using a wooden blade. In other cases, the body is finished after the primary joining of the coils, and the surface is only smoothed. Thinning may be part of the production process, as was evidently the case in Potravlje. It may be applied sporadically, or due to the potter's lack of experience, when the final shape is thinned after he fails to produce a vessel with thin enough walls. This thinning is usually found at the bottom below the maximum bulge. Both the quality of clay and the size of the vessel can influence whether this process is necessary.

A wooden blade, usually with two edges, is a common tool for most producers. In Užice, Serbia (known as Bekuta), it is used with some exceptions only on the outside of the vessel to remove excess material, trim the bottom, smooth the walls, and sometimes join coils or profile the shape. The inside is smoothed and shaped with the fingers or even with a wet cloth (Blagojević 1974, 336). The use of a wet cloth is also typical of most manufacturers; this is the only stage in which water is used in production. Potters do not wet their hands during the production process; they may sometimes use hand wetting for the final smoothing of the shape, but this is usually done with a wet cloth. The cloth can be used to profile and smooth the neck and edges, but also to smooth and shape the whole body on both sides. In Užice, a piece of hemp cloth called 'rub' was used (Blagojević 1974, 336). Some potters also worked with metal blades or wooden ribs.

The analysis of the forming procedures that have been preserved in several villages in Serbia, Bosnia and Herzegovina, and Croatia has proven the variability of the wheel forming process of vessels using the hand wheel technique. Wheel coiling is a group of techniques that use forming via coils to produce vessels while engaging rotational kinetic energy at increasing rotation speeds; its subdivision is based primarily on the method of rotation applied. It is clear that more attention should also be paid to the form of the coils and the way they are placed and attached to the base of the vessel's body. The fact that the techniques could have occurred over a short period of time within a relatively small area essentially across the full range of defined wheel coiling procedures is also important. However, their details may differ, both from one village workshop to another or even between individual potters in the same workshop.

6.2.2 Ceramic fabric for the production of vessels for experimental research on forming techniques

An integral part of the experiment was the acquisition of ceramic mixtures suitable for various forming techniques and corresponding in character to medieval products. In addition to the properties of the fabrics themselves, the properties of the inclusions, especially of graphite, were addressed. Assessment took place mainly subjectively.

Loess is highly workable clays for the production of ceramics via coiling and wheel-throwing. Longer maturation and more adjustments are required for brickmaking, non-loess clays, which were probably a source for potters in areas where there was no loess or loess loam. For higher-quality production, finer clays and even kaolin deposits may have been sought out.

The suitability of regional brickmaking (non-loess) clays for the formation of ceramics was verified via experiment starting in June 2019. Clays had to be left to mature for several seasons before being processed via techniques known from ethnography. An essential part of the process was refinement via levigation to a coarseness of up to 2 mm and 1 mm. Compared to higher-quality loess and throwing clays, this material is less plastic and becomes wet faster. Thus, while the rotation speed needs to be lower, the vessel needs to be formed as quickly as possible. When wheel-throwing, it is possible to allow the shape to dry gradually, but this increases the risk of it cracking during drying or firing. Wheel coiling is a more appropriate technique for these low-quality fabrics, and it allows more time to be spent on the actual forming of the shape itself, as the clay initially does not need to be as wet and does not become soggy due to centring and drawing out the walls of the base body (Fig. 140).

The graphite inclusion affects the forming of the vessels in two ways – it affects the properties, or more precisely the plasticity of the ceramic fabric, as well as the forming itself. In the chapter concerning ceramic fabrics, we mentioned the function of graphite in absorbing excess moisture and thus improving the properties of the ceramic fabric during forming. For this reason, graphite temper may have been preferred over sand, which does not behave in this way. A similar property is exhibited by organic temper (Skibo, Schiffer, Reid 1989, 135–136). This ability of graphite should be seen as essential – adding a suitable amount to the fabric even just before production helped give the clay the necessary consistency for forming.



Fig. 140. Examples of vessels made from natural clays immediately after production: A – vessels made from clay stored in a modern-era pottery workshop in Telč; B – vessels made from loess from Šlapanice; C – vessels made from clay from Telč with a graphite addition; D, E – vessels made from loess from Šlapanice with a graphite addition. Photo by K. Těsnohlídková, K. Slavíček.

Over the course of the actual formation of the vessels, the sheet-like shape of the graphite was meant to facilitate the formation of a smooth, slippery surface (Rzeźnik, Stoksik 2004, 335–336; Gregerová et al. 2010, 131–138). This property is to be expected especially for fine graphite. We found that when using coarse brickmaking clay, the proportion of fine graphite would have to be relatively high to affect this property. On the other hand, coarser graphite grains could have damaged the vessel walls when applying rotational kinetic energy. However, for finer clays, coarse-grained graphite may have added durability during firing and for cooking vessel use, as well as more suitable properties for making vessels with coils.

Among other inclusions, sand and mica and their influence in the formation and firing of ceramics should be mentioned. The inclusion of sand was not dealt with in detail because it was naturally present in many clays, especially brickmaking clays.

A more frequent occurrence and higher coarseness of sandy temper is not problematic in the production of coiling ceramics or in wheel coiling, although it can pose problems for the fingers and abrade the skin as well as damage the walls of the vessels. By reducing the plasticity of the ceramic fabric, sand temper is said to help modify the properties of the clay so that it is easier to work with. A vessel created from coils using fabric with sandy temper is said to hold walls better and does not have to be allowed to dry continuously as often as if it were made of finer fabric. The inclusion of sand also makes the vessel more resistant to use in fire, as the analogies from the Balkans (Carlton-JRC films) show. Organic tempers and graphite are better suited for this usage based on other experiments (Skibo, Schiffer, Reid 1989, 135–140).

A high inclusion of mica or coarser mica in the ceramic fabric could have had an aesthetic significance in addition to its functionality. Although the

experiment was not directly focused on the use of mica temper, some observations can still be made. Only fabrics containing mica as a natural part of their sand component were used in formation. In particular, we have noticed the tendency of mica to concentrate on the surface and situate itself flatly on the surface of vessels, as reported by M. Gregerová and her colleagues (Gregerová et al. 2010, 132–152). The production of thin-walled ceramics with a high content of coarse mica flakes is technologically demanding and will be the subject of further experiments.

6.2.3 Experiments with the production of vessels via wheel coiling

The experiment for the project took place in 2023 and 2024. It was based on the reconstruction of the forming process of traditional hand wheel pottery from the Balkan Peninsula using local clays that corresponded in character to medieval pottery. Several dozen vessels were produced and fired during several field-documented firings, and samples were taken from them for detailed evaluation and comparison with archaeological material. A comparison was made using vessels made of the same materials and thrown on a potter's kick-wheel. The vessels were continually numbered and documented. Photographic documentation was carried out in natural daylight on a photographic table equipped with a size scale; some details were documented using a macro lens or binocular microscope (magnification was roughly up to 10 ×). Selected traces on archaeological pottery were documented in the same way.

For an evaluation of the selected samples, 3D analysis methods were used to compare the deviations of wall thickness in virtual cross-sections of the vessels and deviations while virtually rotating the vessel models along their axis. They were also used to monitor the orientation of particles on covered, thin sections using a polarizing microscope.

In the first year, the aim of the experiment was to verify the suitability of the procedure for the prepared ceramic fabrics and the effectiveness of the throwing wheels that were produced. Next, the production of pot-shaped vessels with profiles corresponding to the material from the kiln batches. The individual stages of the production process and the properties of the materials were monitored. If the fabric allowed for it, advanced wheel coiling techniques were used. From early 2024 onward, the production of vessels continued with the addition of knowledge from a detailed analysis of wheel-forming pottery on the Balkan Peninsula. Additional vessels were produced to verify some of the findings from the previous year. At the same time, several questions were identified for the continuation of the experiment that could not be implemented due to capacity constraints. During the spring and summer of 2024, all experimental vessels were fired in various field firings.

Most of the vessels in this experiment were made by E. Nová from the DANAR, Historical Crafts organisation, but other potters and ceramics producers also participated in the experiments with forming (Fig. 141). Two potter's throwing wheels and a kick wheel made according to iconographic and ethnographic models by A. Nový from DANAR were used to make the vessels (Fig. 142; Těsnohlídková 2021, 21–26). Research into the production of pottery via wheel coiling in the Balkan peninsula and older ethnographic studies also demonstrate variability in the forms of equipment for shaping vessels via wheel coiling. For this experiment, a turntable joined by four crossbars to a cross-shaped base was made and mounted on a wooden axis fixed on a bench, and a solid board mounted on an axis that was fixed onto a wooden base as well (Fig. 142: C; 143).

The chosen process of vessel production was based on the procedures used mainly in Zlakusa, where the relatively highest number of complete records of the forming process was available (Fig. 144; 145). In the first part of production, a bottom was created by kneading a lump of clay and strongly striking and slapping it to work any bubbles out of the fabric. The lump was then formed into a flat cake between the palms of the hands. Dusting was applied to the turntable, a flat piece of clay was dusted on one side and then placed in the centre of the throwing wheel with the dusted side down. Using slow rotation, it was secured to the turntable by striking it with the palm. Then, with faster rotations, the circumference of the bottom was marked with a slight incision in the fabric using a potter's wood knife. The fabric outside this circumference was pressed against the turntable with the fingers, and its function was to keep the vessel attached to the turntable during production. Subsequently, the centre of the bottom was marked with a depression during rotation (Fig. 144: A–D).

The base of the wall was formed by drawing out the clay in a slight rotation with the thumb of one hand towards the palm from the surface of the bottom from the centre towards the edge. During faster rotation, when one hand was used solely to rotate the turntable, the pad of the index finger of



Fig. 141. Potters and ceramists who participated in the experiments presented in this book: A – E. Nová shaping vessels by wheel coiling on a potter's wheel; B – M. Cvejn making vessels by throwing on a kick wheel; C – T. Přichystalová making vessels by throwing on a kick wheel; D – A. Netopilová shaping vessels by clay coiling. Photo by K. Těsnohlídková.

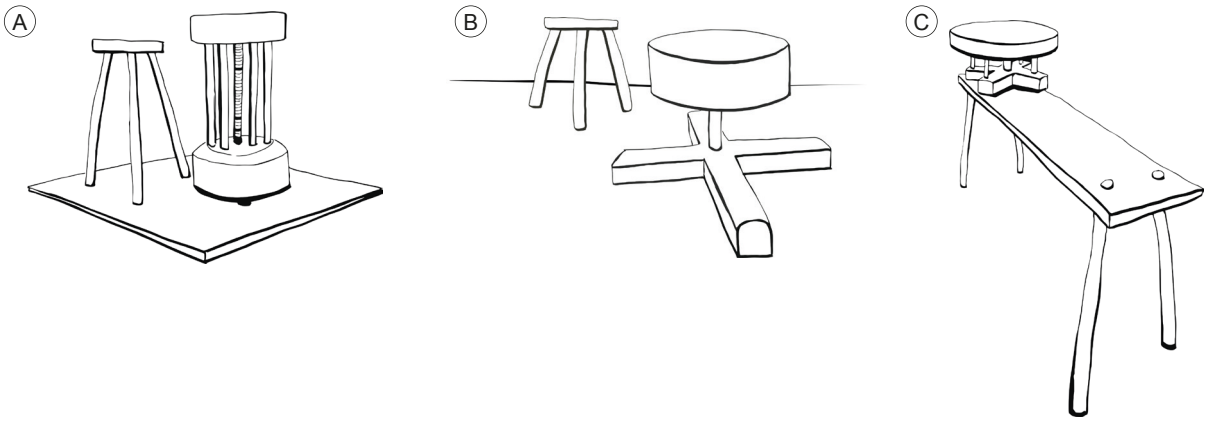


Fig. 142. Potter's wheel (A) and two turntables (B, C) used in experiments with profile throwing based on iconographic and ethnographic sources. Drawings by K. Hamáková.



Fig. 143. Potter's turntable made according to analogies of devices most commonly used for hand-wheel pottery production on the Balkan Peninsula. Photo by K. Těsnohlídková.

the other hand was used from the centre to the edge to straighten out the bottom, making it uniform (Fig. 144: E–G).

From a lump of clay, a coiling roll, which was rather quite thick, was then formed without the use of the wheel. This coiling roll was then pushed and pressed with one hand to the inner circumference of the wall in a spiral pattern while the other hand held the edge of the body – the hands pushed towards one another, causing the wheel to slowly rotate spontaneously (Fig. 144: H; 143: B, C). After that, another coiling roll was added. When necessary, the body was balanced during construction using the pressure of the fingers and a palette knife using rapid rotation. The body was built straight, but the shape was narrowed at the top as required (Fig. 145: D–F). Then, one hand was used to turn the wheel while the other hand flattened and smoothed the inner and outer surface with a palette knife or scraper. The vessel was kept centred, and the pressure of the palette knife or fingers from the inside could be

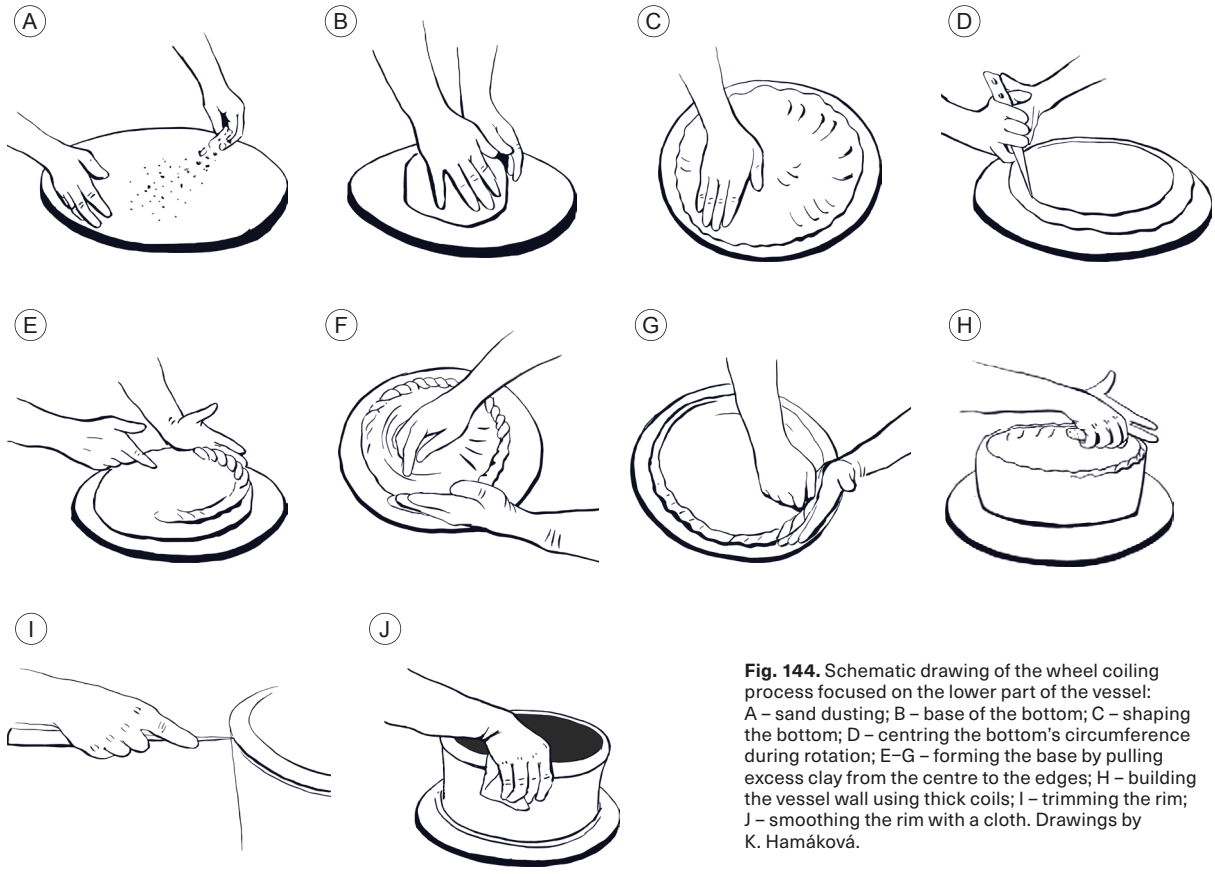


Fig. 144. Schematic drawing of the wheel coiling process focused on the lower part of the vessel: A – sand dusting; B – base of the bottom; C – shaping the bottom; D – centring the bottom's circumference during rotation; E–G – forming the base by pulling excess clay from the centre to the edges; H – building the vessel wall using thick coils; I – trimming the rim; J – smoothing the rim with a cloth. Drawings by K. Hamáková.

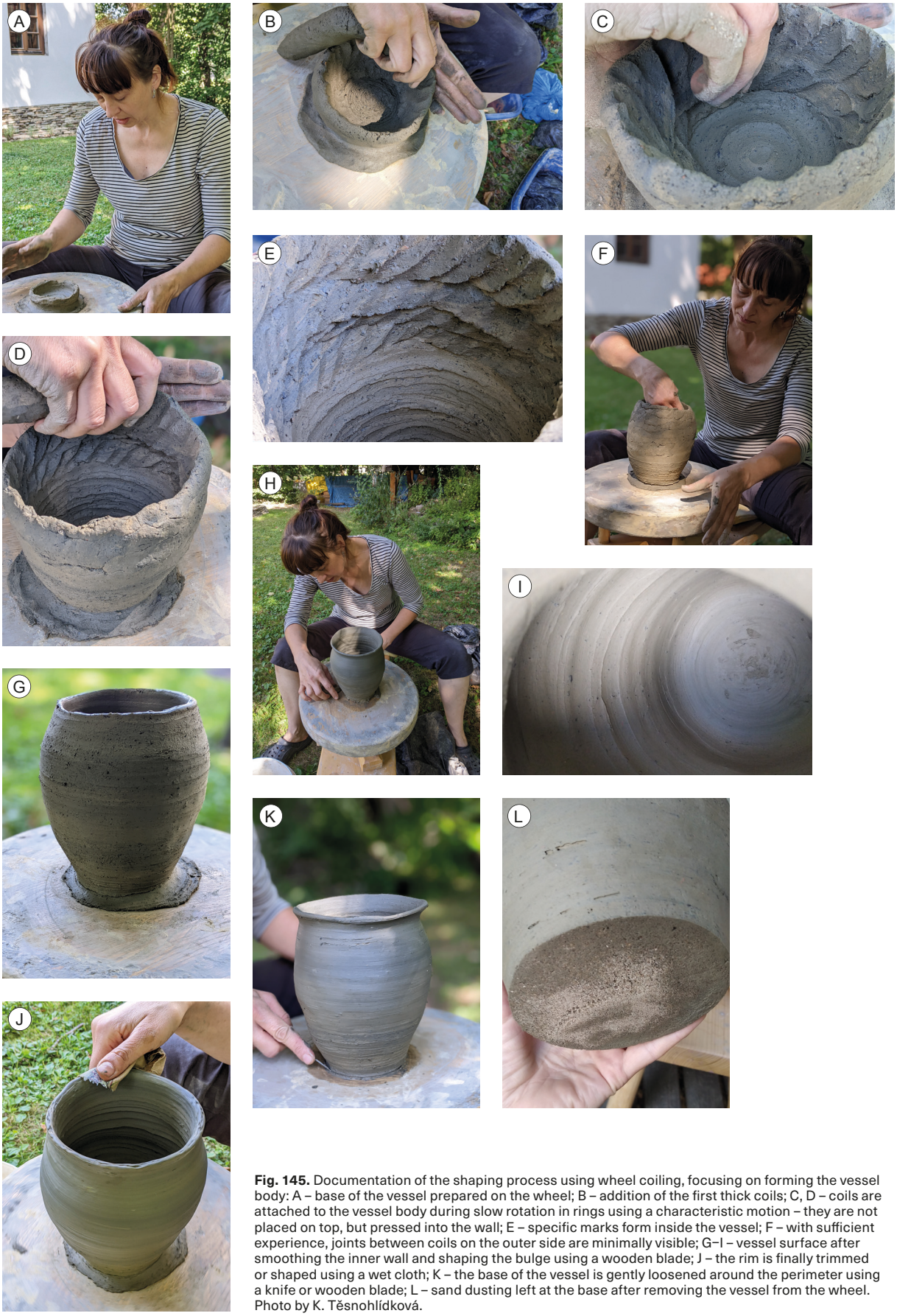


Fig. 145. Documentation of the shaping process using wheel coiling, focusing on forming the vessel body: A – base of the vessel prepared on the wheel; B – addition of the first thick coils; C, D – coils are attached to the vessel body during slow rotation in rings using a characteristic motion – they are not placed on top, but pressed into the wall; E – specific marks form inside the vessel; F – with sufficient experience, joints between coils on the outer side are minimally visible; G–I – vessel surface after smoothing the inner wall and shaping the bulge using a wooden blade; J – the rim is finally trimmed or shaped using a wet cloth; K – the base of the vessel is gently loosened around the perimeter using a knife or wooden blade; L – sand dusting left at the base after removing the vessel from the wheel. Photo by K. Těsnohlídková.

used to slowly expand the belly as the other hand alternately turned the wheel and exerted counter-pressure from the outside of the vessel body with greater pressure on the inner wall (Fig. 145: G–I).

Finally, the rim of the vessel was shaped. In the first stage, the edge was trimmed with a small knife while rotating it. It was then smoothed and shaped using a wet cloth, and the neck was also finished at this stage (Fig. 144: I, J; 145: J).

The vessel was removed from the turntable with a knife, the sharp-edge of a palette knife or a pointed scraper, whereby a cut was made through the layer of clay around the circumference of the vessel bottom at the level of the turntable while rapidly spinning the wheel, thus separating the hitherto joined bottom of the vessel from the residual clay that had been pressed on. Excess clay is then removed. The vessel can then be easily removed from the turntable (Fig. 145: K, L). In the last stage, the surface could be decorated and the ear could be glued on.

In the case of the fabrics that were chosen for the production of the vessels in the experiment with clays (loess and non-loess brickmaking clays without any other inclusions), it was not possible to carry out the whole procedure without wetting the hands, as is the rule for essentially all ethnographically observed potters. This may be influenced by the different properties of the material used, especially its plasticity and clay mineral content, but also its consistency. Brickmaking clays also proved to be not highly plastic – they would quite frequently tear and collapse, and the adhesion of the coils was less than perfect. On the other hand, the properties of loess proved to be ideal for this technique.

It was important to constantly monitor the centring of the shape, which was successful depending on the practice and experience of the potter with this forming technique. This can be made easier by consistently resting one or both hands on the thigh during production, allowing more stable pressure to be put on the vessel.

Squeezing on the clay coils in a spiralling motion was effective. By doing so, the clay coils adheres very well to the already built-up wall of the vessel and the traces of its adhesion are relatively unnoticeable (Fig. 144: G, H; 145: B–D). Another important factor is that thicker coils can be used, which are pressed into the inner wall. This is a significantly more effective method for this technique than the traditional approach of stacking thin coils on top of each another, which is probably more suitable for basic forms of coiling than its profiling variants. It seemed simpler to finish each coiling roll at the same height in a plane, i.e. to add rings to the base of the vessel and continuously smooth and level it than to build the body of the vessel from coils into a spiral. Ideally, the walls are already built relatively thin, and there is no need to taper them by scraping off fabric in the final phase. If the walls need to be thinned, this is usually done in the final phase of production by scraping with a wooden blade from the outer side of the vessel.

It was preferable to finish forming the neck and rim before the final finishing of the vessel body to avoid deformation. Overall, one needs to work fast, as the vessel collapses if a longer time is spent, especially in the neck area. This phenomenon takes place faster if more water is used when shaping the body.

6.2.4 Macroscopic traces on vessels related to the forming technique

A long-term part of the experiments consisted of monitoring the traces on the surface of the vessels in relation to the production technology. A catalogue with a detailed description of macroscopic features on pottery based on this research has already been published (Těsnohlídková 2022), and new traces on archaeological pottery are being continually added to it.

Experiments have confirmed that the widest range of traces is created by coiling, including its profiling variants. Generally speaking, these are various manifestations of imperfect joining of the clay coils or traces of insufficient smoothing. In the case of coils, we can encounter various techniques that involve placing them on top of each other and joining them, and the body can be made of rings or coils. The coils themselves can take different forms, especially in terms of thickness. These techniques have been discussed in more detail in terms of medieval production in the Czech lands, e.g. by P. Macků (2016, 82–89). The coiling roll marks seen after coiling is carried out may be accompanied by traces of slow rotation (Fig. 146). In wheel coiling, we encounter imperfectly smoothed coils most often in the lower part of the vessels or in the area between the neck and the maximum bulge, which are less accessible during the final smoothing process. The traces are more visible on coarser material (Fig. 147).

Vacuoles, lines, or grooves are distinctive features indicating the presence of clay coils, and these features occur irregularly. Grooves provide evidence of the use of coils throughout the whole inner surface. They may occur throughout the vessel or only on a specific part of the vessel, usually at the bottom



Fig. 146. Basic technological features on the interior surface of a vessel made from coils using slow rotation (coiling): A – vessel made from coils with slow rotation; the inner wall shows vacuoles, grooves, lines, as well as fine cracks along the coils. In the profile, imperfectly joined coils are visible in places, especially at the neck and rim; B – lines, fine cracks; C – vacuole, lines, fine cracks; D – lines, grooves; E – lines (scale in cm). Photo by K. Těsnohlídková.

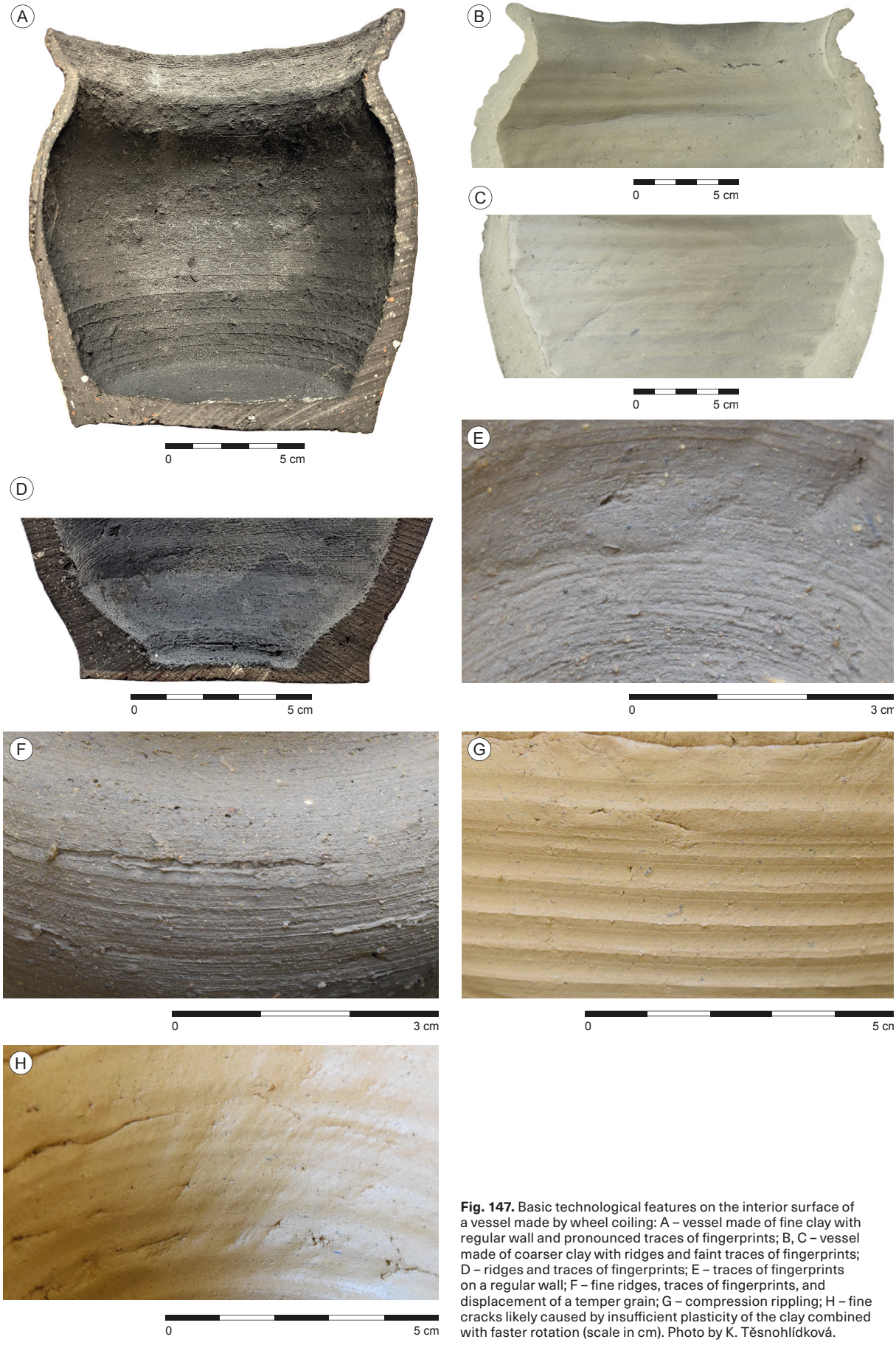


Fig. 147. Basic technological features on the interior surface of a vessel made by wheel coiling: A – vessel made of fine clay with regular wall and pronounced traces of fingerprints; B, C – vessel made of coarser clay with ridges and faint traces of fingerprints; D – ridges and traces of fingerprints; E – traces of fingerprints on a regular wall; F – fine ridges, traces of fingerprints, and displacement of a temper grain; G – compression rippling; H – fine cracks likely caused by insufficient plasticity of the clay combined with faster rotation (scale in cm). Photo by K. Těsnohlídková.

or on the shoulders in the inner wall. In contrast to the ridges that are characteristic of wheel-throwing, they are more sharply defined and can be regular or irregular. The presence of coilsor joints between them can sometimes be recognised on the fractures of fragments. Horizontal cracks may form at the joints between the coils, and in extreme cases the vessel may break and fragments may partially copy the lines of the coils. In the final phase of the forming process, the potter may smooth out many traces depending on the care that is taken and the requirements of the market. The more pronounced the rotation is during wheel coiling, the greater the risk of the complete removal of macroscopic traces of the use of coilsin the walls. The technique can then only be revealed by detailed analyses concerning, for example, the orientation of particles in the vessel wall (Fig. 146, 147).

The range of traces from wheel-thrown vessels is poorer than that of pottery made from clay coils (Fig. 148). These traces are related to the influence of rotational kinetic energy on the mass of ceramic fabric. In addition, wheel-thrown pottery is more often associated with fine ceramic fabric, where we generally encounter fewer traces of the forming process. Wheel-thrown pottery is characterised by a regular wall with a uniform thickness, but fairly distinctly corrugated walls with so-called ridges may also appear. These ridges are symmetrical and relatively regular thickenings in the wall – the grooves between them correspond to the pressure of the fingers or an auxiliary tool on the inner wall of the vessel during rapid rotation. Transitions between the ridges are rounded.

A widespread feature proving the use of rapid rotation are the traces created by the action of the papillary lines of the fingers or the tool used for smoothing. These are more visible in fine fabrics. The up-and-down movement of the ceramic fabric under the action of rapid rotation may also result in characteristic fishbone-like fracture marks. Evidence of over-throwing of the fabric can be seen in compression incisions found in the form of oblique wall corrugations. Distinct or fine cracks and tears can be caused by insufficient plasticity of the clay at high rotation. Particularly in coarser materials, incisions may occur locally due to the displacement of larger grains of non-plastic inclusions through the vessel wall. These have a characteristic shape, i.e. they gradually deepen, and sometimes the grain may be present at the end (Fig. 147: C, D, F ; 148: F, G).

In terms of the techniques listed above, we should also mention features related to the technique of extracting a vessel from a single piece of material using slow rotation, which can be encountered, for example, in the case of lids. In this context, we find marks similar in part to wheel-throwing, e.g. impressions made by papillary lines. However, the shifts in fabric are slower and less uniform; in this context, traces of squeezing or extraction of the material may be visible. There may also be so-called pulls – these have a vertical or oblique direction. The bottoms of the vessels also provide important evidence for the forming technique. In all of the aforementioned techniques in the Middle Ages, the bottoms were usually created from a single piece of material. Traces should be observed in three places on bottoms – namely on the outside and inside, and also at the transition between the bottom and body.

The traces at the transition between the bottom and the body may indicate the method in which the bottom was attached to the body, but also the production equipment, where sometimes at this point we encounter the remnants of a strip after the vessel was attached to the production plate or traces of its trimming on the outer side of the wall. From the inside, the so-called 'coil on bottom' is often present in these places. We also observe a more pronounced wall rippling, probably due to an attempt to achieve stability during subsequent vessel production. This may be an actual coiling roll or traces of the bottom fabric being extracted to join it to the first coiling roll; however, the aforementioned phenomenon is also caused when a thicker wall is left at the bottom of the vessel during wheel-throwing. These cases can be distinguished only in some cases, based on the way the coiling roll transitions into the next wall of the vessel or the way it is joined to the actual bottom. During wheel-throwing, compression 'over-throwing' may occur at the transition of the body and bottom (Fig. 149).

The marks on the inside of the base and on the inner walls of the vessels are partially identical, especially in the case of bottoms made of coilsor the production of a bottom during rotation. In the case of wheel-thrown pottery, the bottom was probably most often made by pressing a lump flat on the turntable, then squeezing or laying the now flattened lump on the plate and attaching it to the base circumference (basic and wheel coiling). The foundation of the wall could then have been formed from the fabric of the bottom. Shaping and straightening the bottom was then completed during rotation. This bottom may

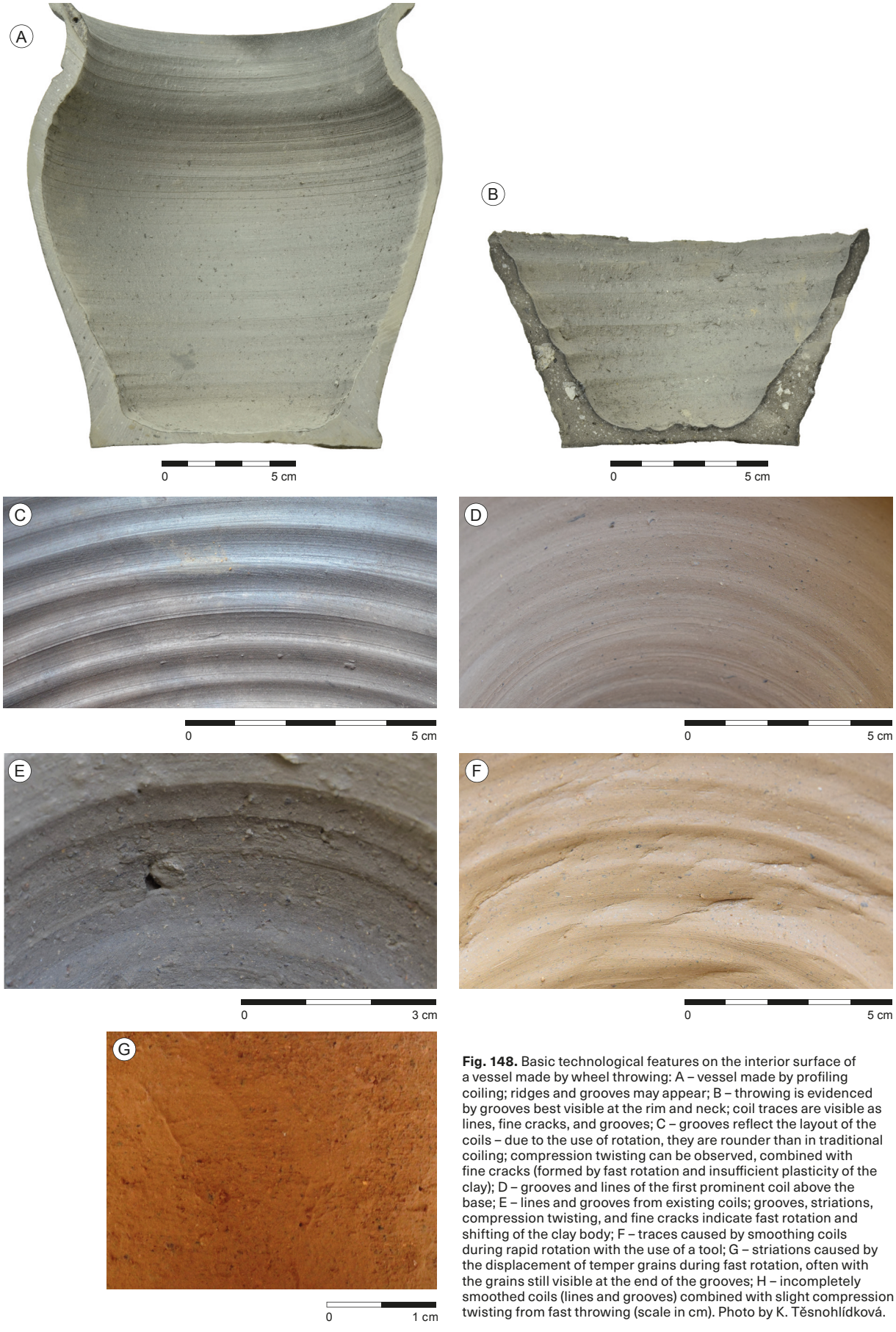


Fig. 148. Basic technological features on the interior surface of a vessel made by wheel throwing: A – vessel made by profiling coiling; ridges and grooves may appear; B – throwing is evidenced by grooves best visible at the rim and neck; coil traces are visible as lines, fine cracks, and grooves; C – grooves reflect the layout of the coils – due to the use of rotation, they are rounder than in traditional coiling; compression twisting can be observed, combined with fine cracks (formed by fast rotation and insufficient plasticity of the clay); D – grooves and lines of the first prominent coil above the base; E – lines and grooves from existing coils; grooves, striations, compression twisting, and fine cracks indicate fast rotation and shifting of the clay body; F – traces caused by smoothing coils during rapid rotation with the use of a tool; G – striations caused by the displacement of temper grains during fast rotation, often with the grains still visible at the end of the grooves; H – incompletely smoothed coils (lines and grooves) combined with slight compression twisting from fast throwing (scale in cm). Photo by K. Těsnohlídková.

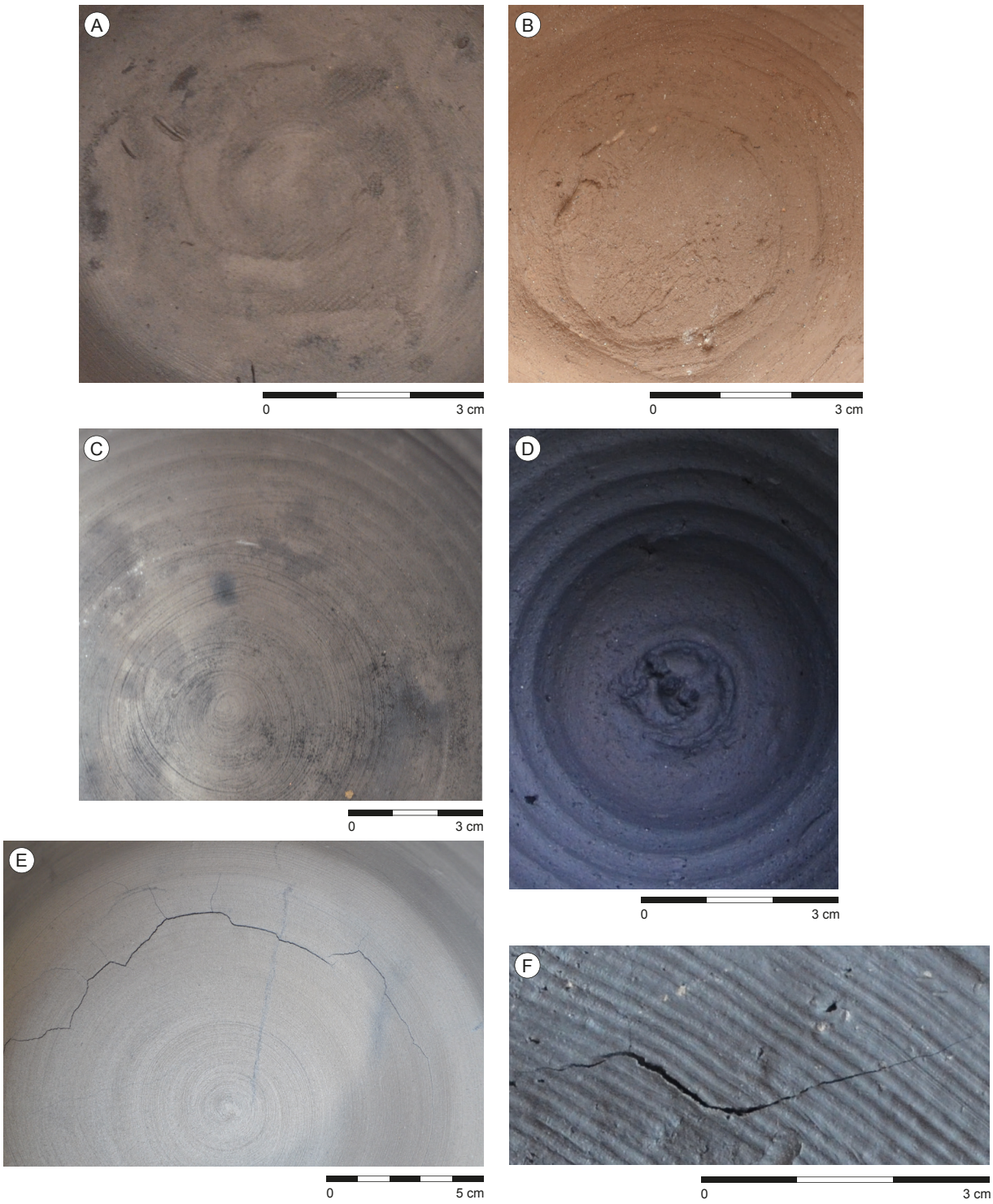


Fig. 149. Bases with macroscopic traces related to vessel forming technology (interior surface and defects). 1. Bases made by coiling: A – grooves, lines, and indentations; B – grooves, voids (vacuoles), indentations. 2. Bases made from a single lump during wheel throwing: C – traces of fingerprints and concentric ridges on fine clay; D – unsmoothed centre of the base during throwing, forming a so-called 'scroll' pattern. 3. Cracks on bases made from a single lump of clay: E – transverse cracks; F – transverse S-shaped crack (scale in cm). Photo by K. Těsnohlídková.

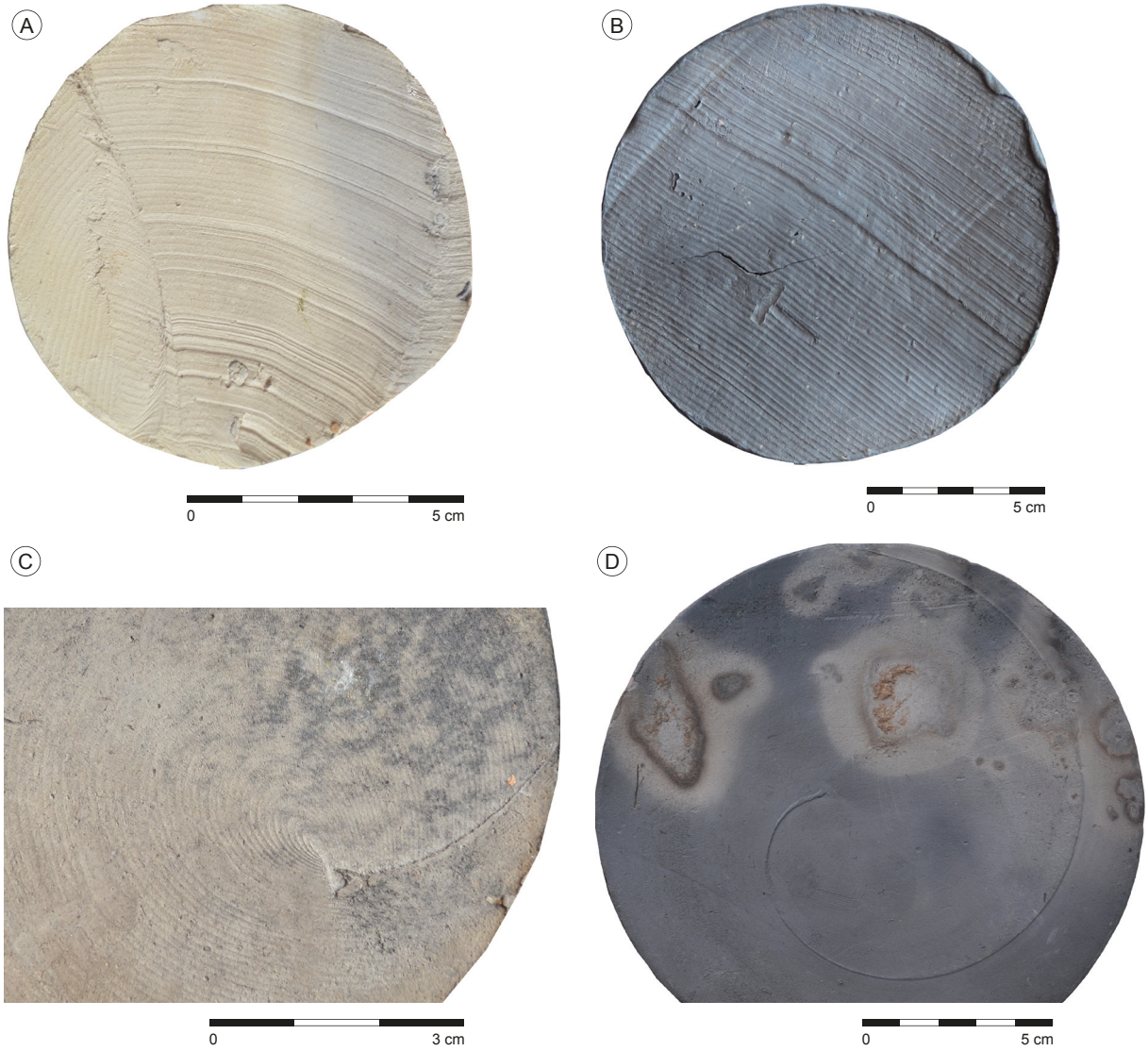


Fig. 150. Bases of vessels with macroscopic traces (outer side and rim) – wheel-thrown pottery: A, B – traces of base cutting with a knife; C, D – traces of base cutting with a string (scale in cm). Photo by K. Těsnohlídková.

be uneven in area and may contain squeeze grooves, and the prominence of these traces is related to the degree of rotation used (Fig. 149).

In wheel-thrown pottery, the bottom is traditionally made from a single piece of fabric in one phase during the forming of the vessel. The use of rotation is evidenced by fingerprint traces, incisions, ridges, slight corrugation (concentric), or the so-called navel, ring, or scroll. Occasionally, the bottom may have been pasted onto the vessel body created via throwing – evidently when it was thinned too much during wheel-throwing or damaged by improper removal of the vessel. This technique can also be considered in the case of more complex shapes, in which different techniques may have been combined (Fig. 149).

The traces on the outside of the bottoms are related to the form of the upper plate of the production equipment or the removal of the vessel, and they are therefore a valuable source for technology analysis. They have often been obliterated by abrasion during vessel use, e.g. graphite ceramics or ceramics fired at low temperatures are more susceptible to abrasion. However, such traces can be assumed to be highly intact on vessels from failed pottery kiln batches that never entered circulation (Fig. 150–152).

Based on ethnographic analogies, bottoms with traces of dusting and imprints of potter's marks are attributed to pottery produced via wheel coiling. The bottoms of vessels made by wheel coiling are characterised by the dusting marks on the bottom's surface and, around the circumference, traces of the

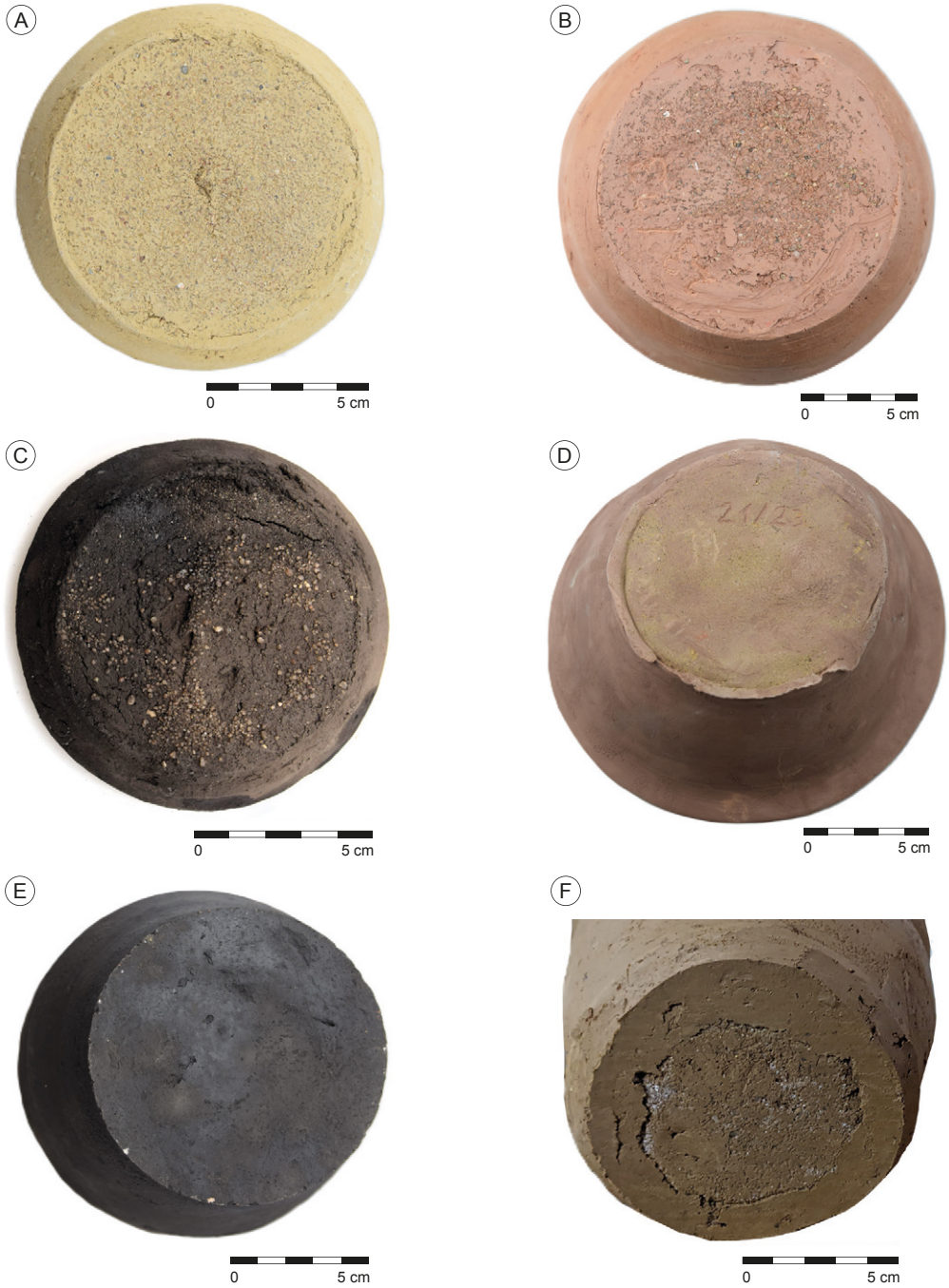


Fig. 151. Bases with macroscopic traces (outer side and rim) – wheel coiling: A – sandy dusting; along the rim, traces of the base adhering to the wheel head (dusting applied to the clay body); B – sandy dusting; along the rim, traces of cutting the base off the wheel head (dusting applied to the wheel head); C – sandy dusting; rim shows traces of the base sticking to the wheel head; D – fine sandy dusting and a characteristic trace along the rim indicating the attachment of the dusted base to the wheel head; E – base without dusting, formed by spontaneous detachment from the wheel during drying; F – base secondarily pressed into a surrounding ring (scale in cm). Photo by K. Těsnohlídková.

bottom's edges being joined to the throwing wheel or, conversely, of the cutting off/removal of the edges (Fig. 151: A–D).

In the past, the possibility of using dusting in wheel-throwing has been experimentally addressed (Bernhardt 2011; Bočková et al. 2014, 124–128). Only partial adhesion of the bottom (circumferentially) to the production turntable reduces the efficiency of the use of rapid rotation but does not make it impossible. Thus, by means of throwing, it is possible to produce vessels on a dusted turntable with the material of the bottom fixed only on the edges, and this procedure could be evidence of the transition between the two technologies.

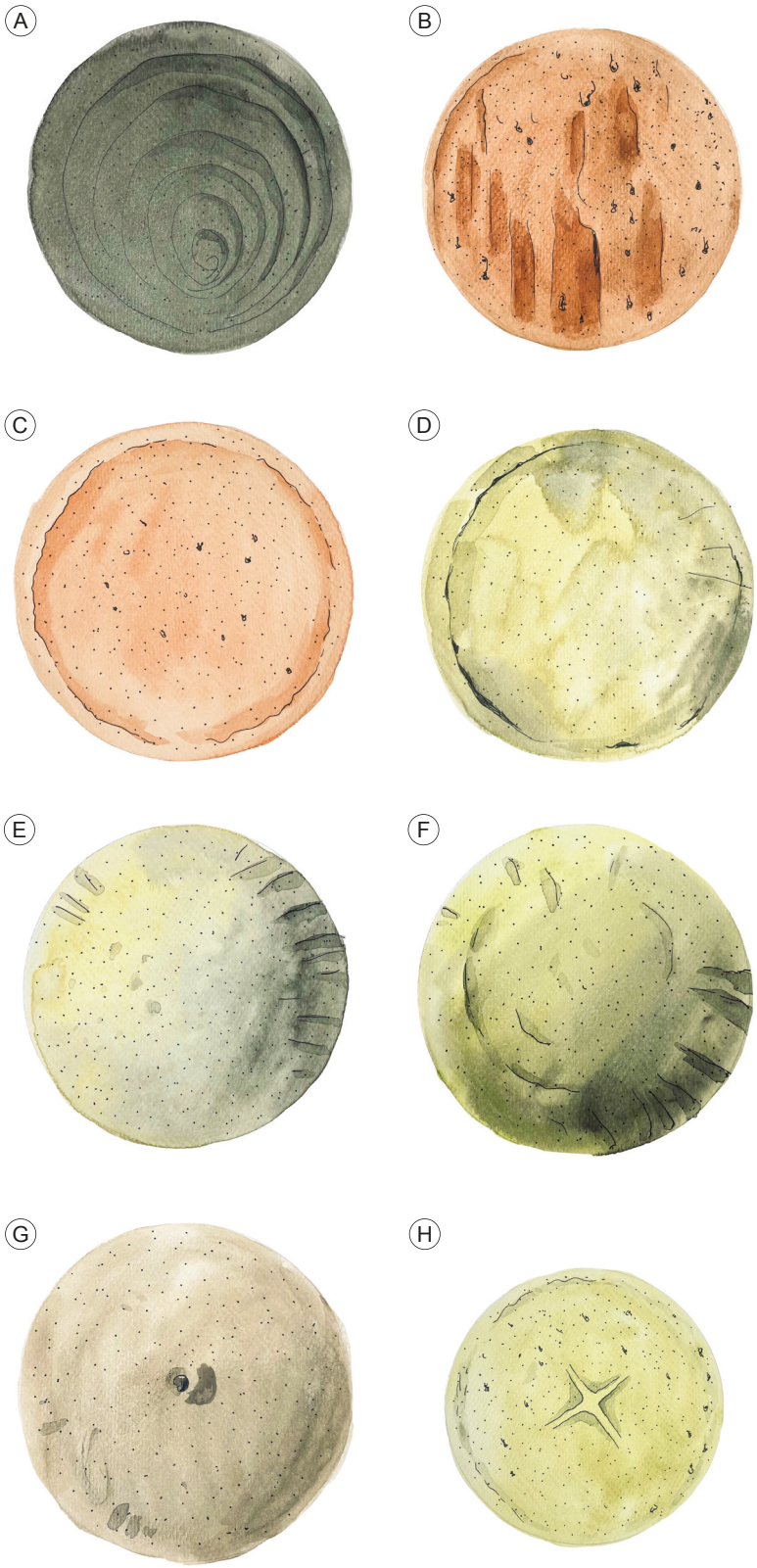


Fig. 152. Graphics depiction of basic types of the outer base surface: A – cut off with string; B – cut off with knife; C, D – sandy dusting with variously distinct traces around the rim from attachment to the wheel head (including possible folding of clay causing an inserted base effect); E, F – sandy dusting with various distinct traces around the rim from cutting off from the wheel head; G – sandy dusting and imprint of the wheel axis; H – sandy dusting and potter's mark imprint. Drawings by K. Hamáková.

Pot ID	Clay	Temper	Shaping technique	Firing
1/23	Šlapanice (loess)	Graphite	Wheel coiled	1-23, Pottery kiln 4
125/20	Telč (clay from early-modern pottery storage)		Wheel coiled	3-24, Pottery kiln 4
14/23	Šlapanice (loess)	Graphite	Wheel coiled	3-24, Pottery kiln 4
16/23	Šlapanice (loess)	Graphite	Wheel coiled	Pottery kiln at Orlík near Humpolec (oxidising firing, 2024)
2/23	Šlapanice (loess)	Graphite	Wheel coiled	1-23, Pottery kiln 4
26/23	Šlapanice (loess)	Graphite	Wheel coiled	1-24, Open-fire
27/23	Šlapanice(loess)	Graphite	Wheel coiled	3-24, Pottery kiln 4
3/23	Šlapanice (loess)	Graphite	Wheel coiled	3-24, Pottery kiln 4
7/23	Šlapanice (loess)	Graphite	Wheel coiled	3-24, Pottery kiln 4
8/23	Šlapanice (loess)	Graphite	Wheel coiled	Pottery kiln at Orlík near Humpolec (oxidising firing, 2024)
X13/21	Šlapanice (loess)	Graphite	Wheel throwing	1-21, Pottery kiln 3
X14/21	Šlapanice (loess)	Graphite	Wheel throwing	1-21, Pottery kiln 3

Tab. 35. List of experimentally produced vessels for the analysis of particle orientation and axial symmetry (raw material, temper, forming technique, firing).

On the outer side of the bottom, an imprint of the wheel's axis or technological mark may also appear. These are negative (impressed) traces that could be preserved, for example, even after they are cut off, but are more often known from vessels with dusted or rough bottoms. These features are related to the form of the forming device's turntable or potentially also to damage to it (Fig. 152: G, H; Hlavica et al. 2016, 381–407).

It is also possible to assume that the vessel was left to dry on the upper table of the wheel or the throwing wheel, or that it was removed from the forming device on an auxiliary plate and, after slightly drying, it could be removed or became unstuck from the table on its own. The traces on the bottom would then correspond to the imprint of the forming device's turntable or auxiliary plate, a procedure suitable for preserving the imprint of a potter's mark. This technique is known from the ethnography of ceramics made via wheel coiling, but it can also be effectively used for wheel-thrown pottery (Bočková et al. 2014, 124–128; see Scharrer-Liška 2007, 23–24).

Wheel-throwing technology requires the fabric to be firmly attached to the forming device. Vessels usually show traces of being cut off. We can distinguish between cutting off with a knife or string (Fig. 150). In contrast to this, the simple coiling did not even require the vessel to be attached, and the dusting could be spread all the way to the edge of the bottom, or the vessel could have been placed simply on the production table, as the adhesion was not strong enough to prevent it from being removed when it was finished, or a knife was used to cut around the circumference of the bottom and its edge was then cut off.

Cracks may appear on the bottoms, and sometimes the vessel may not have cracked completely and was still usable for various purposes. Annular cracks may also appear along the circumference of the vessel, which is not necessarily evidence of the use of coils or a subsequent insertion of the bottom into the vessel. This can be caused by differing wall and bottom thicknesses, which is the transition point between the bottom and the body. On bottoms from a single piece of fabric, transverse cracks, often s-shaped, are more likely to form during drying and firing (Fig. 149: E, F).

6.2.5 Wheel coiling – 3D and orientation on thin sections

As previously discussed, higher levels of the wheel shaping technique might not leave any macroscopic traces on the vessel, and the vessel may appear to be shaped from a single lump of clay. A possible clue to the original technique can be found in the presence of a base with a sanded joint. Even in this case, however, the interpretation may not be wholly straightforward. One of the goals of producing experimental vessels was therefore to verify whether this technique can be demonstrably identified or determined using archaeometric methods, to find out whether these methods could be suitable in the future for determining the manufacturing technology of archaeological ceramics, and whether they could also help identify the different stages of the wheel coiling technique.

Twelve samples of pot-shaped vessels were selected for analysis (Tab. 35; Fig. 153). Nine of these vessels were made using the wheel shaping method. The chosen manufacturing procedure corresponded



Fig. 153. Experimentally made vessels for the analysis of particle orientation and axial symmetry: a – 1-23; b – 125-10; c – 1g-23; d – 16-23; e – 2-23; f – 26-23; G – 27-23; h – 3-23; i – 7–23; j – 8-23; k – X13-21; l– X14-21. Photo by M. Košťál.

to techniques preserved in the Balkan Peninsula, with minor adjustments made according to the properties of the ceramic material, as described in the previous chapter. As a comparison, three vessels made using the technique of throwing from a single lump of clay were selected. The selected vessels were made of ceramic materials with coarse temper or tempered with graphite in order to observe the orientation of particles in the ceramic matrix.

Particle orientation analysis

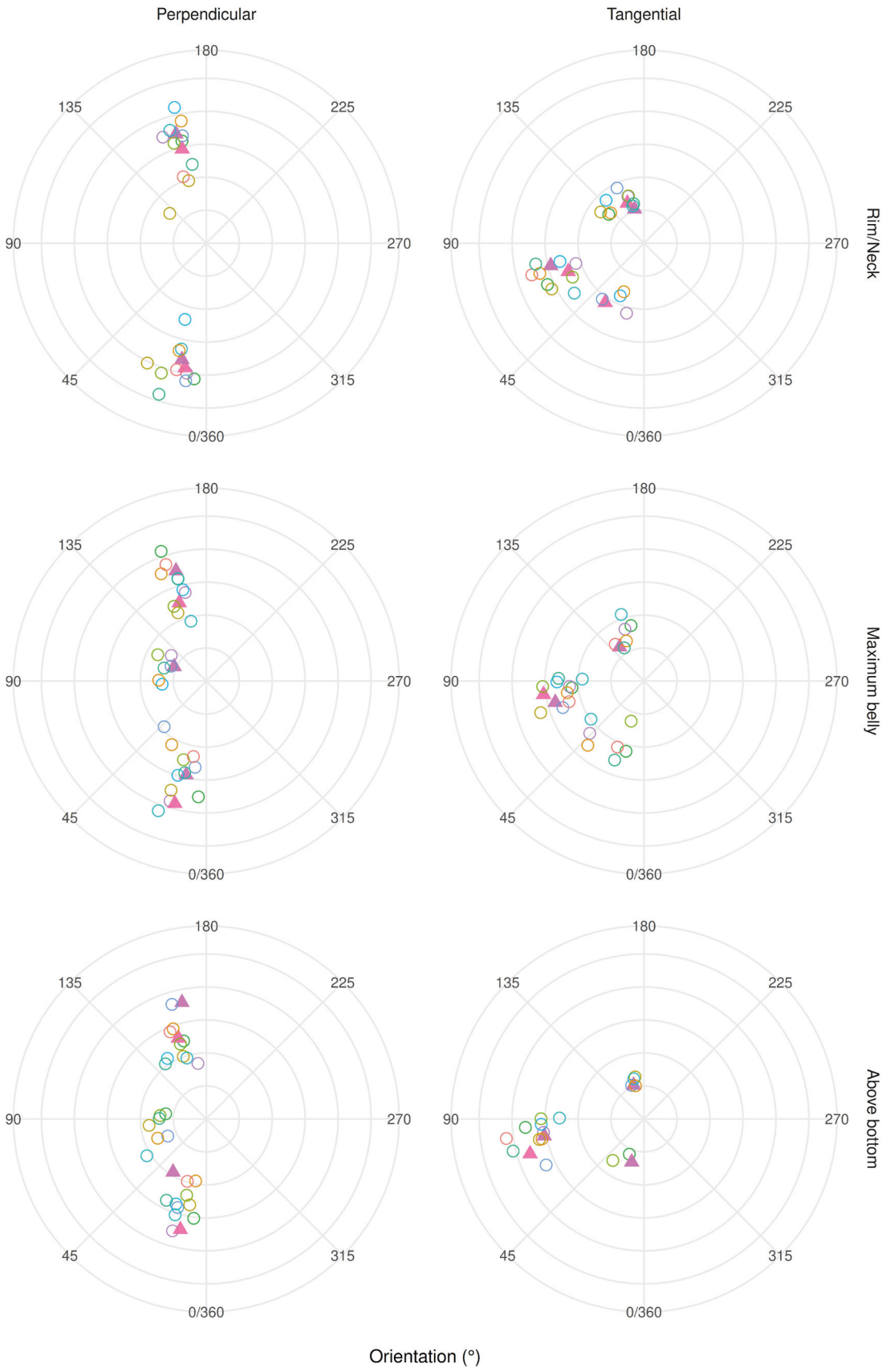
Across all sections, two to three dominant directions of inclusion and void orientation were consistently observed (Tab. 36). In perpendicular sections, the most prominent directions were aligned close to the vertical axis of the vessel (i.e. with averages between 11–22° and 159–165°). In the maximum belly and above-bottom sections, an additional third direction was also detectable, appearing around 80–130°. Notably, this third orientation was absent in above-bottom sections of wheel-thrown vessels, suggesting that it may offer a useful criterion for distinguishing between forming techniques (Graph 26). In tangential sections, the most frequent preferred orientation ranged between approximately 70–83°, while angles aligned with the vertical axis were not strongly pronounced (i.e. 16–33° and 148–165°). The greatest potential for differentiating between wheel-coiling and wheel-throwing techniques emerged in the maximum belly section, where no preferred orientation was observed within the range of lowest angles in wheel-thrown vessels.

The average wall thickness in wheel-coiled vessels tends to decrease from the base toward the rim. This trend was observed in nearly all experimentally produced vessels. Equally noteworthy is the variability in wall thickness at different parts of wheel-coiled vessels. Specifically, higher – and in some cases markedly higher – variability is often found just above the base (see Graph 27: 1_23, 16_23, 7_23). This is supported by the coefficient of variation, which exceeds 20% in half of the wheel-coiled vessels (Graph 28; Tab. 37). The degree of wall thickness variability tends to decrease toward the rim. On the other hand, some wheel-coiled vessels with thinner walls exhibit very low thickness variability (Graph 27: e.g. 125_20, 3_23).

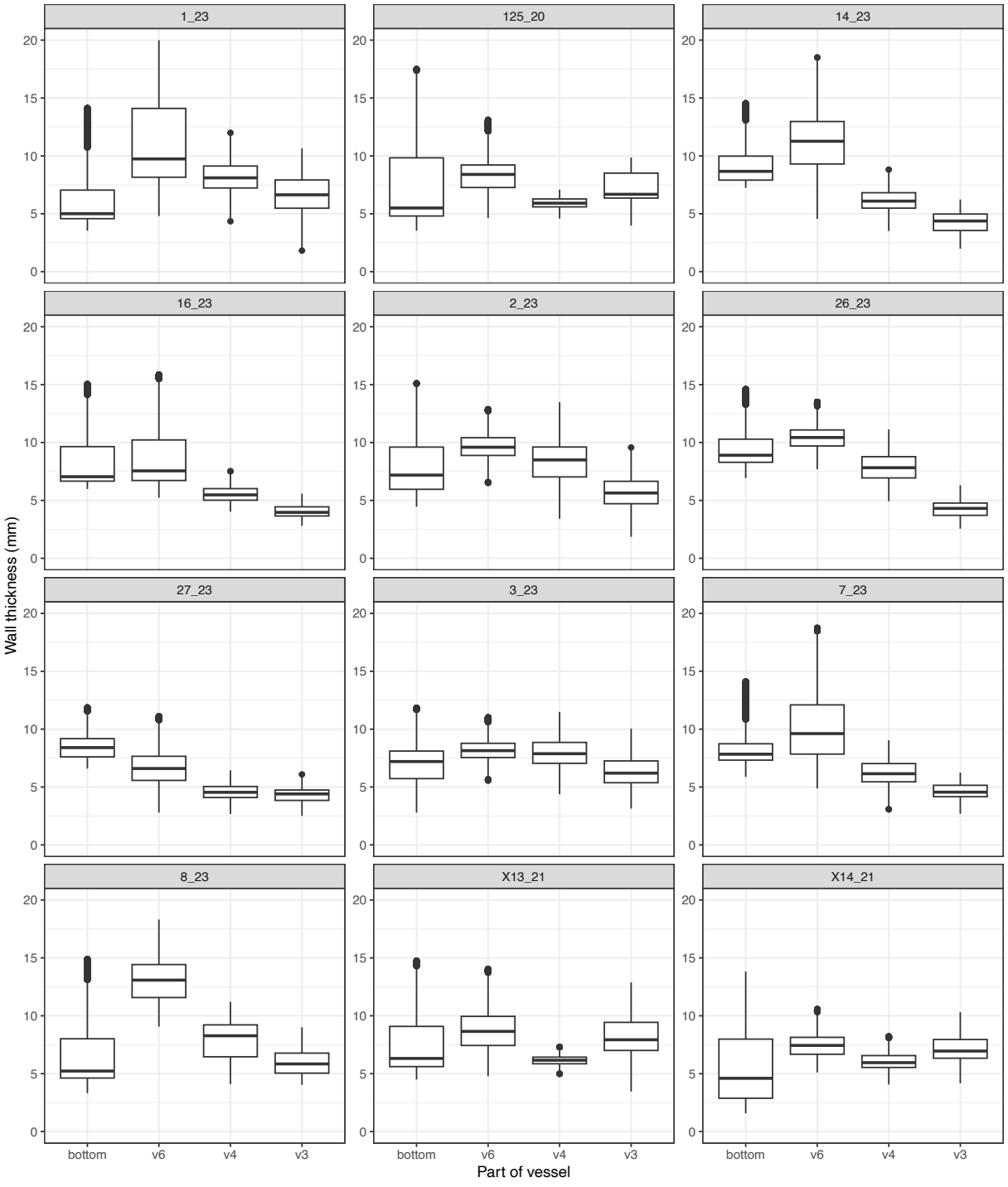
Wheel-thrown vessels show wall thickness comparable to that of most wheel-coiled vessels (Graph 27: X13_21, X14_21), but their thickness variability is generally lower. A particularly low level of variability appears to be characteristic of the section between the maximum belly diameter and the neck, where it is lower than in other parts of the same vessel. Wheel-coiled vessels did not reach such uniformity in this segment, which may represent a diagnostic feature useful for distinguishing between the two forming techniques. Additionally,

			Wheel coiling		Wheel throwing	
Section position	Section plane	Direction cluster	Angle (mean)	Angle (SD)	Angle (mean)	Angle (SD)
Rim/Neck	Perpendicular	Cluster 1	14.1	5.7	10.8	1.1
Rim/Neck	Perpendicular	Cluster 2	129.2	0.0	-	-
Rim/Neck	Perpendicular	Cluster 3	164.6	3.7	165.0	0.5
Rim/Neck	Tangential	Cluster 1	24.4	8.1	33.2	0.0
Rim/Neck	Tangential	Cluster 2	69.7	7.5	73.0	3.5
Rim/Neck	Tangential	Cluster 3	147.9	15.3	161.0	3.5
Maximum belly	Perpendicular	Cluster 1	17.6	10.1	13.2	1.2
Maximum belly	Perpendicular	Cluster 2	106.9	14.3	114.1	0.0
Maximum belly	Perpendicular	Cluster 3	162.0	3.7	162.8	1.8
Maximum belly	Tangential	Cluster 1	30.9	14.7	-	-
Maximum belly	Tangential	Cluster 2	83.1	7.2	79.4	3.0
Maximum belly	Tangential	Cluster 3	155.9	8.2	144.5	0.0
Above bottom	Perpendicular	Cluster 1	15.8	5.2	22.6	9.4
Above bottom	Perpendicular	Cluster 2	79.7	14.3	-	-
Above bottom	Perpendicular	Cluster 3	159.0	7.7	164.6	3.6
Above bottom	Tangential	Cluster 1	29.8	7.1	15.9	0.0
Above bottom	Tangential	Cluster 2	81.7	7.3	76.6	3.6
Above bottom	Tangential	Cluster 3	164.8	3.0	162.9	0.0

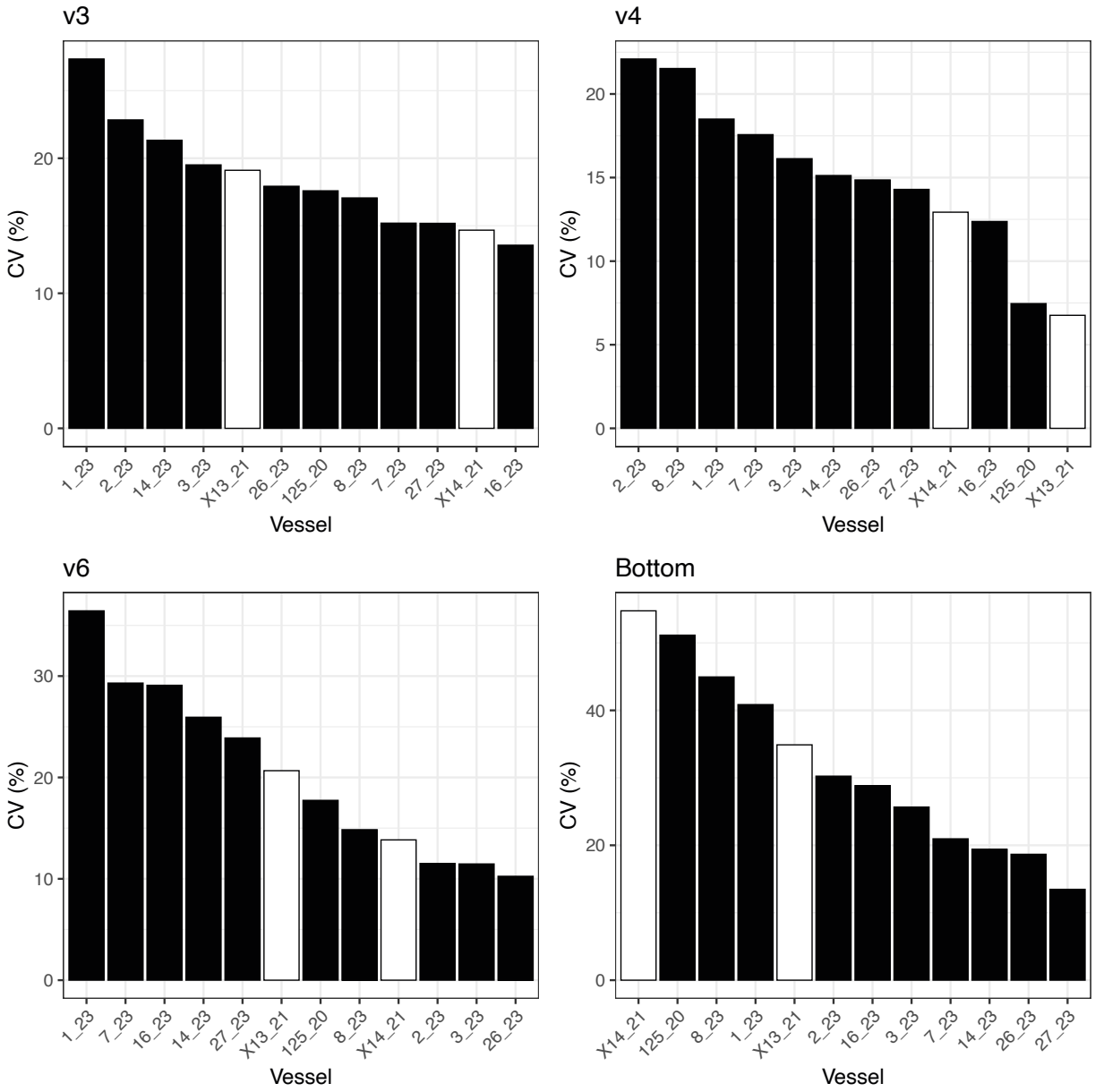
Tab. 36. Mean angles and standard deviations of preferred orientation directions. In most sections, three distinct orientation directions were identified. The absence of a third direction in the tangential section at the maximum belly and in the perpendicular section above the bottom may indicate potential for distinguishing between wheel coiling and wheel throwing techniques. Cluster 2 in the perpendicular section at the rim/neck level was identified in only one sample and is currently considered an outlier in this stage of the research.



Graph 26. Polar plots showing preferred orientation angles obtained from perpendicular and tangential sections at three distinct positions on each vessel (experimentally made). Circles indicate wheel-coiled vessels; triangles represent wheel-thrown vessels. Author K. Slavíček.



Graph 27. Boxplots showing wall thickness across different parts of experimentally made vessels. Individuals produced using the wheel-throwing technique are identified by names beginning with the letter 'X'. Author K. Slavíček.



Graph 28. Coefficient of variation in wall thickness across defined parts of each vessel (experimentally made). Black columns represent wheel-coiled vessels; white columns indicate wheel-thrown vessels. Author K. Slavíček.

the coefficient of variation in the base area tends to be higher in wheel-thrown vessels as compared to wheel-coiled ones (Tab. 38).

The axial symmetry of wheel-coiled vessels was found to be rather variable, with a general tendency to decrease towards the rim. Interestingly, although vessels produced via this technique were in some cases relatively symmetrical – typically near the base or around the maximum belly diameter – this symmetry was rarely maintained throughout the entire profile. Asymmetry frequently emerged in the upper portion, particularly between the neck and rim, as clearly illustrated by the plots of standard deviation from the rotational axis (Graph 29; Tab. 38).

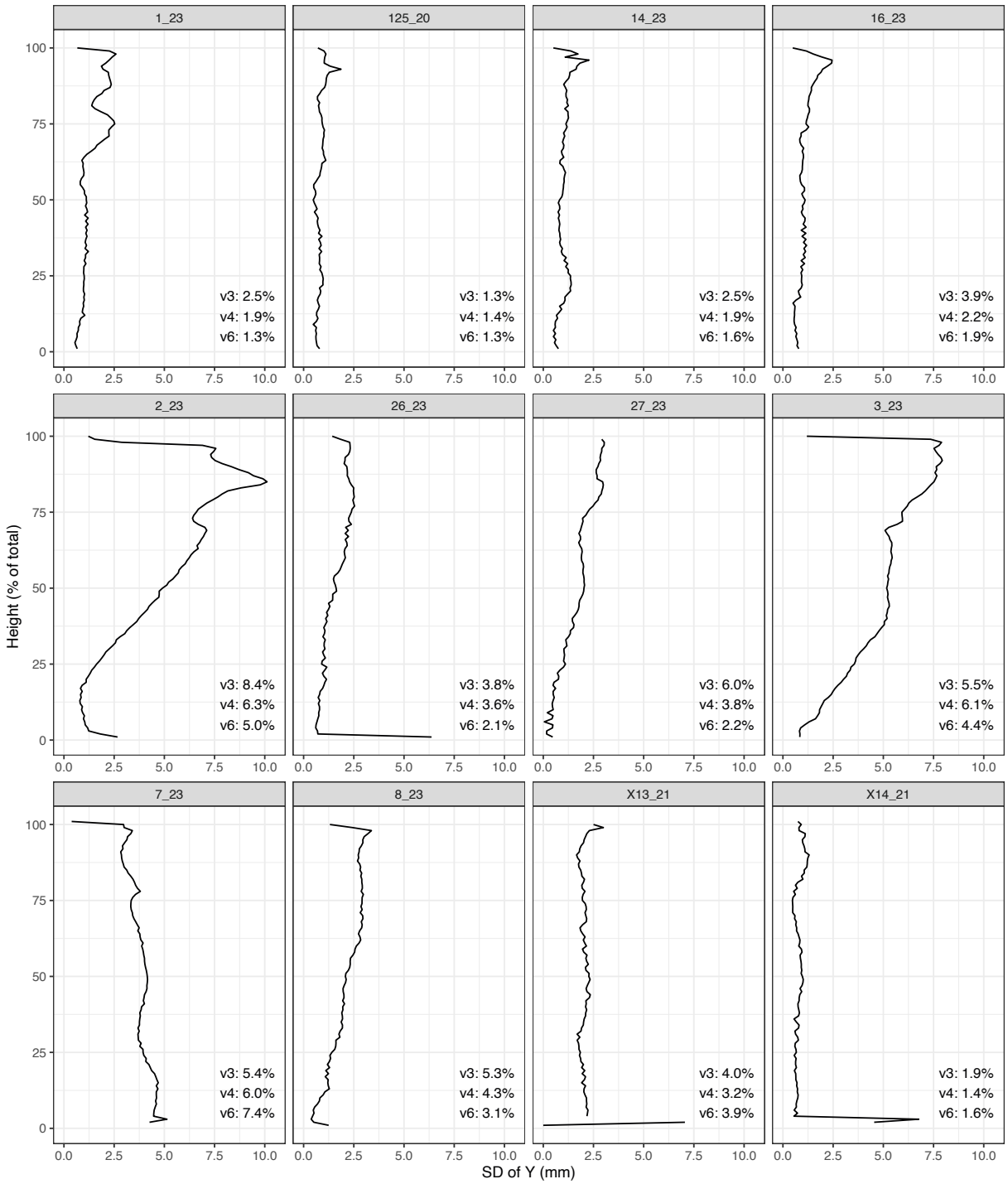
As expected, wheel-thrown vessels exhibited lower deviations from the central axis, and these deviations were also more uniform along the vessel profile. A comparison of the coefficients of variation for individual vessel segments further suggests that segments v3 and v4 offer the highest potential for distinguishing between the two forming techniques (Graph 30).

	Pot	WT (mean)	WT (SD)	WT CV (%)	Y (mean)	Y(SD)	Y CV (%)
v3	1_23	6.6	1.8	27.4	73.7	1.9	2.5
	125_20	7.3	1.3	17.6	52.9	0.7	1.3
	14_23	4.2	0.9	21.3	51.2	1.3	2.5
	16_23	4.0	0.5	13.6	44.9	1.7	3.9
	2_23	5.7	1.3	22.8	76.9	6.4	8.4
	26_23	4.3	0.8	17.9	50.9	1.9	3.8
	27_23	4.3	0.7	15.2	47.1	2.8	6.0
	3_23	6.3	1.2	19.5	86.4	4.8	5.5
	7_23	4.6	0.7	15.2	49.9	2.7	5.4
	8_23	5.9	1.0	17.1	50.9	2.7	5.3
	X13_21	8.1	1.5	19.1	53.1	2.1	4.0
	X14_21	7.1	1.0	14.7	51.8	1.0	1.9
v4	1_23	8.1	1.5	18.5	72.6	1.4	1.9
	125_20	5.9	0.4	7.5	55.9	0.8	1.4
	14_23	6.2	0.9	15.1	55.9	1.0	1.9
	16_23	5.6	0.7	12.4	49.8	1.1	2.2
	2_23	8.3	1.8	22.1	69.9	4.4	6.3
	26_23	7.9	1.2	14.9	55.6	2.0	3.6
	27_23	4.6	0.7	14.3	50.0	1.9	3.8
	3_23	7.9	1.3	16.1	83.6	5.1	6.1
	7_23	6.2	1.1	17.6	56.1	3.3	6.0
	8_23	7.9	1.7	21.5	52.5	2.2	4.3
	X13_21	6.1	0.4	6.8	64.2	2.0	3.2
	X14_21	6.1	0.8	12.9	56.6	0.8	1.4
v6	1_23	11.5	4.2	36.4	66.5	0.9	1.3
	125_20	8.4	1.5	17.7	52.5	0.7	1.3
	14_23	11.1	2.9	25.9	52.9	0.9	1.6
	16_23	8.6	2.5	29.1	45.7	0.9	1.9
	2_23	9.7	1.1	11.5	65.0	3.2	5.0
	26_23	10.4	1.1	10.3	53.8	1.1	2.1
	27_23	6.7	1.6	23.9	49.1	1.1	2.2
	3_23	8.2	0.9	11.5	78.0	3.4	4.4
	7_23	10.2	3.0	29.3	54.0	4.0	7.4
	8_23	13.1	1.9	14.8	48.9	1.5	3.1
	X13_21	8.8	1.8	20.7	64.7	2.5	3.9
	X14_21	7.5	1.0	13.8	56.5	0.9	1.6
Bottom	1_23	6.2	2.5	40.9	-	-	-
	125_20	7.5	3.8	51.1	-	-	-
	14_23	9.3	1.8	19.4	-	-	-
	16_23	8.4	2.4	28.8	-	-	-
	2_23	8.0	2.4	30.2	-	-	-
	26_23	9.5	1.8	18.7	-	-	-
	27_23	8.5	1.1	13.5	-	-	-
	3_23	7.0	1.8	25.7	-	-	-
	7_23	8.4	1.8	21.0	-	-	-
	8_23	6.6	3.0	45.0	-	-	-
	X13_21	7.6	2.7	34.9	-	-	-
	X14_21	5.6	3.1	54.8	-	-	-

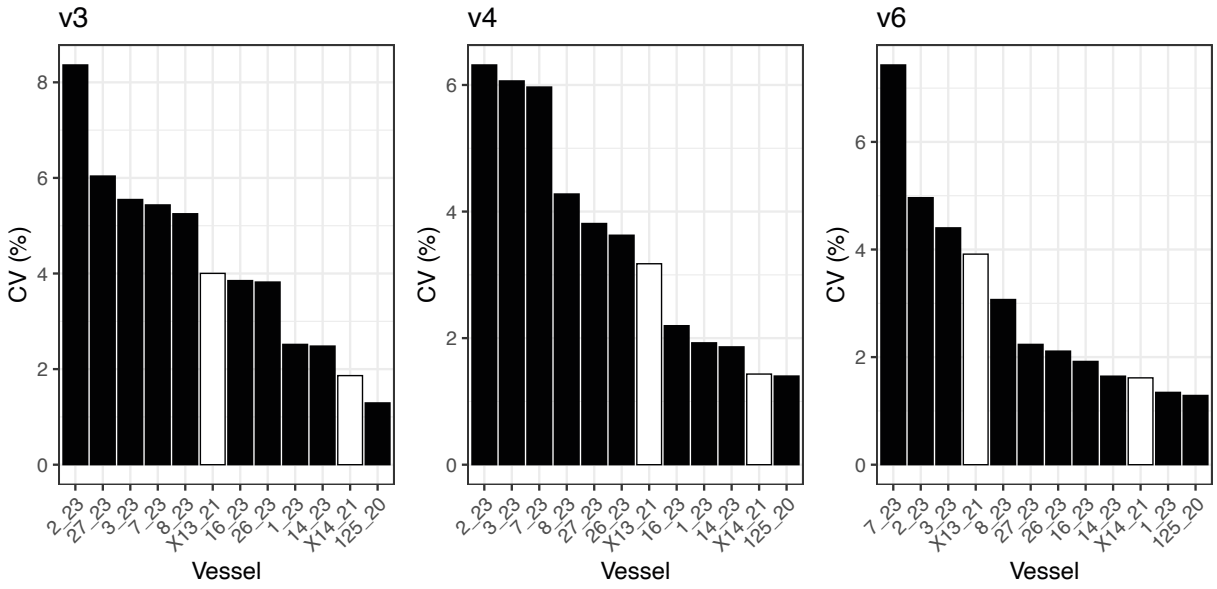
Tab. 37. Descriptive statistics for wall thickness (WT) and symmetry along rotational axis (Y) for each vessel part (v6 – bottom to maximum bulge; v4 – maximum bulge to neck; v3 – neck to rim). The table shows the mean, standard deviation (SD), and coefficient of variation (CV).

Firing number	Firing year and place	Firing furniture	Firing type	Basic description
1-13	2013, Panská Lhota	Kiln 1	Oxidising	Poorly loaded kiln, reaching 800°C
1-14	2014, Panská Lhota	Kiln 1	Smoked pottery	Max. temperature 850°C, duration 14 hours, smoked
2-14	2014, Panská Lhota	Pit	Reducing	Closed pit, attempt at gradual burning-through, max temperatures around 350°C (possibly sensor placed too low)
1-15	2015, Panská Lhota	Kiln 1	Smoked pottery	Underfired, max temperature reached 535°C
2-15	2015, Panská Lhota	Kiln 2	Smoked pottery	Max. temperature 840°C, firing duration 11 hours, smoked with elder wood
1-16	2016, Panská Lhota	Kiln 1	Smoked pottery	Max temperature 1000°C, firing duration 15 hours, smoked with beech wood
2-16	2016, Panská Lhota	Pit	Mixed	Open fire – firing duration 2 hours, duration above 700°C about 20 minutes, cooling closed
3-16	2016, Panská Lhota	Kiln 2	Smoked pottery	Max. temperature 880°C, firing duration just over 14 hours, smoked with beech wood
4-16	2016, Panská Lhota	Pit	Mixed	Pottery protected by auxiliary structure, temperature rose to 700°C within an hour, no hold time – cooling closed
1-17	2017, Panská Lhota	Pit	Mixed	Max temperatures above 800°C, left to cool uncovered
2-17	2017, Panská Lhota	Kiln 1	Smoked pottery	Max temperature 930°C, firing duration 13.5 hours, smoked with beech wood
1-18	2018, Panská Lhota	Kiln 1	Smoked pottery	Max temperature 1024°C, duration 10 hours, smoked with beech wood
2-18	2018, Panská Lhota	Pit	Reducing	Low temperatures, rapid course, closed – burning through from the top
1-19	2019, Panská Lhota	Pit	Mixed	Firing duration 5 hours, above 700°C for one hour, max slightly above 900°C, cooling open
2-19	2019, Panská Lhota	Pit	Mixed	Initially open, then stoked from above and left to burn through, duration 3 hours, above 400°C for one hour, max temperature 475°C, cooling closed
3-19	2019, Panská Lhota	Kiln 2	Oxidising	Oxidizing, reaching 700°C after 7 hours and gradual cooling
4-19	2019, Panská Lhota	Kiln 1	Smoked pottery	Max temperature around 1000°C, duration 8.5 hours, rain during firing, smoked with birch wood
5-19	2019, Panská Lhota	Pit	Mixed	Duration 5 hours, above 700°C over one hour, temperatures up to 900°C, cooling partly covered
6-19	2019, Panská Lhota	Pit	Mixed	Dynamic firing without stoking, temperature peaks around 700°C after 90 minutes
7-19	2019, Panská Lhota	Pit	Mixed	Dynamic firing without stoking, temperature peaks above 900°C after 45 minutes
1-20	2020, Panská Lhota	Pit	Mixed	Dynamic firing without stoking, temperature peaks around 850°C after 120 minutes, affected by rain
2-20	2020, Panská Lhota	Pit	Mixed	Dynamic firing without stoking, temperature peaks around 600°C after 30 minutes, fuel shortage
3-20	2020, Panská Lhota	Kiln 2	Oxidising	Firing with kiln loaded with vessells and fuel without stoking, max temperatures slightly above 800°C
4-20	2020, Žďár nad Sázavou	Kiln 3	Smoked pottery	Firing 11 hours, max temperature 1090°C, underfired rear part of kiln
1-21	2021, Žďár nad Sázavou	Kiln 3	Smoked pottery	Firing 12 hours, max temperature 1065°C, underfired rear part of kiln
1-22	2022, Žďár nad Sázavou	Kiln 3	Oxidising	Firing with kiln loaded with vessells and fuel without stoking, max temperatures slightly above 750°C
1-23	2023, Havlíčkův Brod	Kiln 4	Smoked pottery	Firing 15 hours, max temperature 811°C, problematic small firing opening
1-24	2024, Šelmberk	Fireplace	Mixed	Boundary – single firing without stoking, temperature peak around 800°C after 20 minutes, larger charge
2-24	2024, Šelmberk	Fireplace	Mixed	Firing lasted 3 hours, temperatures above 800°C, finished with 'hartowanie' (quenching)
3-24	2024, Havlíčkův Brod	Kiln 4	Reducing	Dynamic firing with temporary covering of the kiln opening, max temperature 793°C

Tab. 38. Overview table of firings with information on firing code, year, firing device, firing type (based on ceramic surface marks), and a brief description.



Graph 29. Standard deviation from the rotational axis calculated for each of the one hundred horizontal sections of every vessel made as a part of ceramic forming experiment. The figure also includes the coefficient of variation (CV) for each vessel segment. Author K. Slavíček.



Graph 30. Coefficient of variation in the distance from the rotational axis across defined parts of each vessel produced for ceramic forming experiment. Black columns represent wheel-coiled vessels; white columns indicate wheel-thrown vessels. Author K. Slavíček.

6.3 Construction and reconstruction of pottery kilns

The experiment also aimed to test the efficiency and possible forms of kilns from the period under study based on archaeological findings, especially in the Bohemian-Moravian Highlands. From 2013 to 2023, four kilns were built. The possible form of the above-ground part of the kiln, which is not preserved in archaeological contexts, was addressed. Ethnographic materials or manuals for ceramics and pottery hobbyists were used here (e.g. Plicková 1959; Snášil 1970; Agumba, Abbott 1996). The form of the dome, grate, location of the chimney opening, or the method of batch the kiln were discussed (e.g. Dawson, Kent 1984, 13–15; 1999, 168; Görler, Kohtz 1991, 291–298; Heege 2007; Mangel 2016; Döhner, Herdick, Axtmann 2018). Detailed information was recorded concerning the amount of material used and the time required to construct the kilns. The kilns' condition after firings in subsequent years was also studied, as were the possibilities of their maintenance and issues concerning their lifespan.

The first kiln (kiln 1), which was built in 2013 at the scientific research station of Department of Archaeology and Museology, Faculty of Arts, Masaryk University in Panská Lhota, was equipped with two heating channels and a central spoon (horizontal kiln with central spoon-shaped firing floor). Kiln 927 found in Jihlava – Křížová Street was used as a model (Zatloukal 1998, 28–30; 2000a, 63–64). In the Middle Ages, it was a relatively common type of kiln with numerous occurrences mainly in Austria and in Moravia (Heege 2007; Scharrer 2001; Procházka 2015). In 2015, a smaller single-chambered bonfire-like clamp kiln (kiln 2) was built there. It was constructed as an approximate replica based on ethnographic analogies. Kiln 3 was built in the summer of 2020 near the château in Žďár nad Sázavou, also as an analogy of the aforementioned Jihlava kiln. Compared to the previous replica, it had higher dome dimensions and a rear opening that was walled up after batch. In the Vlkov region, on the premises of the Havlíčkův Brod Museum of the Highlands, a replica of a simple bonfire-like clamp kiln built according to the findings in Žďár nad Sázavou in the site of 'Staré Město' and in Jihlava – U Skály Street was built in 2023.

6.3.1 Horizontal kilns with central spoon-shaped firing floor (kiln 1 and 3)

Most firings were carried out in variants of kiln 1, which is a replica of a pottery kiln discovered in Jihlava – Křížová Street (Šedo, Zatloukal 1993, 7, obr. 3–37, tab. 22–24; Zatloukal 1998). According to classical typology, this is a vertical kiln with a central spoon for the placement of a grate or the vessels themselves (Nekuda 1963, 78–82). According to new typology, it is a type of horizontal, single-chambered kiln with a central spoon (type 2b;

Procházka 2015, 217). This type of kiln is also known from Mstěnice and other sites mainly in Moravia, and is also widespread in Germany and Austria as a horizontal kiln with central spoon-shaped firing floor (Čapek, Preusz 2019, 323, Tab. 2; Heege 2007).

Kiln 1 was successively built in two different designs on one base (Fig. 154–156). For the construction of the first version of the kiln, which took place from 15 July to 30 July 2013, approximately 1,000 l of clay from the Brtnice Valley were used and tempered with approximately 100 l of sandy clay obtained from the excavation of a construction pit. This mixture was enriched with two bags of crushed straw. Approximately 200 kg of paragneiss and granitoid rocks were used for the foundation of the kiln. Realistically, the construction of the kiln could have taken place over the course of five days with the work of two to three people if we exclude the time needed to find and transport material (Bočková et al. 2014, 129–131).

There was no suitable slope on the site for the kiln to be partially sunken into the ground, and therefore an oval-shaped pit with a 180 cm long, 120 cm wide and 120 cm deep ground plan was dug, including an adjacent stoking pit opening. The bottom was lined with stone slabs on a layer of daub. In addition, the horseshoe-shaped structure of the kiln foundation with a central spoon was built 25–30 cm high and 20–25 cm wide. It consisted of stones with maximum dimensions of 20 × 20 × 5 cm. The base was reinforced and coated with a mixture of clay, sandy loam and crushed straw. An arch above the heating opening (firebox) was then created (Fig. 154: A–C).

During the construction of the dome, a mixture of clay made lighter with the use of straw was applied to a wicker structure made of hazel-tree and willow rods placed on the base of the kiln. The height of the dome in the inner section was approximately 100 cm from the bottom of the kiln and 75 cm from the upper surface of the central spoon and the surrounding ledge. The walls of the dome were 10 cm thick in the upper parts to 25 cm in the lower parts. The chimney opening with a diameter of 30 cm was created at the top of the dome, thus giving the kiln a vertical design (Fig. 154: D–F).

Further structural modifications were made after the kiln was dried before the first firing. For better operation of the kiln, the heating area was extended to include a platform with stones in front of the kiln (60 × 60 cm). The heating opening was narrowed using dried bricks to a size of approximately 20 × 30 cm.

After the first firing in the summer of 2013, the kiln was irreversibly damaged due to the wrong choice of material. This was caused by the use of specific fine material from the River Brtnička, which basically contained no clay minerals, only fine quartz (see Těsnohlídková 2021, 105–106). During the drying process and the firing itself, only very small cracks appeared on the kiln, which itself was proof of the clay's low plasticity. After firing, considerable damage to the inner part of the kiln was detected. The clay that formed the dome of the kiln (the inner part) and the daub of the stone structure of its base crumbled and fell apart. Another observed defect was the damage done to the rocks in the masonry of the lower part of the kiln – the heavily weathered, coarse-grained granitoids did not withstand the heat. During the winter of 2013, the weakened dome of the kiln significantly buckled and cracked (Fig. 155: A). The dome was demolished in the summer of 2014 (Fig. 155: B).

A new kiln was built on the cleaned foundations in July 2014 (Fig. 155: C). The base of the old kiln was reinforced, and stones were added to the structure. The foundation was then daubed with clay from the brickyards in Luka nad Jihlavou. A new dome was created, once again using a wicker base. The heating opening was extended using an auxiliary wicker structure, and the chimney was moved further back to the rear of the dome (Fig. 155: D–F). The clay, made lighter with straw, was applied in a single layer – about 10 cm in the top section and 20 cm at the bottom. Around 1000 l of clay from the aforementioned brickyards and one bag of straw were used for the 2013 stone foundation.

Since 2014, six firings of smoked ceramics have been carried out in the kiln with maximum temperatures between 800–1000°C. In 2015 and 2016, the kiln was repaired before firing. In 2015, a second outer layer was added to it. This was applied to the dampened surface; even so, it still did not fully adhere to the mass of the original dome, but it did manage to strengthen it. A part of the arch was also re-daubed, but the material did not adhere well. The interior of the kiln was not damaged (Fig. 156: A, B).

Since 2017, repairs have been minimised. Before firing, the kiln was at most only lightly cleaned. Due to the excessive depth of the kiln and insufficient protection from rainwater, the rear part of the dome under the chimney became heavily waterlogged. In 2019, significant cracks could already be observed in this spot, and the kiln wall had weakened around the whole circumference of the chimney. The back of the kiln was slightly bent inwards. The arch was also



Fig. 154. Construction of replica kiln 1 in Panská Lhota near Jihlava at the research station of the Institute of Archaeology and Museology, Faculty of Arts, Masaryk University: A – stones forming the base of the perimeter and the central spoon of the kiln; B – the kiln dome; C – plastered base and dome of the kiln; D – placement of the dome's wicker framework onto the kiln base; E – dome with chimney opening; F – finished kiln. Photo by K. Těsnohlídková, K. Slavíček.

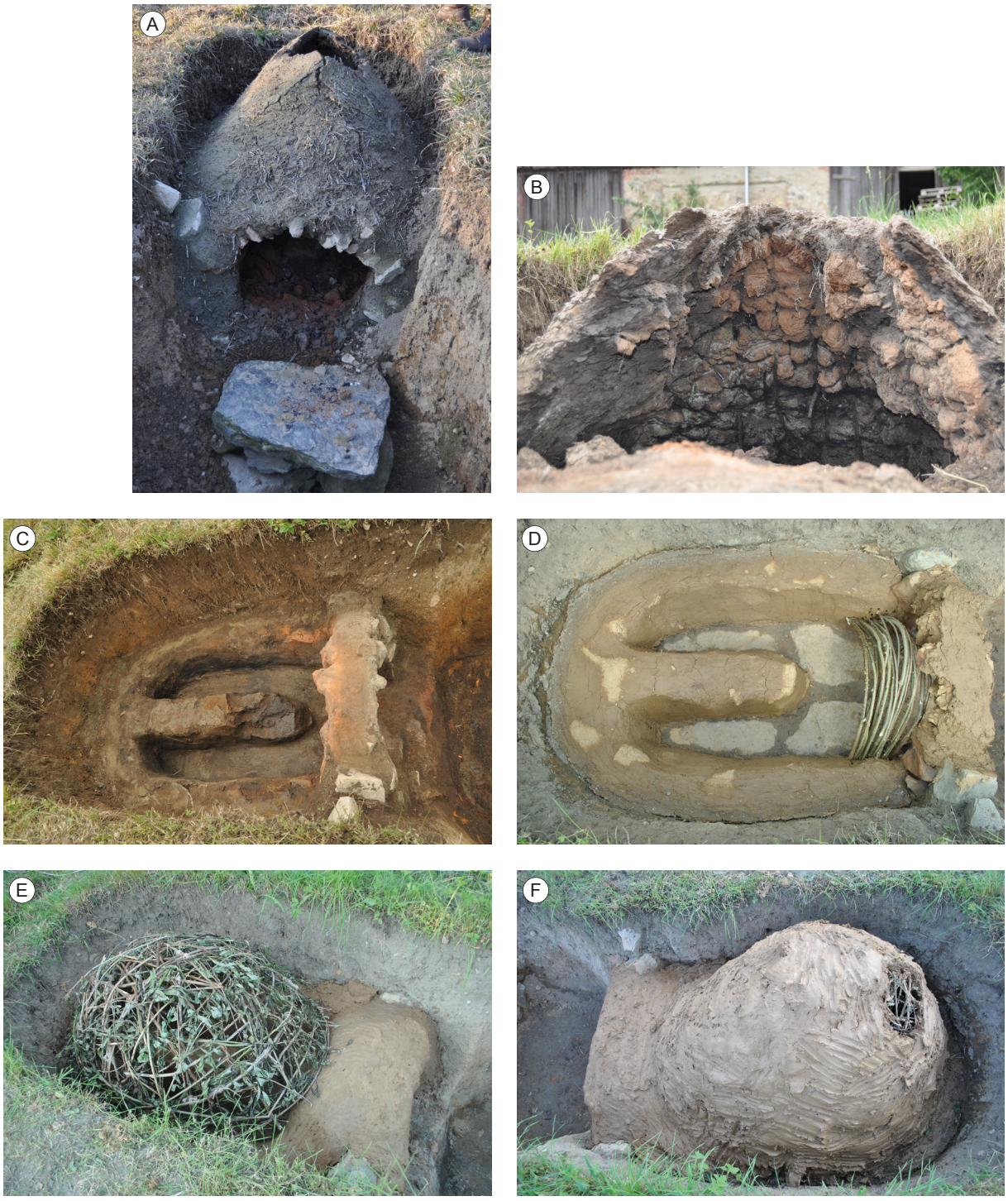


Fig. 155. Reconstruction of replica kiln 1 in Panská Lhota near Jihlava at the research station of the Department of Archaeology and Museology, Faculty of Arts, Masaryk University: A – collapse of the dome caused by sagging of weakened walls after firing; B – burned-through dome structure after removal of one half, visible loss of material and impressions of the wicker framework; C – cleaned kiln base; D – daubed kiln base, new dome with added wicker structure, which extended the firebox area; E – daubed arched firebox and installed dome framework; F – finished kiln after dome daubing, chimney shifted backward compared to the previous structure. Photo by K. Těsnohlídková, K. Slavíček.

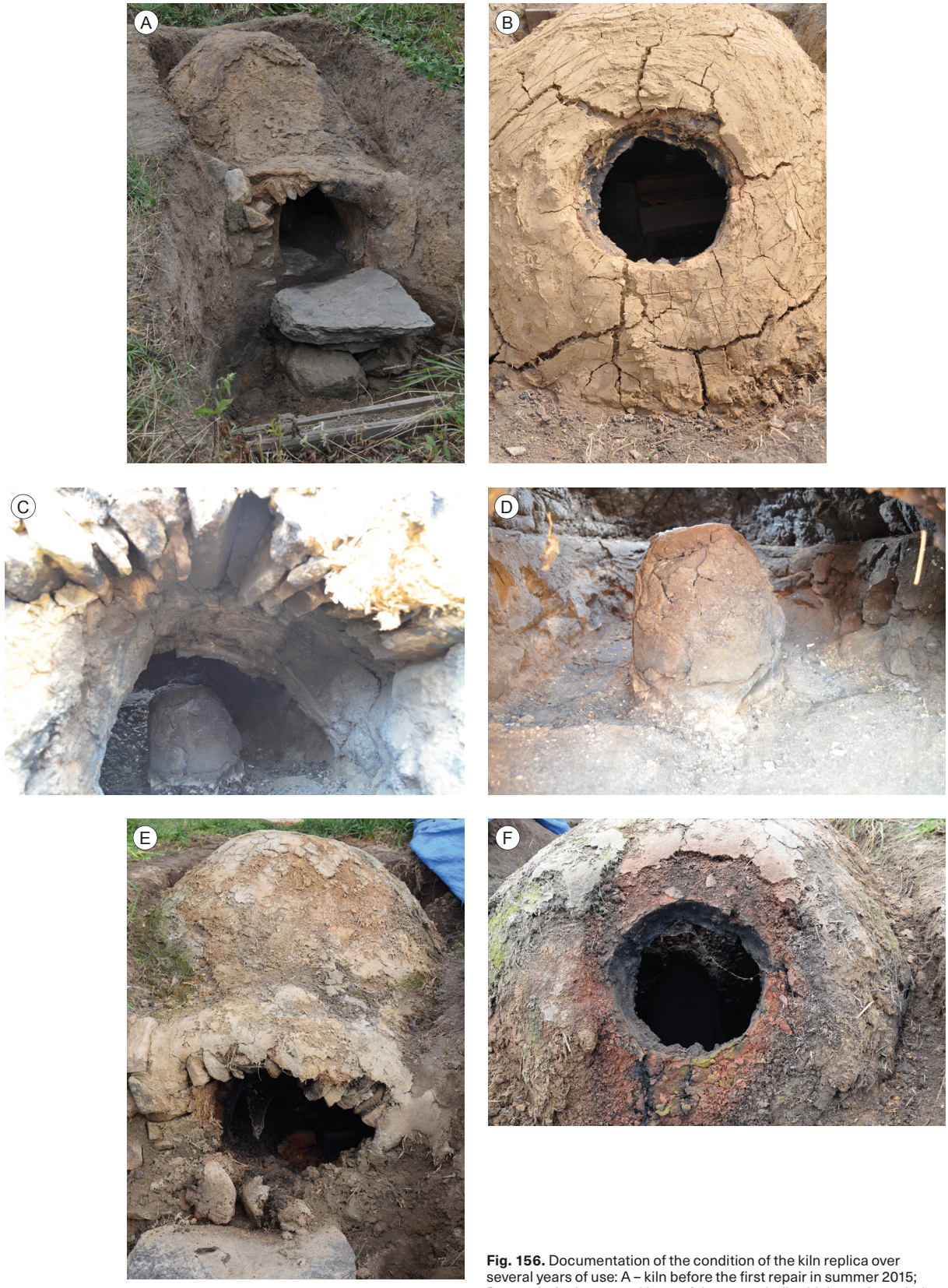


Fig. 156. Documentation of the condition of the kiln replica over several years of use: A – kiln before the first repair in summer 2015; B – cracks in the second layer of the outer shell, which was intended to reinforce the walls but did not adhere properly (2015); C – crumbling of the dome (2017); D – eroded parts of the coating on the central plinth and around the heating channels (2018); E – damaged dome and outer shell of the kiln (2019); F – damp and weakened area with cracks beneath the chimney opening (2019). Photo by K. Těsnohlídková, K. Slavíček.

weakened (one stone fell out of it), as was most of the vault's daub. We can conclude that if the arch had not been reduced in size that protected it from direct heat before firing, it would have been the weakest link in the whole structure. Significant damage was also caused to the inner part of the kiln, mostly due to heat in the direction of the firebox. The daub fell from the walls and the central spoon. More stones came loose, particularly in the front area of the central spoon, and part of the surrounding ledge for supporting the grate or vessels was disturbed. This damage complicated the placement of the auxiliary grate and loading into the kiln (Fig. 156: C–F). Repairing the inner part of the kiln and arch would have been quite complicated. It seemed more effective to tear down the above-ground section of the kiln and clean it at the level of its foundations as was the case in 2014. The time invested in repairing it would have been slightly more economical than building a new kiln, and some of the material could have also been recycled – for example by grinding up the daub and reusing it as an ideal temper for the new kiln.

Kiln 3 was built on the same ground plan as the previous one in Jihlava – Křížová Street. It was built in the summer months of 2020 (SH film 1). The kiln was built on the same plan as kiln 1. The pit for the kiln was thus 180 × 120 cm with an adjoining stoking pit. The walls and central spoon, which were built with stones and daub in the lower part, were 25–30 cm high and 20–25 cm wide. The dome, which was built on a wicker structure, was about 15–20 cm thick at the bottom and about 10 cm at the top. The height of the dome reached approximately 130 cm in the inner part from the bottom of the kiln and 115 cm from the upper surface of the central spoon and surrounding ledge.

The material used was potter's clay imported from modern clay deposits near the River Svratka and local clay obtained by excavating the base of the kiln. The clay was made lighter by adding cut grass. Stones were collected in the surrounding area. The base of the dome was made of hazel-tree wicker. The quantity was not precisely monitored as with the first kiln. Compared to the first version, the dome of the kiln was higher and steeper, and an opening for filling the kiln was left in the rear part, which was partially walled up after the kiln was filled before firing so that only the chimney opening in the top section remained (Fig. 157). The time investment was roughly five days of work for two people. Two firings of smoked ceramics were carried out in the kiln in 2020 and 2021. A rapid bonfire-like clamp firing was carried out in 2022.

6.3.2 Single-chambered kilns without separation of fuel and batch: Kiln 2 and kiln 4

Kiln 2 was built in order to compare the firing process with the first kiln. A bonfire-like clamp kiln was chosen, i.e. a one-chambered device with a vertical to diagonal flame draught and two heating holes. The thickness of the outer layer was around 10 cm in the upper parts of the kiln and increased moving downwards to 15–20 cm. The stove was built on a circular ground plan with a diameter of 150 cm. The dome reached a maximum height of 100 cm. Clay bricks were laid in the centre of the kiln, and the first tier of vessels was placed on them. Heating channels were created along the circumference by placing the vessels next to each other from the centre towards the kiln walls. The kiln was equipped with a chimney placed slightly below the peak of the dome and a loading hole, which was walled up after loading and removed again after firing (Fig. 158: A–D).

We have indirect analogies from archaeological findings, e.g. from Loštice (Goš 1980, 96). Similar kilns with larger dimensions (height up to approximetely 2 m, capacity of 500–600 vessels) were still in use in Slovácko at the beginning of the 20th century for firing smoked pottery (Snášil 1970, 331; Zatloukal 2000a, 62). In terms of volume and construction, the kiln corresponds to simple devices assumed to have been used in the Early Middle Ages for firing pottery in Slavic areas and known from Eastern European ethnography (Varadzin 2010, 31).

The kiln was not built as an exact replica, so precise material consumption was not monitored. The kiln was originally planned for only one firing, so the ground under the kiln was not reinforced in any way. The lower part of the kiln was made of three rows of bricks joined with clay. Two heating channels opposite one another were also arched with bricks. The bottom of the kiln consisted only of compressed subsoil clay. The dome of the kiln was made of fresh wicker with leaves, placed on a brick base, and daubed with a mixture of clay from the brickyards in Luka nad Jihlavou and from the vicinity of the kiln, which was made lighter by adding straw. The thickness of the outer layer was around 10 cm in the upper parts of the kiln and increased in a downward direction to 15–20 cm as the moist fabric settled. The construction of the kiln took place over the course of three days (13–15 July 2015). With two to three workers, it is realistic to build a kiln in one day including the preparation of the material.

Three firings were carried out in this pottery kiln. In 2015 and 2016, it was used to fire smoked ceramics, then oxidation ceramics in 2019. In the



Fig. 157. Construction of replica kiln 3 at the Žďár nad Sázavou château/cloister: A – pit with the stone foundation of the kiln; the bottom is lined with flat stones; B – daubed kiln base; C – base of the dome before placement of the wicker structure; D – wicker framework of the dome; E – finished kiln with a firing opening; F – finished kiln with a stoking pit – loading opening. Photo by K. Těsnohlídková, K. Slavíček.

off-season, the kiln was covered with a tarp held down with stones to protect it from the rain. The only major repair was the application of a second outer layer in 2016. The kiln was also cleaned and wetted beforehand. A second layer strengthened the kiln's outer layer so that the cracks that were present did not spread further; however, full adhesion to the original wall did not occur. Minor modifications were made to the subsoil under the kiln – in the off-season, the dried to slightly burnt material became a rather attractive place for small rodents, which burrowed under the kiln and its immediate surroundings. Thus, it was necessary to compact the subsoil beneath the kiln and in its immediate vicinity before firing (Fig. 158: E, F).

After the firing in 2016, the kiln was covered and only occasionally exposed. It was not used for further firing until spring 2019. After three years of disuse, the kiln was damp – this was especially evident on the brick base of the kiln, as the bricks around the heating holes, which had been under thermal stress during firing, were crumbling. The kiln sunk slightly,



Fig. 158. Construction of replica kiln 2 in Panská Lhota near Jihlava at the research station of Department of Archaeology and Museology, Faculty of Arts, Masaryk University: A – one of the heating openings in the kiln base made of three rows of bricks, and placement of the dome's wicker framework on the brick base; B – application of the clay dome onto the kiln structure; C – loading opening; D – chimney opening; E, F – state of the bonfire-type kiln after four years – visible sagging of the kiln's overall shape due to moisture; F – damaged dome and crumbling bricks around the heating opening. Photo by K. Těsnohlídková and K. Slavíček.

and its walls sagged. Even so, after basic cleaning and stamping down the terrain around it, it was used for firing without any significant modifications or pre-drying. The only archaeological trace of this kiln would be a burnt place in the dirt with possible remains of daub (if we exclude the bricks that were used in its construction), therefore making any remnant of this device difficult to interpret.

Kiln 4 was created in cooperation with the Vysočina Museum in Havlíčkův Brod in Vlkovsko in 2023. It was built according to ground plans that were very similar to the kilns in Jihlava –U Skály Street and Žďár nad Sázavou – 'Staré Město'. The simple bottom sloped slightly downwards towards the heating channel, and the pit opened slightly in the chimney area; otherwise, the walls were quite sharply angled. A simple dome with wicker reinforcement was built on the walls of the pit as in the previous cases (Fig. 159: A–F). Plans were also made to test a relic with only temporary dome. The bottom of the kiln was 120 × 100 cm, and it was sunk 50 cm below ground level. The dome was placed into the pit and



Fig. 159. Construction of replica kiln 4 at Vlkovsko in Havlíčkův Brod, in cooperation with the Vysočina Gallery and Museum in Havlíčkův Brod: A – excavation of the firing and stoking pits; B – low heating hole connecting the stoking and firing pits, with the rear part of the firing pit opened toward the chimney space visible; C – placement of the wicker dome into the firing pit (in the case of a permanent vaulting of the kiln); D – daubing the dome; E – finished kiln – chimney and loading openings; F – finished kiln – front view. Photo by K. Těsnohlídková, K. Slavíček, A. Jindrová.

daubed. The walls of the kiln were about 10 cm thick at the top and about 20 cm at the bottom. The full height of the dome reached 65 cm.

For the construction of the kiln, clay obtained from the construction of the sunken part of the kiln and the stoking pit was used. The Vlkovsko site has the advantage of being in the area of the former brickyards near today's Cihlářský rybník (Pond). Hazel-tree wicker was used for the construction of the dome. Stone was not used in this case. Construction duration can be estimated at two days of work with the participation of two workers. The clay for the construction of the dome was made lighter by adding straw. After the first firing in 2023, the dome, which was covered with a tarp, collapsed in the winter due to the weight of snow. For this reason, firing in 2024 was carried out with a temporary cover. In the summer of 2024, a wooden shelter was built over the kiln.

6.4 Firings

The part of the thesis devoted to the reconstruction of the medieval pottery firing process draws on 30 experimental firings carried out between 2013 and 2024. The first 20 firings carried out in 2013–2019 were carried out in the facilities of the Scientific Research Station of the Institute of Department of Archaeology and Museology, Faculty of Arts, Masaryk University in Panská Lhota as part of K. Těsnohlídková's doctoral thesis (Těsnohlídková 2021). Half were kiln firings, and the other half were pit firings (Fig. 160). In addition to mastering different types of firing in an effective manner, the aim was to reconstruct the firing process, thus simulating the manifestations that characterise medieval pottery in the region, i.e. dark cores, oxidised surfaces or fully reducing firing. Particular attention was paid to firings of smoked pottery, which have already been published comprehensively (Těsnohlídková, Slavíček 2021). These firings were followed up by more in 2020–2024, which were based on the results of previous and current archaeological findings and intended to extend and verify some of the findings (Tab. 38).

As with the forming experiments, a compromise was accepted due to the lack of high-quality local raw materials. Most batches of the kilns and partially of the pit firings were made up of ceramics from industrially prepared wheel-throwing clays with properties that were significantly different from regional brick (non-loess) clays that are assumed to have been a source of clay for medieval ceramics. The use of loess clays was thus a compromise. Vessels from local sources were created in higher quantities only during the 2019 firings; until then, their properties were verified during firings using so-called test tablets or small vessels.

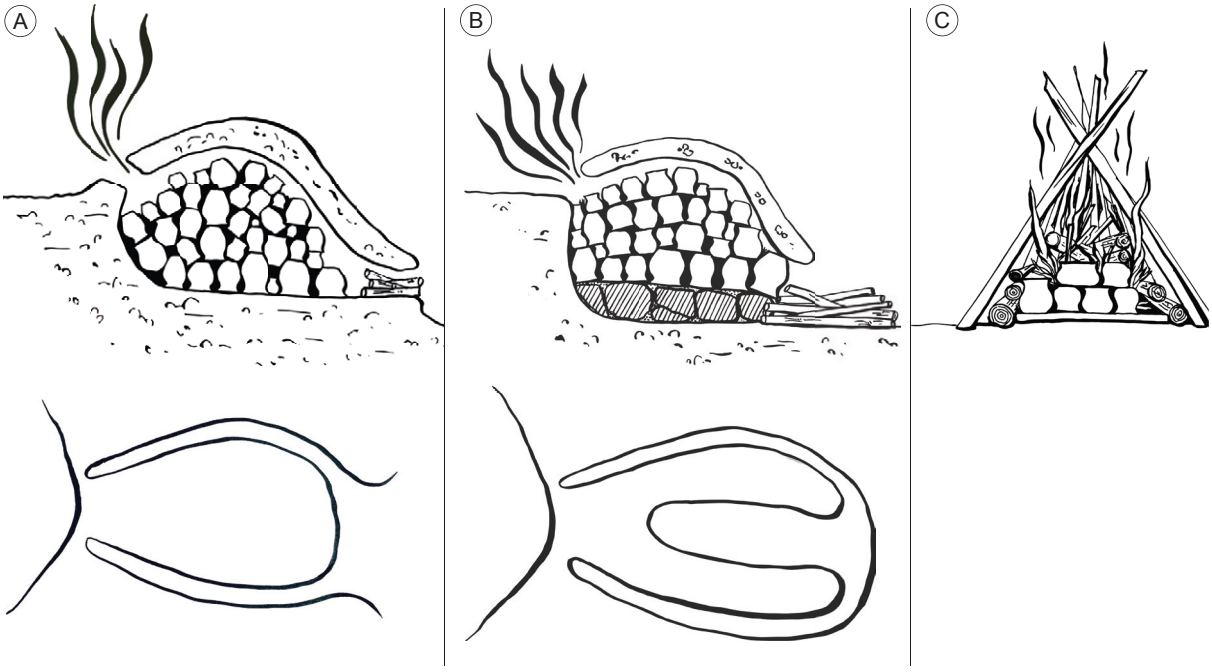


Fig. 160. Graphic representation of basic types of firing carried out: A – firing in a single-chamber kiln; B – firing in a single-chamber kiln with a central spoon; C – dynamic firing. Drawings by K. Hamáková.

6.4.1 Documentation of experimental firings

A special form was created for recording the firing process (Těsnohlídková 2021, Appendix 8). In it, each firing was given a code, number (sequence of firing in a given year – year), and basic information about its characteristics, firing equipment, temperature measurements, weather, personnel, planned implementation, and goals were recorded on the form. In addition, the characteristics of the batches were recorded: the number of vessels and their basic descriptions, test tablets or other samples, a description of their placement, and specific characteristics.

The type of fuel, its consumption, and the planned strategy of adding fuel during firing was monitored. Fuel consumption was recorded in cubic metres. Some of the published experiments list fuel data by mass, which can be roughly converted to volume. Data in units of fuel volume also seemed to be more objective due to the varying tempo at which the fuel dried (see also Thér 2009, 196). The complete course of the firing itself and information on cooling was recorded. Temperatures were taken down at fifteen-minute intervals, and we recorded what was happening in the kiln, the manner in which fuel was added, how the weather changed (especially in the case of rain or wind), etc. The firings included detailed photographic documentation and in some cases video documentation.

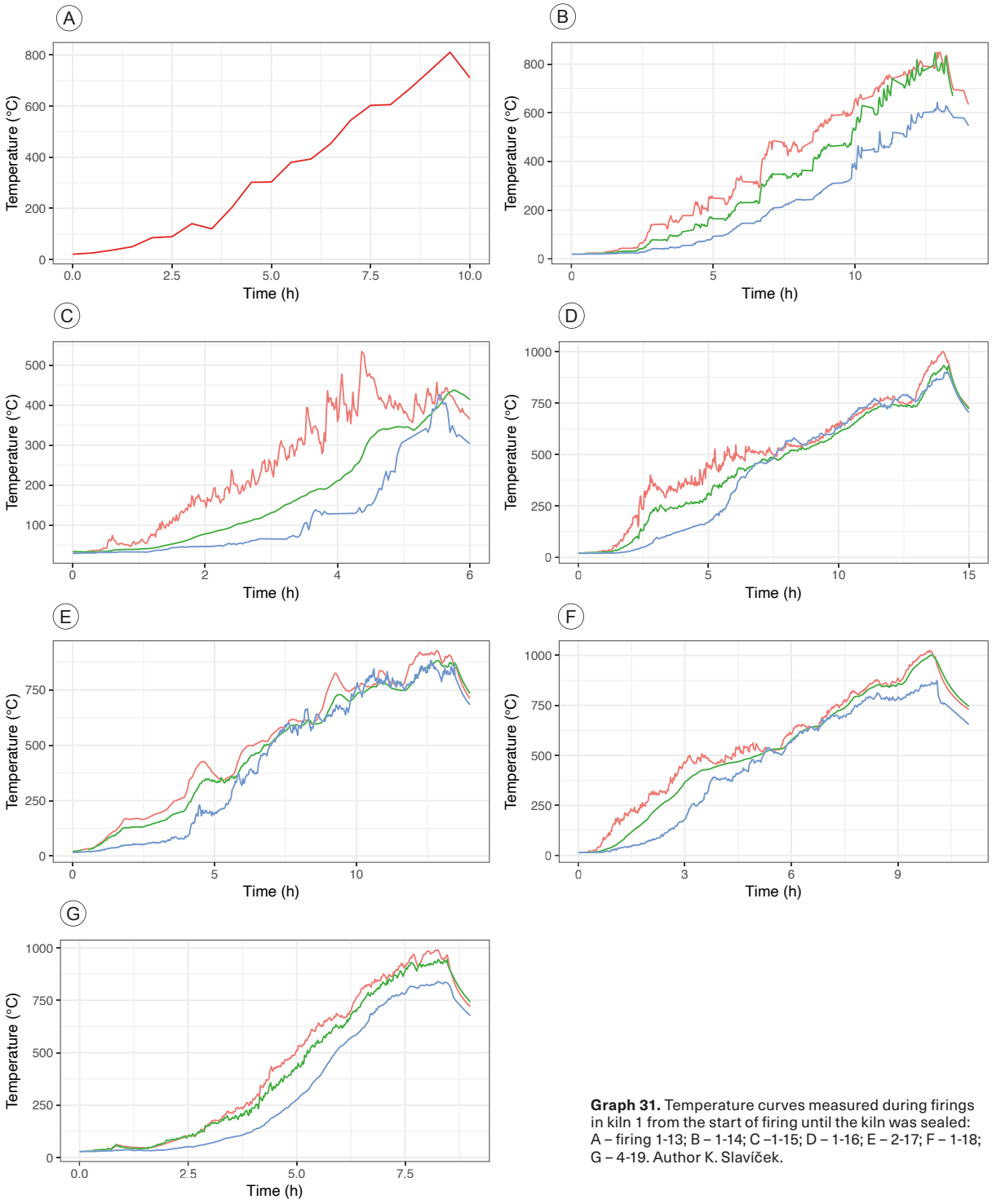
The firings were measured using Comet thermometers with the use of K-sensors. These are suitable for temperatures up to approximately 1300°C. The thermometer saved readings every minute. In order to monitor the firing process and prevent potential data loss, temperatures were recorded every 15 minutes. From 2018, an infrared thermometer was used to read the temperature directly from the surface of the ceramics, fuel, or kiln. The number and location of the sensors or points for infrared thermometer readings depended on the type of ceramic firing equipment. For kilns 1 and 4, three sensors were installed in the front, middle and rear areas of the kiln to monitor gradual rises in temperature and temperature differences while striving to equalise the temperatures on all three sensors. Two sensors were usually used for smaller kilns 2 and 4; one under the chimney and the other at the opening for loading. In terms of pit/fireplace firings, usually only one sensor was used, or a second sensor was inserted as a control. For infrared thermometer measurements, the parts of the kilns that were visible through the chimney were selected, and the temperatures on the kiln's outer layer or the firebox were also monitored. During firings in fireplaces, the visible parts of the vessels were measured.

6.4.2 Ceramic firing in kiln 1

The most firings were carried out in the kiln built in the summer of 2013. The first firing (1-13) was an oxidation firing, during which the smoking process failed. Five firings (1-14, 1-16, 2-17, 1-18, 4-19) resulted in smoked pottery. The next firing (1-15) was not completed due to a collapse in the grate and part of the batch. (Graph 31, for details on individual firings, see Těsnohlídková 2021, Appendix 10; SH film 2).

In this type of kiln, there is an ongoing debate concerning whether a grate was present and potentially what it looked like. The grate made of clay bricks used in the first firing was rather robust; it took up a great deal of space in the kiln while simultaneously limiting flames/fire from reaching the vessels (Fig. 161: A). The design of the grate thus influenced air flow into the kiln. During subsequent firings, the grate was gradually minimised until it finally served merely as an aid in securing the pottery from falling into the heating channel, and it could have been excluded altogether if there were enough suitable (large bulbous and tall) vessels (Fig. 161: B). Similar vessels used repeatedly for this purpose and referred to as 'kabáty' (meaning 'coats') are known from Czech ethnography; alternatively, vessels may have been placed in the rear area of the channels or directly inside them, with vessels then stacked on top of them (e.g. Snášil 1970, 331; Weiser 2003, 15). The use of vessels in the construction of the central spoon is known from St. Pölten in Austria (Scharrer-Liška 2009, 183–184). In addition to the central spoon, a ledge around the circumference of the kiln, which is also documented on the archaeological model for the kiln, was used to support the vessels or for a grate to be placed on it.

In this kiln design, the batch is placed through the chimney opening. Initially, the heating opening was also used for loading. The most difficult task was bridging the space in front of the kiln above the firebox. Here, one or two large vessels had to be placed here, and these were inserted through the chimney and handled from below by a person lying in the firebox (the kiln is just long enough to make it impossible for a person to reach this place through the chimney). The next loadings were carried out exclusively via the chimney. The size of the chimney opening thus limited the size of the vessels.



Graph 31. Temperature curves measured during firings in kiln 1 from the start of firing until the kiln was sealed: A – firing 1-13; B – 1-14; C –1-15; D – 1-16; E – 2-17; F – 1-18; G – 4-19. Author K. Slavíček.

A tier of vessels was first stacked on the grate. This first tier, mainly in the front and middle section, was designed so that the vessels covered the grate without creating large gaps that would prevent an even draught for the flame. Larger vessels were first loaded into the kiln. The space was then filled in with smaller ones. Some of the vessels leaned against the walls. Preferably, vessels were placed bottom-up or diagonally. The free space by the walls and between the vessels was filled with vessels of a suitable shape. With smoked ceramics, the aim was to smoke as much surface area as possible, and for this reason



Fig. 161. Loading procedure of a large pottery kiln and grates used to bridge the firing channels: A – solid brick grate made from Brtnice clay (condition after firing 1-13); B – auxiliary grate made from cut grog board (firing 2-17); C – kiln being filled through both the chimney opening and the firing channel (1-16); D – the most demanding part is placing the first vessels in the front section of the kiln above the firing channel (1-16); E – the first tier of vessels consists of large and medium shapes; vessels are placed upside down where possible (1-15); F – near the kiln walls, vessels are tilted or rotated to maximise the efficient use of kiln space (1-15). Photo by K. Těsnohlídková, K. Slavíček, Z. Bočková.

the vessels were not lined up against one another. An effort was made to minimise the space/surface where they were touching or where they were resting against the kiln wall. On the next tiers, vessels were aligned from the edges towards the centre in order to maximise the use of space. The last vessels were placed close to the chimney opening (Fig. 161: C, D). The loaded kiln contained vessels on 2–4 tiers. Kiln capacity for firing smoked ceramics was between 108–140 vessels.

Experimental firings in this kiln lasted between 7.5 to 13.5 hours. This time was influenced by experience with managing firings, the weather, or the various research issues concerning individual firings. If a coarser ceramic fabric that corresponded macroscopically to the 13th century was being fired, it would have been possible to conduct the firing even faster. The thin, long spruce or pine battens that were created as a waste product from the production of planks proved to be a good fuel.

The first stage of firing involved the drying of the vessels and of the kiln itself. Temperatures of up to 100°C were held for 1 to 3 hours. At this stage of firing, fuel was added in front of the kiln or at the edge of the heating opening. Slightly damp smoke rose from the chimney opening of the kiln. If the kiln surface was wet, steam would also rise from the kiln's walls (Fig. 162: A, B).

Vessel drying was also carried out in the next stage of firing, when temperatures were raised ideally by 100°C per hour. The first phase involved a rise in temperature up to 300°C, with heavy, thick, and moist smoke rising from the kiln. At temperatures above 200°C, some of the vessels became covered with black soot. The smoke became gradually drier, and the stoking of the firebox could be intensified. Red-hot and subsequently fresh fuel could then be moved to the heating ducts (Fig. 162: C, D). By then, the temperature was already over 300°C, and vessel drying was still occurring up to about 500°C. The smoke gradually ceased to be moist, the chimney was now emitting a rather strong heat, and the vessels were alternately light or covered with soot depending on the stage of adding fuel – we could now consider this to be an oxidising or reducing environment. If cracking was observed in vessels during firing, or cracking of the grate as in the case of 1–15, it usually occurred around 300–400°C in the front area of the kiln and at lower temperatures in the middle and rear part (100–300°C; Fig. 162: E–H).

From the beginning of the firing, it was possible to observe the kiln gradually heating up. The highest temperatures were recorded at the front sensor closest to the firebox, and the lowest at the rear sensor below the chimney opening. Different heating methods and (in the early years) attempts at partially closing the chimney or heating hole were applied in the attempt to equalise the temperature in the kiln as soon as possible. This was done primarily in order to heat the vessels evenly and mitigate large temperature differences within a single vessel. This practice is known from ethnography (Mangel 2016, 285). Attempts to close the openings proved ineffective, and various heating methods did not contribute significantly to solving the problem. The results of six firings show that this kiln establishes draught, and temperatures always equalise at similar degrees. Differences decrease on the sensors starting at 350°C or 400°C. From 500°C at the most, temperatures are balanced. The only deviation was seen in firing 4-19, where the temperatures of the front and middle sensors equalised at around 650°C, while the rear sensor stayed more than 100°C lower the whole time – this firing was strongly influenced by the weather, especially persistent rain, and differing air pressure could also have had an influence.

Vessels were already dry and actual firing was taking place at a temperature of around 500°C. Temperatures were rising rapidly. The quartz phase transformation temperature of 573°C was quickly exceeded; if the temperature were to fluctuate around this value for a long period of time, the quartz grains could have damaged the vessel walls. At this stage of firing, the temperatures on individual sensors had usually already equalised.

From this stage onwards, the addition of fuel was carried out in the same manner until the end of firing and was adjusted to fit the current behaviour of the kiln. The aim was to minimise fuel consumption. The most effective heating technique proved to be the cross-heating technique, as battens were laid over each other to ensure good combustion. Fuel was often added only to the firebox, and red-hot embers were moved into the channels. Occasionally one or two battens were added to the channels. If a large flame was coming out of the chimney opening, heating intensity was reduced so as to prevent unnecessary heat dissipation. Above 800°C, now above flame temperature, the retention of heat or further increase in heat was determined by the volume and accumulation of hot fuel in the kiln more than by the intensity of adding fuel. Simply raking the red-hot fuel in the channels often sufficed to increase temperature. On the contrary, adding fuel lowered the temperature slightly until the new fuel began to burn properly.

Reaching 800°C was perceived as a certain limit in our firings, but firing was maintained above this value for at least one hour. The highest temperature reached in this kiln was slightly above 1000°C. At this temperature, depending on the fabrics used, the first deformations (e.g. bent edges of vessels) occurred.

Dry smoke was already coming out of the kiln at temperatures between 500–800°C, alternating from thick and black to thinner and light-coloured. Thus, reduction and oxidation phases were probably alternating. When black smoke was visible, the surface of the vessels was covered with soot, and a hot ember probably penetrated a vessel (Fig. 162: G). Inthe next phase with light-coloured smoke, soot (or carbon from the ceramic fabric) combusted, and the vessels in the oxidasing environment acquired a light-coloured surface (Fig. 162: F). These phases were repeated several times and reached different lengths of time. Experience with heating helped influence this variable.



Fig. 162. Firing process until vessels began to glow in kiln 1: A – fire is started in front of the kiln and gradually moved inside (firing 1-18); B – vessels in the kiln chimney at temperatures up to 100°C on the front sensor – without significant visible effects, at most only slight smoke (4-19); C – vessels in the kiln chimney at temperatures of around 200°C on the front sensor (100°C on the back sensor; 4-19) – heavy, damp smoke coming from the kiln; D – at temperatures above 200°C on the front sensor, soot begins to deposit on the vessels in the chimney (1-18); E – the dark smoke emitted at high temperatures has a characteristic smell, likely related to the reduction phase of the firing (1-18); F – combustion of soot at around 650°C (1-18); G – vessels covered with soot at around 600°C (2-17); H – at higher temperatures (750°C in the image), soot remains only on parts of the vessels in the chimney facing outward (2-17). Photo by K. Těsnohlídková.

At temperatures above 800°C, light and dark smoke could be observed in the chimney opening. In contrast to the previous phase, the vessels no longer retained soot, which had probably combusted immediately off the hot vessels. The presence of soot could be observed for the longest amount of time on the cooler parts of the vessels (the sides of the vessels facing towards the chimney opening).

The smoke was accompanied by a flame that came out of the chimney opening starting at around 500°C. Between 550–700°C, a clear bright flame (called 'lišák', which means 'fox' in Czech) (Fig. 163: A) usually appeared for the first time, followed by a hot, narrow flame that produced smaller flames at its end (Fig. 163: B), which sometimes also formed around the kiln chimney. These flames probably reflect further reduction phases (cf. Döhner, Herdick, Axtmann 2018, 73). The temperatures in the kiln were already at about the same level at this stage due to the heat accumulation in the fabric of the vessels and kiln walls, and also due to the sufficient amount of hot fuel in the channels. During significantly stronger additions of fuel, the kiln became 'choked'. Oxygen then re-entered the kiln and relatively large flames shot out through the chimney (Fig. 163: C, D). When no flame was coming out of the kiln, it could be assumed that air was being drawn into the kiln and an oxidasing atmosphere was present. Again, these phases can be influenced by experience with firings, but both are necessary for successful firing. During one, formation and accumulation of heat takes place. In the other, combustion and the efficient use of heat energy take place.

From temperatures above 500°C, the vessels gradually became hotter. It was possible to observe vessels that were beginning to glow dark red in the lower area of the kiln. Above 600°C, even the vessels in the chimney opening glowed dark red (Fig. 163: E). The colour of these vessels gradually changed in intensity from dark red to cherry red around 700°C (Fig. 163: F). At about 800°C, the vessels were already quite orange (Fig. 163: G, H), and at 900°C, they were light orange to yellow. At 1000°C, they were almost pure white (Fig. 163: I, J). In daylight, it is only possible to observe the glow of the vessels at higher temperatures.

Closing the kiln is the last stage of firing for smoked ceramics (Fig. 163: K). The stove was prefilled with the chosen fuel for smoking, and for our case beech, birch, spruce, pine, and elder branches were successively tested. First, the heating vent was closed and daubed; the same was then done with the chimney. In some firings, a strong flame shot out of the kiln after closing the heating hole, and the kiln 'hummed' due to the overpressure of the burning fuel. In these cases, we waited until the situation slightly calmed down out of fear that the internal pressure might cause the kiln to burst. Small cracks were observed on the surface of the closed kiln, with smoke from the kiln escaping through them. Soot was also deposited around them. The affected areas were gradually daubed. At night, they could be identified with the use of a burning candle; in places where air leaked out of the kiln, the candle flame would waver when it approached the kiln's outer layer (e.g. Snášil 1970, 331–332). In the case of oxidation firing, the kiln would have been left open to cool, or the chimney or heating hole would only be covered to slow the cooling process.

Cooling took place ideally at temperatures below 100°C and took approximately 48 hours (Fig. 163: A). Large kilns known from ethnographic records were left to cool for 2–3 weeks, but 11 hours could have been enough if the remnants of burning fuel were quickly removed from the kiln after opening (Snášil 1970, 331–332).

In addition to the thermometer readings, it gradually became possible to monitor the firing process subjectively by means of the senses as was done historically. It was possible to detect by ear when the kiln established a draught (this was easier at night), i.e. when in our case it reached a temperature of around 500°C and above, and also the humming of the kiln at high temperatures (around 800°C and above), when the pressure in the kiln was rising due to the high heat in the kiln and continual addition of fuel. Touch was used during the vessel drying process to determine the intensity of the moisture of the smoke from the kiln's chimney. Once the smoke was dry (between 400–500°C), it was possible to start quickly increasing the temperatures. The sense of smell was useful in determining the reduction phases of the kiln, which were usually accompanied by thick black smoke with a 'smoky or earthy' smell.

Kiln behaviours are visible in varying ways depending on the time of day – e.g. dark smoke and soot-covered vessels are more easily observed in daylight; in the darkness, the kiln's increasing temperature and the flame coming out of the kiln stand out – e.g. the clear bright flame was previously observed (at lower temperatures) in kilns at night. Similarly, observations of the shade and colour of the glowing vessels may vary according to the lighting conditions, or even according to the colour perception of the person conducting the firing.

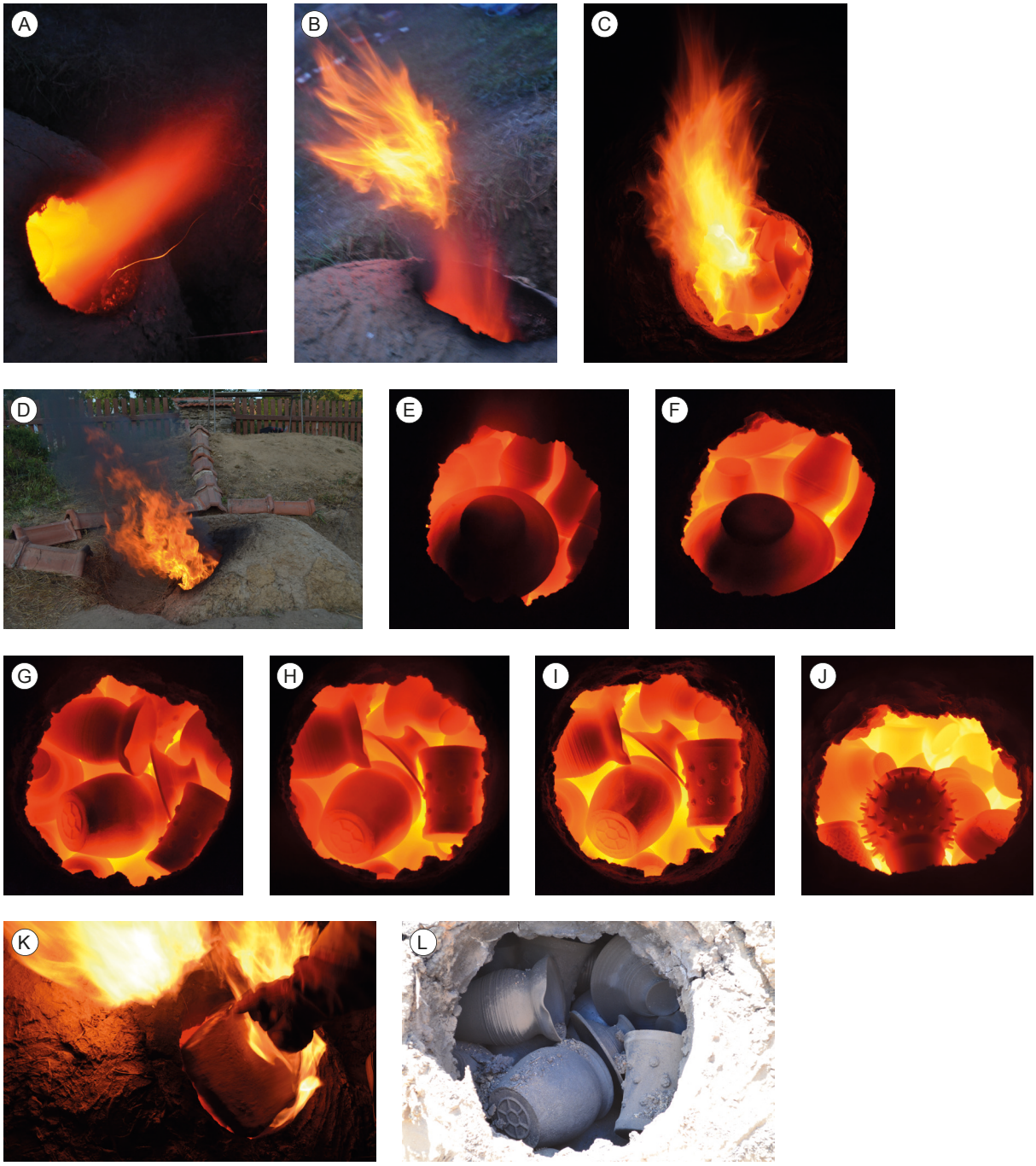
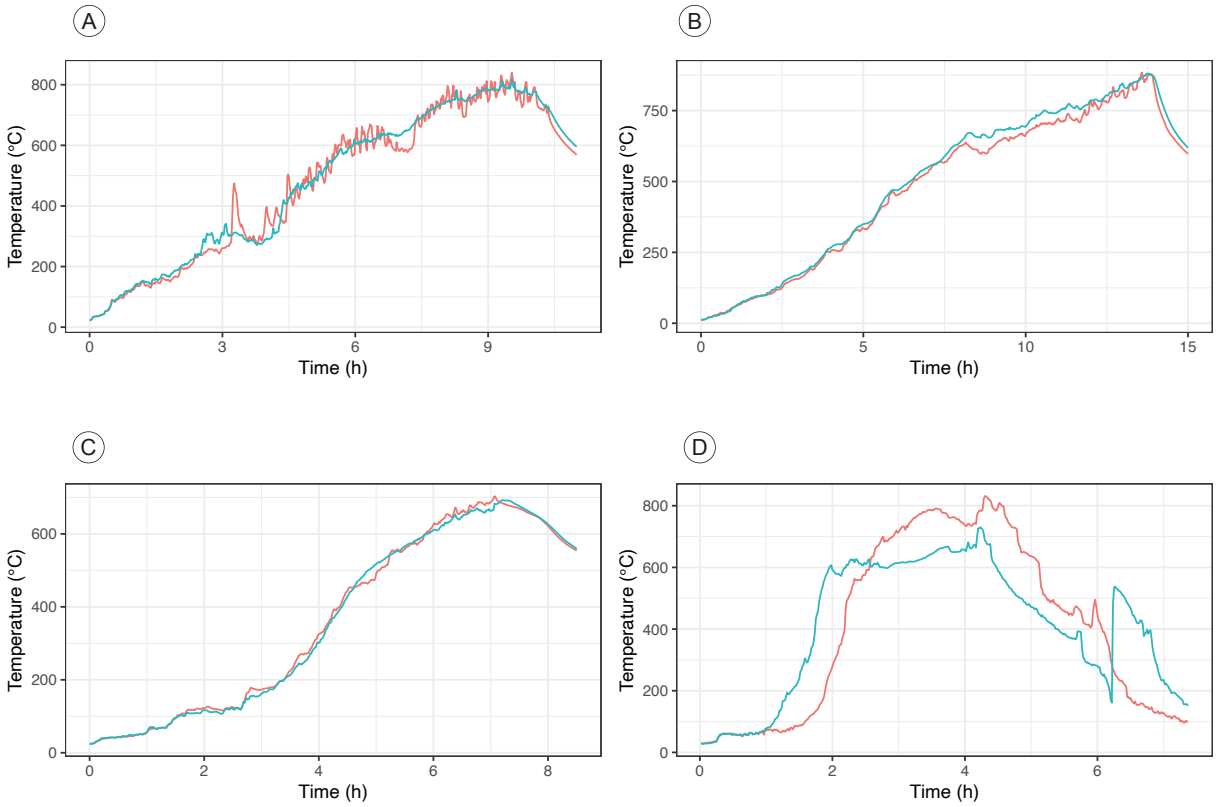


Fig. 163. Firing phases above 500°C and the conclusion of firing in kiln 2: A – direct flame known ethnographically as the 'fox' (firing 1-14); B – flame with small flickering tips, ethnographically called the 'rooster' (1-14); C, D – large flame usually accompanied by dark smoke coming from the kiln at high temperatures after stoking (2-17, 1-18); E – temperatures around 650°C – dark red colour (1-16); F – temperatures around 750°C (1-16); G – temperatures around 800°C (2-17); H – temperatures around 850°C (2-17); I – temperatures close to 900°C (2-17); J – temperatures around 900°C – vessels at the back of the kiln show a yellow to almost white colour (4-19); K – at the end, the kiln is sealed airtight – the chimney opening is the last to be covered and daubed (2-17); L – chimney hole after being opened (2-17). Photo by K. Těsnohlídková.



Graph 32. Temperature curves measured during firings in kiln 2 from the start of firing until the kiln was sealed: A – firing 2-15; B – 3-16; C – 3-19; D – 3-20. Author K. Slavíček.

6.4.3 Ceramic firing in kiln 2

Four firings were carried out in the bonfire-like clamp kiln. This included two firings of smoked ceramics (2-15, 3-16), one oxidation firing with reduction in a vessel (3-19), and a dynamic firing, in which the interior of the kiln was filled with fuel and vessels (3-20). In the case of kiln 2 as well, the firing is described using the example of smoked ceramics. The oxidation firing differed only in the fact that the kiln was not filled with fuel and closed in the final phase, and the maximum temperature that was reached was deliberately lower than in the reduction firing (Graph 32; detailed in Těsnohlídková 2021, Appendix 11; SH film 3).

The kiln was furnished with an opening for loading, and filling it was thus relatively easy. The chimney opening worked as an aid here. Three clay bricks were laid in the centre of the kiln, leaving space for heating channels around the circumference (Fig. 164: A). The first part of the batch consisted of nine large pots or jugs placed on clay bricks (so-called 'kabáty' could also have been used), or the space between them could have been filled in with some smaller pieces (Fig. 164: B). During the next phase, tall and fairly slender shapes that supported the pots placed from the centre towards the walls were used (Fig. 164: C). Some were partially wedged against one another. This created a wreath of vessels along the circumference of the kiln, and underneath the vessels were heating channels. The kiln was then loaded with more vessels starting in the centre, initially using rather larger pieces. Loading then continued according to the space in the kiln or available vessels (Fig. 164: D). As a final step, vessels were aligned directly by the loading opening – here there was nothing for them to lean against, so they were arranged basically on top of each other. The greatest amount of free space was always left in this spot. The loading hole was filled in after the kiln was loaded.

If the space in the kiln allowed for it, vessels were mostly arranged bottom up. The relatively small dome and the vessels' resistance to the kiln walls required some vessels to be positioned diagonally – preference was always given to the bottom-up direction, or the vessels were positioned in such a way that the mouth of the vessel was not fully covered by the wall of the kiln or another vessel. If necessary,



Fig. 164. Loading and firing in kiln 2: A – placing three bricks on the kiln floor (firing 3-19); B – first tier of large pots and jugs (2-15); C – second tier of large and medium vessels with slender jugs, pots, or possibly goblets braced against the kiln walls (2-15); D – top tier of the loading consists of smaller vessels, e.g. bowls and lids (3-19); E – firing process – two firing channels are operated by two people (2-15); F – firing method by adding wood splinters in a 'V' shape (3-19); G – glowing, red-hot vessels at the bottom of the loading (3-16); H – reduction phase of firing – kiln is glowing hot and the hot flame draws air outside above the chimney (3-16); I – glowing vessels in the kiln chimney at temperatures between 800–850°C (3-16); J – kiln after opening – visible collapse of the loading (3-16). Photo by K. Těsnohlídková.

some vessels were also arranged bottom down. The capacity of the kiln was 50–70 vessels of varying sizes. Since the goal was to achieve ceramics with the highest possible smoked surface area (with the exception of oxidation firing 3-19), the vessels were not purposely arranged to fit closely together, which would have increased their number.

The firing was started by lighting a small fire in front of both heating holes (Fig. 164: E). Over the course of an hour, the fire was moved into the heating holes, drying out the kiln and vessels. Temperature was maintained at around 100°C. Gradually, the fire was moved into the heating channels on both sides, the aim being to heat up the whole circumference of the kiln. For finer ceramic fabrics, it was advisable to increase the temperature by 100°C every hour and attempt to equalise the temperature on the two sensors used (one was located under the chimney, the other near the vessels past the loading hole). From about 500°C onwards, the fire was stoked to increase temperatures. Temperatures approaching 900°C were achieved in the kiln.

As was the case with kiln 1, heating was carried out using thin battens, which were arranged in a 'V' shape on top of each other in the heating hole and then in the channels to better facilitate the burning process (Fig. 164: F). This prevented the channels from being overfilled with insufficiently burnt wood and thus clogging them. The battens were sometimes left to burn in the front area of the firebox before being inserted into the heating channels. At high temperatures, when there was enough hot fuel in the kiln, it often sufficed to add fuel to the fireboxes relatively sparingly, and the kiln held this heat (Fig. 164: G–J). It was advisable to have two individuals operating the two heating openings during firing. At higher temperatures, stoking was carried out by alternating from one hole to the other. Depending on the strength of the kiln's draught and on the weather, flames would sometimes shoot out of the hole opposite to the one into which fuel was being added. One heating hole could also be covered while adding fuel to the other.

6.4.4 Ceramic firing in kiln 3

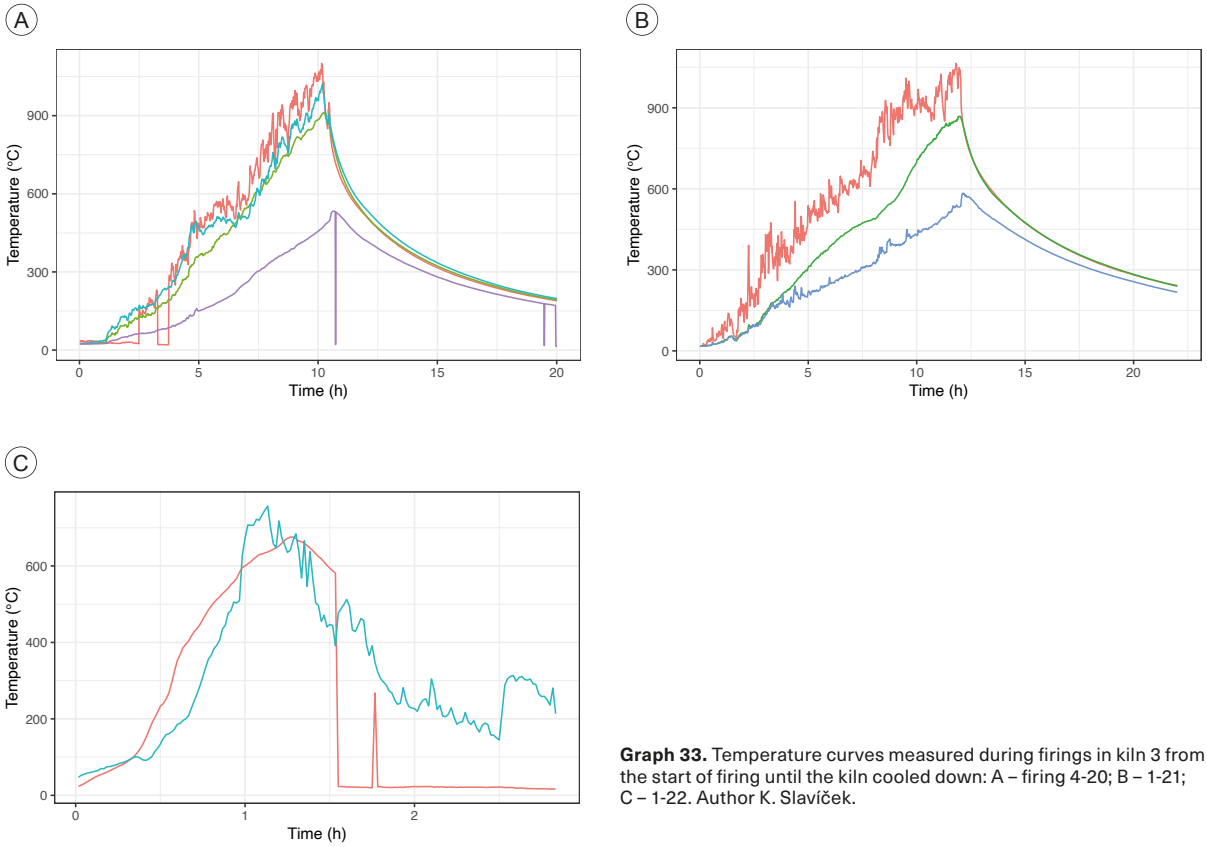
The kiln at the château in Žďár nad Sázavou was built on the basis of the same model as kiln 1, i.e. according to the ground plan of the kiln from Křížová Street in Jihlava. The aim was to test the differences in functionality of a device whose above-ground part was designed differently, mainly with a loading hole at the rear, which made it possible to increase the size of the dome. Two firings of smoked ceramics (4-20 and 1-21; SH film 4) and one rapid dynamic firing (1-22; Graph 33) were carried out in the kiln.

The process of filling the kiln differed from kiln 1, which was otherwise similar in design. The ceramics were placed into the kiln through the loading hole at the back of the kiln (Fig. 165: A). Therefore, the size of the vessels was not limited by the size of the chimney opening, and arranging the vessels was easier than in kiln 1. The issue of the grate was dealt with in the same way as with kiln 1, i.e. by using a small temporary grate, which, however, could be replaced by bridging the heating channels with large pots leaning against each other. These pots could either be part of the batch or the same vessels reused for this purpose.

Due to the larger filling hole, the dome was built higher to increase kiln capacity. However, once the 5th and 6th tiers of vessels had been arranged, it became apparent that the lower parts of the vessels had already begun to be damaged from the weight of the load they were carrying (Fig. 165: B). This included ruptures in the edges, mainly in beakers, even though the vessels were stacked with large ones at the bottom and small ones at the top. Therefore, this kiln height was already at its maximum limit, and it was necessary to adjust the batch accordingly. After filling, the loading hole was walled up using bricks and clay mixed with straw, leaving only the square chimney in the upper section of the kiln.

The firing process for the smoked ceramics was kept identical to the previous firings to record efficiently the effect that the kiln's structural deviations had on the firing. The firings lasted 11–12 hours, with the aim of keeping temperatures above 800°C for at least one hour ideally at all measured points while simultaneously achieving temperatures of around 1000°C in at least a part of the kiln. Due to the predominance of vessels made of fine ceramic fabric, a gradual temperature increase curve was chosen so that it would stay around 100°C for roughly 2 hours and then increase by 100°C per hour. From 500°C upwards, temperatures were increased as quickly as the kiln allowed (Fig. 165: D–F).

Except for the problematic rear section of the kiln, the objectives were achieved. The highest temperatures measured were between 1050–1100°C. In the front area of the kiln during one of the firings, there were already slight deformations, especially on the edges of the vessels of the batch (sagging). Otherwise, well-fired, relatively evenly smoked pottery was obtained with a minimum of mechanically



Graph 33. Temperature curves measured during firings in kiln 3 from the start of firing until the kiln cooled down: A – firing 4-20; B – 1-21; C – 1-22. Author K. Slavíček.

damaged vessels, including those that were damaged during the actual loading of the kiln (in both cases up to 5% of the batch; Fig. 165: G, H). Despite the larger size of the kiln, wood consumption was not significantly higher than in the smaller kilns. After the kiln heated up, higher temperatures were only maintained and slightly increased by gradually adding more fuel; the fact that lower consumption was due to the smaller heating opening was confirmed.

The vessels at the rear of the kiln were not fully fired, which was probably due to the location of the chimney. After bricking up the loading hole, the vessels at the bottom in the rear area of the kiln were placed in a position that was not in the path of the flame's draught. Heating this part of the kiln would have significantly prolonged the duration of firing, and the vessels in the front of the kiln could have been damaged. This occurred during both kiln firings. Part of the problem could have been solved by arranging the kiln's batch differently, but in this kiln, we were limited by the height of the dome. The composition of the loading must allow for the lower tiers of the batch to support the vessels in the upper part. With a lower dome, heating the back of the kiln would probably have been easier. The height of the chamber in this kiln can thus be considered the maximum limit for firing a vessel with a size corresponding to the High and Late Middle Ages.

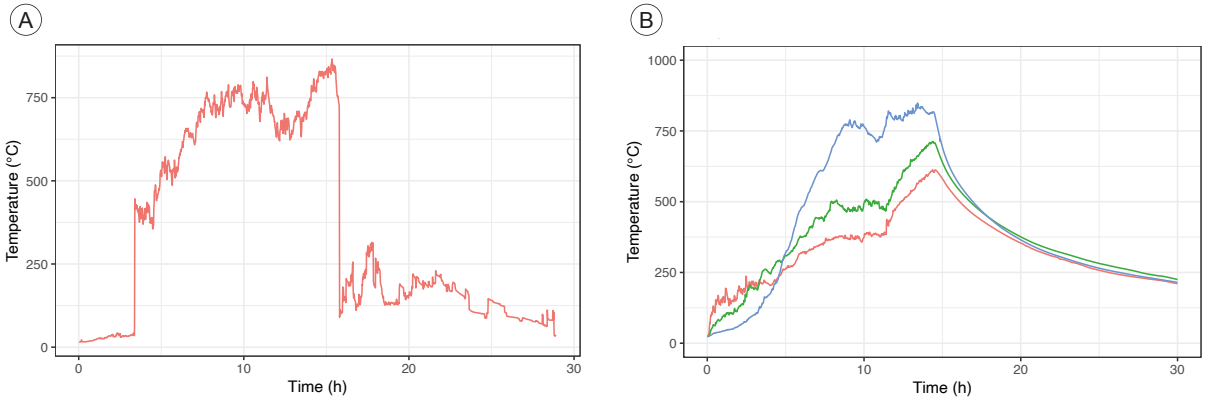
6.4.5 Ceramic firing in kiln 4

In response to the discovery of a new type of pottery kiln used in the Bohemian-Moravian Highlands in the 13th and first half of the 14th centuries, a kiln was built based on finds from Žďár nad Sázavou – 'Staré Město' and Jihlava – U Skály Street. Two firings were carried out in it according to two of its possible uses (1-23, 3-24; Graph 34).

Both preserved relics of this type of kiln – especially the find from the Jihlava, U Skály Street – raised the question of how this device may have been used. It was assumed to have had a relatively small and narrow heating hole, the absence of daub and, inf the case of the Jihlava kiln, also disorderly vessel arrangement (if we assume that this was a batch and not a secondary filling-in of an unused kiln with defective vessels, which, however, would have had to take place in several stages). The aim of the experimental firings was to: 1) verify the assumption that it is actually possible to heat up the kiln via the heating opening in this form and achieve sufficient



Fig. 165. Firing in the replica kiln 3: A – loading vessels into the kiln through the loading opening is quite convenient (firing 4-20); B – vessels are placed in the kiln in 5–6 tiers (4-20); C – vessels in the kiln chimney start to become covered with soot (4-20); D – arrangement of vessels at the kiln front above the firebox and heating channels, with a supporting grate visibly bridging the channels (1-21); E – vessels glowing in the chimney opening (temperature around 600°C; 4-20); F – glowing vessels in the chimney opening (temperature around 800°C; 4-20); G – opening the kiln by breaking apart the masonry around the loading opening (1-21); H – the kiln after opening (4-20). Photo by K. Těsnohlídková.



Graph 34. Temperature curves measured during firings in kiln 4 from the start of firing until the kiln cooled down: A – firing 1-23; B – 3-24. Author K. Slavíček.

temperatures; 2) test the kiln with a permanent and temporary clay dome, and 3) use the kiln for the classical firing of smoked ceramics in comparison with dynamic firing.

The firing of smoked ceramics according to the procedure used in the other types of experimental kilns took place after placing a wicker dome over the base of the kiln and covering it with clay made lighter with straw. The size of the dome roughly corresponded to kiln 2; however, kiln 4 lacked a grate and heating channels, and the batch was slightly larger (Fig. 166: A, B). Heating up the kiln through the small, narrow opening was rather difficult and impractical, although it was eventually carried out successfully (Fig. 166: C). Temperatures between 600–700°C were reached after about 7 hours. Then, however, the increase slowed and finally halted, and it took almost 5 more hours to reach temperatures approaching 800°C on one of the sensors. Then, the temperature dropped again for two hours, and only after about 14 hours did it stabilise above 800°C on one of the sensors (the other sensors showed lower values, but problems arose here in recording the measurements, and for this reason the result is not expressed in the graph; Fig. 166: D). After another hour, the kiln was filled with oak wood and closed (Fig. 166: E).

After cooling, the kiln was opened. The pottery was smoked fairly evenly, with a dark surface (Fig. 166: F). Most of the organic impurities had combusted, including graphite, despite the small heating opening and a number of reduction stages during firing. Several vessels were mechanically damaged; as usual, cracks appeared mainly in vessels with large-diameter bottoms (bowls, tripod vessels).

The second scenario for firing in the kiln which was built based on finds from Žďár nad Sázavou and Jihlava – U Skály Street was a dynamic firing using a temporary kiln roofing after loading. The batch was more modest compared to the previous one, because the kiln chamber had to be filled with vessels and fuel, and the method of creating a temporary roof involved closing the kiln chamber slightly above ground level. Due to the uncontrolled firing process that was planned, only vessels made of natural clay were chosen, as they are suitable for this type of firing. A total of 21 vessels, mostly with larger pot-shaped forms, were thus loaded into the kiln (Fig. 167: A). The batch was stacked on a wooden base, preferably with vessels placed bottom-up. Wood chips and sawdust were strewn over them, then all the available space was filled with additional fuel, from small wood chips to large pieces of planks and logs (Fig. 167: B). After being filled in this way, the pit was covered with hazel-tree wicker and daubed so that only the chimney opening remained in the rear area (Fig. 167: C, D).

The fire was lit in front of the heating hole and the burning fuel was gradually pushed inside so that the wood in the chamber also caught fire. It was left to burn slowly and, after two and a half hours, the temperature peaked at around 793°C on the sensor. Then, the two holes were daubed and the kiln was sealed to prevent further oxidation phases.

The resulting pottery had a black surface, and the vessels were sufficiently fired (Fig. 167: E, F). Minor cracks were recorded only in the rim of a storage vessel; otherwise, no vessel was mechanically damaged. The rapid rate of firing combined with the kiln's sealing should ensure the retention of organic carbon and graphite in the fired fabric. This type of firing is thus suitable for graphite ceramics and goods with completely black fabric or thick dark cores.



Fig. 166. Firing in replica kiln 4 with a permanent dome version (firing 1-23): A – the loading is placed on the dried kiln floor and the first vessels are arranged traditionally with the bottom down; firing occurs only in the front part of the kiln; B – the second phase of filling the kiln is significantly influenced by its shape; the arrangement of vessels can also affect the flame draught in the later firing phases; C – view of the kiln from the heating opening – compared to other kilns, this opening is narrow and relatively long; the dome created over the wicker frame protrudes above the surface; D – in different parts of the kiln, larger temperature differences can be expected, which only fully even out after closing the kiln; through the chimney at the rear, vessels in the front are already visibly 'glowing', while soot deposition and combustion can still be observed on vessels at the back; E – just before closing the kiln, vessels in the chimney opening are also glowing; F – part of the fired loading inside the kiln. Photo by K. Těsnohlídková.



Fig. 167. Firing in replica kiln 4 with a temporary dome version (firing 3-24): A – the loading is arranged differently than in the kiln with a permanent dome; vessels are placed inside the kiln on a wooden base and may be dusted or filled with small wood debris, chips, or scraps; B – the vessels are stacked and surrounded with wood for firing, filling what is to be the entire kiln chamber; C – the loading with fuel in the pit is covered with fresh twigs; D – the wicker structure is coated with daub, creating a provisional kiln dome. Firing commences gradually with a low heating hole; before the fuel inside the kiln chamber ignites, the vessels undergo drying and preheating; firing continues while adding fuel only until a large part of the wood in the kiln chamber ignites, after which the kiln is sealed on both sides; E – opening the kiln after cooling; F – finished ceramics after charcoal residues are cleaned off. Photo by K. Těsnohlídková.

6.4.6 Failed kiln firings

Two kiln firings that did not reach their intended completion for two different reasons are presented here: in the first case, an obstacle prevented completion, and in the second case, temperatures rose more than was appropriate for the ceramic raw material that was being used.

Firing 1-15 in the large pottery kiln had to be stopped due to the fact that the batch collapsed, even though the firing was initially running completely according to standard. An auxiliary grate made of parts of old ceramic roof tiles was placed in the kiln, and a standard batch of 140 vessels (28 large, 56 medium, and 56 small) was loaded onto it, predominantly including vessels made of wheel-throwing materials. Spruce battens were used as fuel. At a time interval of 4.5–5.5 hours from the start of firing and at temperatures of 200–400°C, several parts of the grate gradually cracked, and finally a part of the batch collapsed into the heating channel (Fig. 168: A–D). This was caused by an inappropriate choice of grating material. The firing was stopped and the kiln was left to cool. Losses amounted to 15% of the vessels. Mechanical damage was evident on 11 vessels (5 were broken completely; edges were broken off in 11). The rest of the vessels were used in the next firing. This aforementioned firing was therefore not completed and the vessels were not fired completely. Nonetheless, valuable information was obtained. For example, the experiment showed that when a batch collapses during firing, it does not necessarily mean it will be completely lost. Only a few vessels were damaged, and the rest could be fired again after the grate had been repaired. Worse damage would have been caused if the kiln's dome or part of it collapsed.

The firing that achieved unexpectedly high temperatures was conducted under the direction of A. Netopilová in Stará Huť u Adamova in 2018 in a kiln with a grate (Těsnohlídková 2021, 152–153). The firing was documented in a different way, and only the highest achieved temperatures were recorded at the grate and in four other locations. At the grate, the highest measured temperatures ranged between 1125°C and 1172°C; in the other locations in the kiln, only the highest reached temperatures were recorded: 1016°C, 1055°C, 1075°C and 1086°C. Vessels made of loess from Šlapanice could not withstand the high temperatures and melted either completely or partially among the other ceramics. Some of the fabrics were partially sintered, and an effect corresponding to an ash glaze was produced in places on the pottery (Fig. 168: E, F).

6.4.7 Discussion on the efficiency of different pottery kiln designs

All the kiln types implemented in these experiments were simple in design. Kilns 2 and 4 can be built with two workers in 1–2 days (including material preparation). Kilns 1 and 3 are a bit more demanding, but with two people, they can be built in about 3–4 days. These are reusable devices, and the size can be adapted as necessary, from small kilns for home production to the large devices known from ethnography even as late as the 19th century (Plicková 1959; Snášil 1970; Varadzin 2010, 29–30).

Kiln 1 was sunken more deeply compared to the original plan and the supporting archaeological materials. Both the entire foundation and also part of the dome were below ground level. This had no effect on the kiln's operation. During the winter, however, water settled in the kiln between the ground and the dome area, especially in the rear part of the kiln. The kiln was thus quite damp before firing season. The tendency to draw more moisture from the subsoil is a general characteristic of sunken kilns (Snášil 1970, 329). This problem no longer occurred in kiln 3, which was constructed using the same ground plan but built essentially at ground level. The reason for sinking the kiln may have been to isolate its foundations from the surrounding elements, to limit temperature losses during firing, but also for practical/safety reasons. The kiln's orientation, which differed from that of the archaeologically excavated original, was not handled in any special manner – it was simply adapted to the site where the replica of the kiln was built.

For kilns 1 and 3, the question of the grate that was intended to bridge the heating channels and the ledge located along the circumference of the kiln was also addressed. The grate is considered to be the most important structural element of the kiln (Wasilczyk, Wasilczyk 2014, 36–37). It must withstand the highest temperatures and firing so as not to compromise the pottery batch. This of course depends on the type of kiln. Because we have no evidence of this in terms of the kilns in question here, it can be assumed that the first tier of vessels was supported by the central spoon and the ledge spanning the kiln's circumference or directly by the kiln walls. It would also be possible to use auxiliary vessels in part of the heating channels to create another auxiliary point for arranging the first tier of vessels. These may have been repeatedly fired vessels, 'kabáty', or large vessels that had not yet been fired (Snášil 1970, 331; Weiser 2003, 15). In terms of our firings, the grate was gradually minimised



Fig. 168. Failed firings in kilns: A–D – incomplete firing in a large pottery kiln caused by the breakage of the grate above one of the firing channels (1-15); E, F – firing by A. Netopilová in Josefov at temperatures above 1200°C with some vessels made from loess loam – ceramics and kiln walls damaged by heat. Photo by K. Těsnohlídová, A. Netopilová.

to auxiliary plates made of grog fabric so that they would affect the firing process and kiln capacity as little as possible.

The dome of all the kilns was made of wicker and daubed with clay made lighter with straw with a thickness of about 20 cm. Its size and shape were subordinated to the main objective, i.e. for the kiln to be as stable as possible. The maximum suitable height of the dome depends on the size and type of the vessels being fired. In terms of the experimental firings in kiln 3, the weight of the 5th and 6th tiers of vessels began to damage the vessels in the lower part of the kiln.

The course of firing in different kilns and with different volumes of batches confirmed that it is more advantageous to fire a kiln with a full load of ceramics as opposed to only partial loadings. Maintaining high temperatures in the kiln and increasing them is mainly determined by heat accumulation in the walls of the vessels and the kiln.

After the first firings, in which the chimney hole was formed in the middle part of the dome, the hole was moved in all other cases to the rear section for the sake of air flow and to achieve sufficient temperatures in the rear part of the kiln. In kilns 1 and 3, the kilns' firebox where fuel ignition took place was also extended. In contrast, the main function of the channels was to ensure the flow of hot air. During the vessel drying process between 300–500°C, the channels were also used for heating. After the kiln had 'established a draught', i.e. during the actual firing, fuel was either added only occasionally or none was necessary at all; hot fuel from the firebox was merely shifted inward.

A significant factor affecting fuel consumption was the size of the heating opening. In kilns 1 and 3, it was always reduced to about 20 × 20–30 cm before firing. This size also reduced the risk of heat damage to the arch above the heating hole.

The two opposing heating vents for kiln 2 proved to be fairly ineffective – one would often burn more as the other drew air into the kiln. During firing 3-19, the kiln chimney was essentially inoperative, and the flames stayed at the bottom of the kiln. One of several causes for this was windy weather. Gradually covering the openings or having a larger kiln area may have presented a partial solution, but for such a small kiln, two heating channels proved to be ineffective, i.e. one sufficed. Another problem – the clogging of the heating channels due to insufficient fuel combustion – was solved during the experiments by more efficient addition of fuel. Experience played a major role here.

Firing 2-15 showed how important it is to properly load the kiln. Part of the batch near the loading hole repeatedly failed to be arranged tightly enough, leaving a considerable amount of free space. The sensor located there then recorded significant jumps in the rise and fall of temperatures, starting at around 300°C, in contrast to the sensor between vessels under the chimney, where the temperature rose slowly and did not fall. Especially up to temperatures of around 573°C, i.e. the phase transformation of quartz, this phenomenon can cause damage to the vessels (Graph 32: A).

The two variations of dome design (permanent and temporary) in kiln 4 showed how different firing strategies can be implemented in a kiln with an essentially identical archaeological footprint. Here it was possible to fire quality smoked pottery, but also softer products that are saturated with an organic inclusion.

6.4.8 Firing strategy and fuel

Thin spruce and pine battens (e.g. waste products from wooden plank production) proved to be a suitable fuel, and it was useful to stack them in a 'V' pattern for efficient combustion and energy use. The properties of the fuel used also had a positive effect in that the heating channels and firebox did not become dirty and needed no cleaning during firing. This procedure essentially simulates the presence of a grate under the fire. In the first years, the channels became clogged due to still-inconsistent techniques of adding fuel. Although it was possible to clean the channels with a long metal poker, this resulted in unnecessary heat loss and thus greater fuel consumption. As the heating technique was improved, this problem was eliminated.

Up to about 500°C, efforts were made to carry out a gradual temperature increase of about 100°C per hour, and the addition of fuel was adapted to this. In the first phase of vessel and kiln drying at temperatures of around 100°C, heating took place at the front sensor only in front of the kiln and gradually also at the edge of the heating hole. The fire was then moved into the kiln, and the intensity of fuel addition into the firebox was gradually increased. Above 300°C, the firebox was heated intensively and hot fuel was moved into the channels (Tab. 39).

During the actual firing above 500°C, with the aim of rapidly increasing the temperature, heating was carried out with varying intensity in the firebox as the situation required, and hot fuel was merely moved into the channels. At most, 1 or 2 planks at a time were added to the channels as required. At high temperatures above 800°C, hot fuel had already accumulated in the kiln; here the heat radiating from the fuel was decisive in maintaining and increasing temperature, not the addition of more fuel. Adding fuel at this stage tended to bring down temperatures but was still necessary to create hot fuel. At these high temperatures, feeding only small wood chips into the heating hole was often sufficient (Tab. 39).

In terms of the technique of adding fuel, we can compare it to the experience gained by authors of experimental firings in the UK in the 1970s, who pointed out that a temperature rise above 700°C led to a significant increase in fuel consumption (Bryant 1973, 155). This did not happen in our case.

In an attempt to balance the temperatures measured by sensors in the different parts of the kiln, partially or fully covering the kiln and chimney during firing was also tested in the first years. These procedures proved to be ineffective. After the kiln

Temperature in the front section,°C)	Firing techniques	Properties of the kiln and the vessels	Progress considering the temperatures in the middle and rear parts of the kiln
Below 100	Firing is done in front of the kiln and at the edge of the firebox opening	Gradually, a bit of moist smoke begins to emerge from the chimney	Vessels in the middle and rear are not yet fully drying
100–300	The fire is moved into the kiln – the firing intensity in the firebox is gradually increased	Moist smoke from the chimney; some vessels may gradually become covered with soot	Due to rising temperature, the vessels in the middle and rear parts of the kiln gradually finish drying
300–500	Intensive firing in the firebox, shifting of embers, and firing through the channels	Smoke gradually becomes dry; heat is visible from the chimney. Vessels appear alternately light or covered with soot	Between 400–500°C, temperatures equalize across all parts of the kiln
500–800	Mostly only in the firebox with varying intensity (depending on kiln behavior), embers shifted into channels, occasionally 1–2 sticks/logs added	Smoke: The kiln emits dry, alternating black smoke (vessels are covered with soot – reduction phase) and light smoke (vessels are white – oxidation phase)	Temperatures are generally balanced throughout the kiln (variations may be caused by rainy weather)
		Flame: Between 550–700°C, the 'fox flame' appears for the first time. Small flames may form at its tip or appear at the edge of the chimney (possibly reduction phase); alternatively, a large flame emerges from the kiln (more likely oxidation)	
		Vessels: Glowing is visible between the vessels in the kiln, and the vessels begin to glow dark red (around 600–700°C)	
		At 700–800°C, the vessels glow light red to orange	
Above 800	Mostly only in the firebox with varying intensity (depending on kiln behavior), embers shifted into channels, occasionally 1–2 sticks/logs added	Smoke: Smoke is light or dark, but soot no longer adheres to the vessels	Temperatures are generally balanced throughout the kiln (variations may be caused by rainy weather)
		Flame: A fox flame may emerge from the kiln, sometimes with small flames at the tip or as a large flame	
		Vessels: The vessels glow, and soot no longer settles on them	
		At 800°C, the vessels glow orange	
		At 800–900°C, the vessels glow deep orange and gradually whiten	
		At 900–1000°C, the vessels glow light orange, eventually turning white	
Sealing and cooling	Kiln loaded with fuel (beech, birch, spruce, pine, elder)	Sealing of the firebox opening and chimney, and plugging gaps in the kiln wall	Temperatures in the kiln equalize regardless of weather conditions
		Cooling ideally down to temperatures below 100°C (approximately 48 hours)	

Tab. 39. Generalisation of the ideal firing process based on firings conducted in experimental kiln replicas.

heated up sufficiently, the temperature in it levelled off at around 500°C, when it 'established draught'. To compensate for the temperature in the kiln at this value or even higher ones, ethnographic sources show that small pieces of fuel were added towards the chimney, which would draw the flame from the kiln and ignite (Wasilczyk, Wasilczyk 2014, 40).

The type of fuel and its consumption is another monitored factor that depends on the technique of adding fuel. Here, two groups must be distinguished: fuel for the firing itself and fuel for the final smoking (for smoked ceramics).

For the first few seasons, leftover spruce wood (battens from an old roof) was used for firing, and also chips left from sawing boards mostly made of pine, which did not need to be further treated. At most, the pieces of wood were broken into shorter ones. Both spruce and pine have ideal properties for firing, and their behaviour during firing fully met our requirements. It was a cheap and readily

available fuel, and therefore no alternatives were sought out. Both spruce and pine are suitable fuels for increasing temperatures (e.g. Wasilczyk, Wasilczyk 2014, 35). Resinous pine chips 50–60 cm long were also used in the firing of smoked pottery in Slovácko (Snášil 1970, 331). Some authors are inclined to use deciduous wood (e.g. Gregerová et al. 2010, 30). The predominance of deciduous trees for firing was also used by R. Thér (2009, 196). This choice is strongly influenced by the fuel types available in the vicinity. In general, harder wood burns more slowly, the temperature increases more evenly, and the maximum temperature reached may be higher.

From the beginning, attention was given to using the least amount of fuel in terms of the technique used in order to achieve the lowest possible costs and exert the least effort during firing. If we use data from the last four kiln firings in kiln 1 (1-16, 2-17, 1-18, 4-19), when we now had more experience with adding fuel and kiln behaviour, fuel consumption per firing ranged from 0.3–0.6 m^3. In addition to the technique of adding fuel, consumption was also influenced by the duration of firing. All cases involved firings with temperatures held above 800°C for 1–2 hours and temperature peaks between 930–1030°C. Heating for firings 1-16 and 2-17 with a higher consumption (0.5 and 0.6 m^3) was carried out for 15 and 13.5 hours respectively. The lowest consumption was achieved in firing 1-18, with only 0.3 m^3 for a duration of 10 hours. The fastest firing 4-19 (7.5 hours) was affected by rainy weather, and consumption reached 0.4 m^3. It can be assumed that batch the kiln with a coarser ceramic fabric corresponding macroscopically to high medieval pottery could have somewhat accelerated the firing, or that a shorter duration of higher temperatures would have been sufficient, which would probably have led to even lower consumption.

Further data for comparison are available from firings in Mayen (Rhineland-Palatinate). These employed a different kiln with a central spoon, spoke-like grate and lacking a permanent dome (the batch was covered with ceramic plates). Amount of fuel (wood), which was used for the firing of more than 300 vessels lasted 10.5 hours, was 1.6 m^3. The open top of the kiln and the large heating hole led to the relatively high fuel consumption. In the firebox, temperatures of almost 1000°C were reached, but some measured points between vessels did not exceed 700°C (Hanning et al. 2014, 431–440; Döhner, Herdick, Axtmann 2018, 76).

The data on fuel consumption from the firing processes in kiln 2 are less relevant. For the first firing (2-15), consumption was not measured. For the second, it amounted to 0.7 m^3. This number is high due to the fact that the firing lasted longer due to the rainy weather. The third firing (3-19) had a low consumption of 0.2 m^3, but its aim was to maintain temperatures above 600°C for over an hour – it is therefore not useful for comparing consumption with a large pottery kiln, but may serve as a suitable parallel for pit firings.

The bonfire-like clamp kiln in Slovácko with a capacity of 500–600 vessels needed a total of 2 m^3 of fuel to fire at temperatures of around 900°C. The kiln had a circular base with a diameter of 4 m and reached a height of 2 m (Snášil 1970, 331–332). The kiln used for firing glazed ceramics in Knínice near Telč in the first half of the 20th century consumed 4.5 m^3 of wood (Hladík 1988, 173–174; kiln size 250 × 300 cm, height 180 cm). A relatively quick firing of smoked ceramics in a kiln was carried out by M. Mogielnicka-Urban. During a three-hour process, the temperature reached about 690°C, and 0.6 m^3 of fir wood was burned (Mogielnicka-Urban 1975, 463–465).

A more varied range of fuel types was chosen to smoke the ceramic surface. Except for firing 1-13, we managed to smoke the pottery in all cases. Spruce, beech, and birch wood were progressively tested. Larger-sized logs were used for smoking, as they burn longer and create more smoke in the kiln. Less dry and more resinous wood was always preferable to dry and rotting pieces. Fresh elder branches were also used for smoking in the small kiln.

Birch yielded the darkest and somewhat opaque smoking. Beech smoking was medium to dark grey, often with a metallic sheen, while the use of spruce resulted in lighter or medium shades of grey. The lightest shades were recorded on vessels from a small kiln smoked using elder wood, which gave the vessels most often a light to medium grey-brown colour. Elder branches or nettles, which are mentioned in ethnographic literature for smoking pottery, should be supplemented with logs of wood if one wishes to obtain a more intense effect.

6.4.9 Oxidation – reduction – smoking

The next topic is the oxidation and reduction atmosphere in the kiln. These phases can be partially detected empirically during firing. The final surface of the ceramics is influenced mainly by the end of the firing process. A detailed cross section of the fired fabric may then reflect several phases of firing (Orton, Hughes 2013, 152).

The initial phases of firing are oxidation firing. Reduction firing clearly takes place at the moment when the kiln is so full of hot fuel that the oxygen in the kiln is completely burned and the kiln emits a bright flame, which can also have small red-hot flames at its ends, which are caused by the air that the kiln is drawing in at the edge of the chimney or at the end of the bright flame. Reduction can also be said to occur when dark smoke with a characteristic 'smoky, earthy' smell comes out of the kiln at temperatures above 500°C and soot is present on the vessels that are visible through the chimney. After partial combustion of the fuel, the oxidation phase occurs intermittently. In terms of the final oxidation phase, the ceramic fabric may oxidise to its core depending on temperature, while in the case of smoked ceramics, the surface will be smoked.

For deliberate reduction, we experimented with partially/fully covering the chimney opening to limit the influx of air into the kiln, but this was not effective. Subsequently, the intensity of the burning decreased, and therefore the kiln began to draw in additional air needed for combustion. Completely sealing the chimney and heating openings would require covering and daubing them and then opening them in order to add fuel, which would be an unnecessary complication. The reduction phase is thus triggered more by the aforementioned accumulation of hot fuel in the kiln and sufficient combustion of oxygen than by sealing the kiln.

Another issue involves the form of reduction that can take place in the absence of oxygen after it is fully consumed by the kiln. This prevents any organic or graphite components from combusting off the fired material. The second possibility is the migration of organic carbon from the fuel into the fired material, thus the 'smoking', when the carbon can secondarily penetrate the surface of the ceramics, while at the same time the soot deposited on the surface of the ceramics prevents organic carbon or graphite from combusting off the fired material. In field firings, the predominance of reduction with the presence of organic carbon from the fuel can be assumed. This is evidenced by observations of soot being deposited and combusting off the surface of the ceramics. Above roughly 800°C, soot no longer settles on the ceramic surface and the reduction atmosphere is clean.

Research carried out in the UK, which also includes experimental firings, has shown that reduction phases in firing may have been reached deliberately. In clays containing iron oxides, partial vitrification of the fabric occurred earlier during reduction than in the oxidasing atmosphere. The resulting products were thus stronger and less porous than in predominantly oxidation firing (Blackmore, Pearce 2010, 131–134).

6.4.10 Pit firings of ceramics

Since 2014, a total of 14 simple firings have been carried out without the use of structural elements. Twelve of these firings took place in a slightly sunken pit for safety reasons. The last two were then carried out in suitable conditions in a surface fireplace. Placement in a pit partially protected the firing from the wind and helped to better insulate the temperatures. Pit/fireplace firings are carried out without roofing or temporary shelter and are thus directly dependent on the weather.

The implemented firings can be divided into four categories. The first includes open firings in a pit, resulting mostly in oxidation ceramics. Their main aim was to determine the temperatures that pit firing can reach, to test the possibility of a gradual increase in temperature, and whether it is possible to create a temperature curve similar to firing in a kiln. We also conducted closed pit firing, which focused on the possibility of achieving full reduction and the highest possible temperature. In between these two categories are open firings that were filled in during the final phase and firings with an auxiliary structure, which were intended to test the variability of the character of the resulting ceramics, especially in terms of atmosphere or the number of damaged vessels. The last type of firing is dynamic, one-time firing in a pit fireplace. The difference between this and the previous types mainly lies in the different method of heating – only a 'pyre' of fuel and ceramics is prepared, then lit and allowed to burn without adding additional fuel. The question was whether it would be possible to achieve sufficient temperatures in our environment for this type of firing and what the resulting ceramics would look like.

Generally speaking, there is a wide range of these firings, which can be divided into different groups and variations. This work has focused only on the basic types to test basic possibilities and obtain comparative data for kiln firings and comparative samples for the analysis of archaeological pottery firing technology. A similar range of firings was chosen for ceramics with a predominance of oxidation features by M. Daszkiewicz and M. Wetendorf (2017, 11–12). Experiments focusing on prehistoric pottery have addressed this issue in more detail

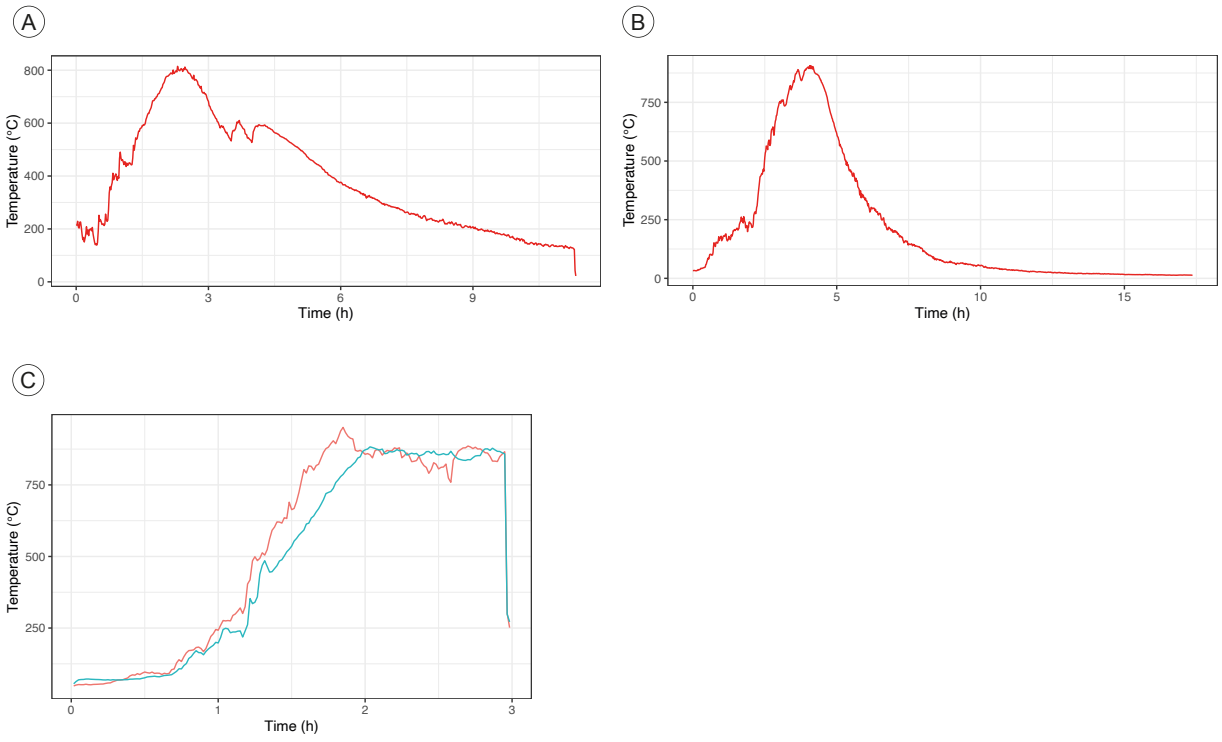
(Thér 2008, 130–134). As part of research on early medieval pottery, different types of pit firings were tested in Germany (Böttcher, Böttcher 1997, 87–93). Here, in another experiment, ceramics were also fired in one-time firings (Lüdtke, Dammers 1990, 321–326). Inspiration can also be sought in overviews of ethnographically documented firings (e.g. Whitehand 2013).

Open pit firings

Three open firings were conducted as part of this work (1-17, 1-19, and 2-24; Graph 35; SH Film 5). Their realisation was based on ethnographic data (Fig. 169). A small fire was lit in a pit to dry it out and the vessels were arranged around its edge (Fig. 169: A). Hot embers were raked to the sides after burning and the vessels were then placed in the pit (Fig. 169: B). Initially, a fire was lit on both sides, then fuel was added around the vessels themselves (Fig. 169: C). The fire came gradually closer to the vessels. After temperatures of around 200°C were reached, fuel was added directly onto the vessels (Fig. 169: D). After that, fuel was added intensively, and temperatures increased above 800°C, when some vessels began to glow. The fire was allowed to burn without being contained (Fig. 169: E). To achieve a smoky surface for the pottery in the final stage, wood/woodchips could be added and the pit could be covered with earth or lined with sod to prevent air flow (Fig. 169: F).

The main objectives of this type of firing were not only to achieve maximum temperatures of around 800°C, but also to achieve required durability. For certain ceramic fabrics or early medieval pottery, a lower value would have been sufficient, but our aim was to try to mimic the temperature curve of kiln firing. Depending on the fuel type and heating strategy, temperatures of around 1000°C can be achieved (Wasilczyk, Wasilczyk 2014, 33).

The firing tests confirmed that this process can achieve temperatures sufficient for firing ceramics. In both cases, it was possible to maintain values above 800°C, and in the second case this was done for a whole 1.25 hours, which corresponds to the requirement set for the first firings in pottery kilns. Similarly, a gradual increase in temperature was achieved – it was possible to maintain temperatures up to 200°C for over two hours, after which a more significant increase was observed when adding fuel over the vessels, which caused losses. The firing time was 4.75 hours and 5 hours, plus the time required to dry out the pit, i.e. a total of between 5–6 hours. Overall, 0.45–0.75 m^3 of fuel was consumed (similar to Wasilczyk, Wasilczyk 2014, 35).



Graph 35. Temperature curves measured during open firings: A – firing 1-17; B – 1-19; C – 2-24. Author K. Slavíček.



Fig. 169. Open firing in a pit: A – warming of vessels around the fire pit (firing 2-24); B – after placing the loading in the centre of the pit, the fire slowly moves toward the vessels (2-24); C – firing in close proximity to the vessels (2-24); D – firing over the vessels (2-24); E – smouldering phase (2-24); F – results of the open firing predominantly show vessels with oxidation marks (1-17). Photo by K. Těsnohlídková.

Despite the seemingly gradual increase in measured temperatures, it should be noted that the measured value came from the sensor located in the assumed core of the firing. The temperature of the vessels varied, especially in the marginal areas of the firing. This problem is likely to increase in proportion to the size of the vessels. A large temperature difference could also occur within a single vessel, which could cause mechanical damage. The results show that temperature equilibrium is only achieved at higher values, when the vessel walls begin to accumulate thermal energy.

The fired ceramics can be described as mixed – signs of an oxidasing atmosphere are predominant, with reduction stains appearing in places of direct contact with the fuel (Fig. 169: F). When firing in fireplaces, it is necessary to expect certain losses of ceramics due to temperature jumps and uneven heating of the vessels. For both firings, there was a relatively large loss in the number of vessels (31 and 40 %) due to mechanical damage – cracks, fissures, chipping of the walls, or potentially even the destruction of the entire shape. This was due to the use of vessels made from fine, industrially produced

ceramic fabric, which are not highly resistant to temperature shocks. In the third firing, which used more vessels made of coarser natural clays, which are more suitable for this type of firing, the proportion of damaged vessels was lower.

The process called 'hartowanie' or 'obvara' (Holubowicz 1950, 227), which is evidenced in ethnography but was presumably used already in the Middle Ages, was used in the final phase. The red-hot vessels were taken out of the fireplace and dipped in a mixture of water and flour. All vessels mechanically survived the temperature shock caused by being soaked in the cold mixture. After a few days, the surface began to show damage from the rapid cooling, with small fragments beginning to chip off most of the vessels. This was probably caused by an inappropriate choice of ceramic raw material.

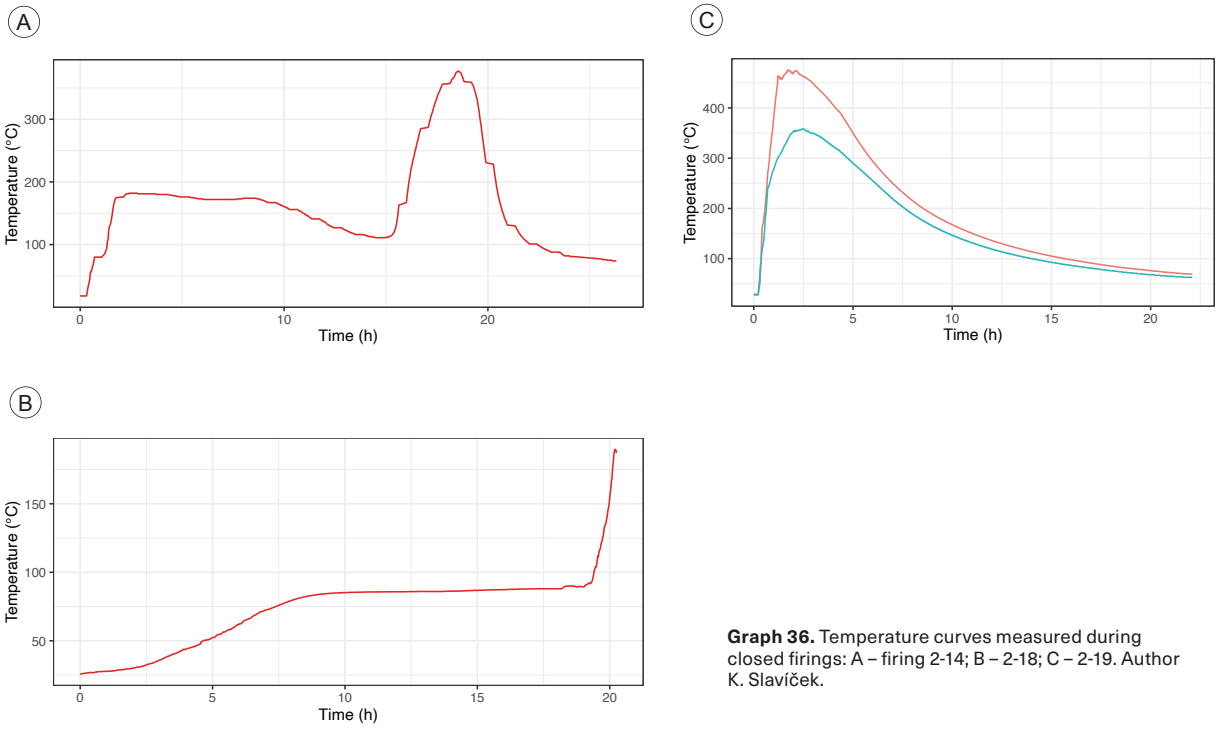
Closed pit firings

For three closed firings (2-14, 2-18, 2-19), we attempted to achieve full ceramic reduction (Graph 36; SH film 6). The bottom of the pit was lined with wood and woodchips/hay/sawdust. The pottery batch of roughly 10–20 medium and small vessels was arranged in the centre (Fig. 170: A) and completely surrounded with fuel (Fig. 170: B), which was aligned to leave gaps to facilitate burning. Firing was started from the top and fed so that the vessels were constantly covered with a layer of hot fuel and oxidation did not occur (Fig. 170: C, D).

In order to keep the ceramics in a reducing environment, the entire pit was filled in after the upper layers of the fuel had partially burned (Fig. 170: E). It was assumed that the fuel would combust gradually, the remaining oxygen in the pit would be consumed, and the ceramics would take on a reduction character. This process proved to be very problematic. After filling in the pit, temperatures rose only minimally and the fuel was combusting insufficiently. Increasing the intensity of burning by creating several holes in the fill of the pit was tested with success.

Most of the pottery that was created cannot be described as fully fired. If the pottery was fired, it bore signs of a mixed atmosphere, probably due to the air supply through the auxiliary holes (Fig. 170: F). Mechanical damage ranged from 0–48%, depending on whether there was an initial rapid rise in temperature. In terms of fuel consumption, this firing was slightly more economical than open pit firing. Measuring the firing temperature was also problematic in certain ways, as it was difficult to estimate the place with the highest temperature in advance. Therefore, the measuring probe was not necessarily placed in an optimal location.

Creating flue chimneys or openings for air intake would probably lead to greater effectivity in achieving temperatures. This has been successfully tested in experimental firings of early medieval pottery in Germany (Böttcher, Böttcher 1997, 87–91).



Graph 36. Temperature curves measured during closed firings: A – firing 2-14; B – 2-18; C – 2-19. Author K. Slavíček.

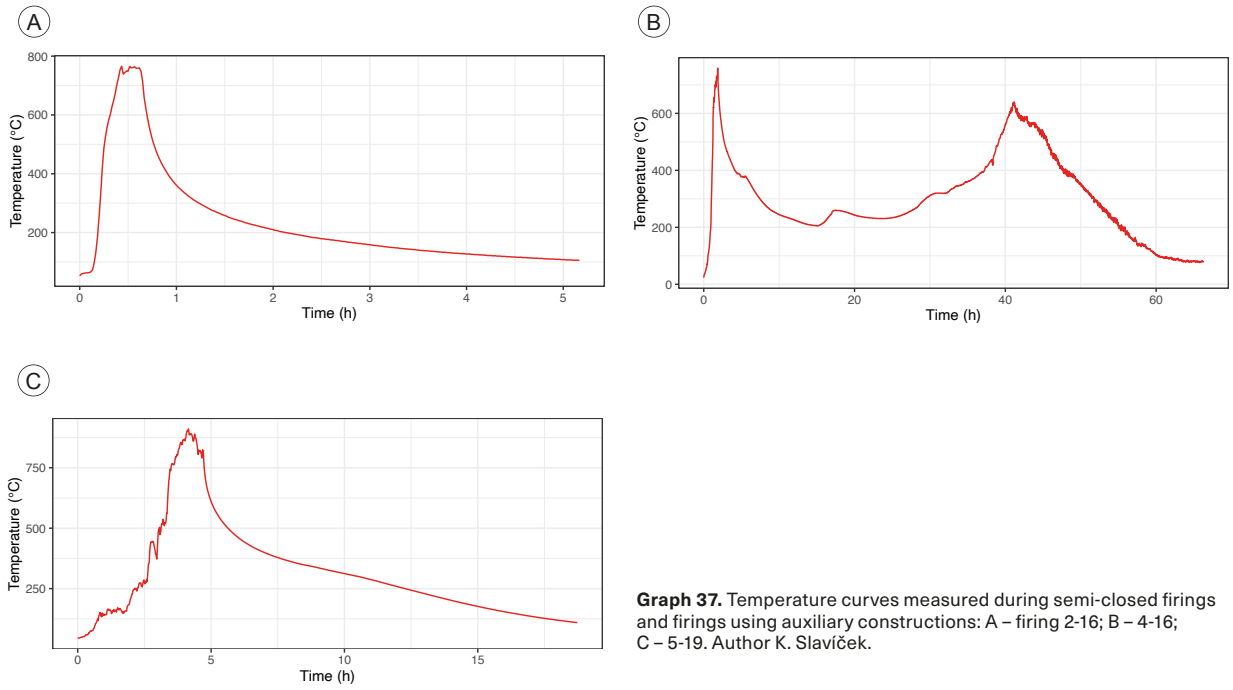


Fig. 170. Closed pit firing (firing 2-14): A – stacking vessels into the pit on a base of wood and straw; B – gradually surrounding the loading with wood and covering it with straw; C – commencement of firing; D – adding fuel; E – covering the firing with clay and sod after ignition and temperature rise to the desired level; F – the result is ceramics with a predominance of reduction effects. Photo by K. Těsnohlídková.

Open pit firings with final-phase fill and firing with an auxiliary structure

Three pit firings (2-16, 4-16, and 5-19) were kept open until the final phase, when the pits were then filled in (Graph 37). During the 4-16 firing, an auxiliary structure was tested to protect the vessels from direct contact with the fuel. The beginning resembled an open firing – the vessels were dried around the pit, then inserted into it, or a protective structure created by lining the batch with ceramic plates was placed around them (Fig. 171: A). Initially, fuel was added from both sides, then around the vessels, and the fire slowly came into contact with the pottery (Fig. 171: B). Eventually, the fire moved above the protective structure (Fig. 171: C). Once the desired temperatures and appearance of the ceramics was achieved, the last addition of fuel was carried out and the batch along with the fuel was covered with dirt (Fig. 171: D).

The resulting products show signs of a mixed atmosphere (Fig. 171: E–G). In various places on the fired batch, signs of reduction or oxidation may



Graph 37. Temperature curves measured during semi-closed firings and firings using auxiliary constructions: A – firing 2-16; B – 4-16; C – 5-19. Author K. Slavíček.

prevail. We failed to obtain pure reduction ceramics that would have been completely smoked after a predominantly oxidation firing process. In regard to the speed of temperature rise in some of the firing phases, it is necessary to expect some losses of the loaded ceramics. These losses could have been minimised by the use of more durable ceramic fabrics. An auxiliary structure, e.g. made of shards, can also protect the ceramics from sharp rises in temperature. However, we find analogies for this procedure more in prehistory or in ethnographic documents.

Dynamic firings in pits/fireplaces

Dynamic firings are characterised by the absence of fuel addition. At the beginning of the process, the 'pyres' of fuel and vessels are prepared, ignited, and left to burn freely. This type of firing is not feasible for products made from industrially prepared wheel-throwing and grog materials, and for this reason we began to test it later once vessels made from treated natural clays became available. Five of these firings were carried out (6-19, 7-19, 1-20, 2-20, 1-24; Graph 38; SH film 7). The procedure drew on firings of this type that are known from ethnography (e.g. Perryman 1998, 21; Skibo 2013, 45).

The ceramics were arranged together with the fuel so that a one-time firing was possible without the addition of fuel. A group of vessels was placed at the bottom of the pit on the prepared fuel and formed the base of the pyre (Fig. 172: A). More logs, chips and splinters were piled around the batch, and wood chips or straw were additionally strewn over the vessels. Residual or waste wood material can be used for firing, and its properties determine the firing process. The pyre was ignited from above to allow the fuel to burn down to the batch (Fig. 172: B). The firing process was not interfered with in any way. As expected, the temperature rise was very rapid and the firing was short. Maximum temperatures of 600–900°C were reached after 0.3–1.5 h (Fig. 172: C, D). This firing was highly variable with respect to the size of the batch, volume, and type of fuel. It was also difficult to assess in terms of the measured temperature values, as temperature jumps were massive, as were the differences in various parts of the firing. We always tried to place the sensor roughly in the middle of the batch.

Burning took place for about 2 hours for firing 6-19 and 1 hour for firing 7-19. Both firings contained a similar batch volume. The quantity of fuel was also identical, i.e. 0.18 m^3, but it differed in type. The pyre with only pine wood burned for 1 hour with a temperature maximum of 942°C, and the pine and beech combination burned for 3.5 hours with a maximum of 690°C, both until the temperature dropped below 500°C. In the case of the pine fuel, temperatures rose faster – a value of 600°C was reached in 0.3 hours; in the case of the combination

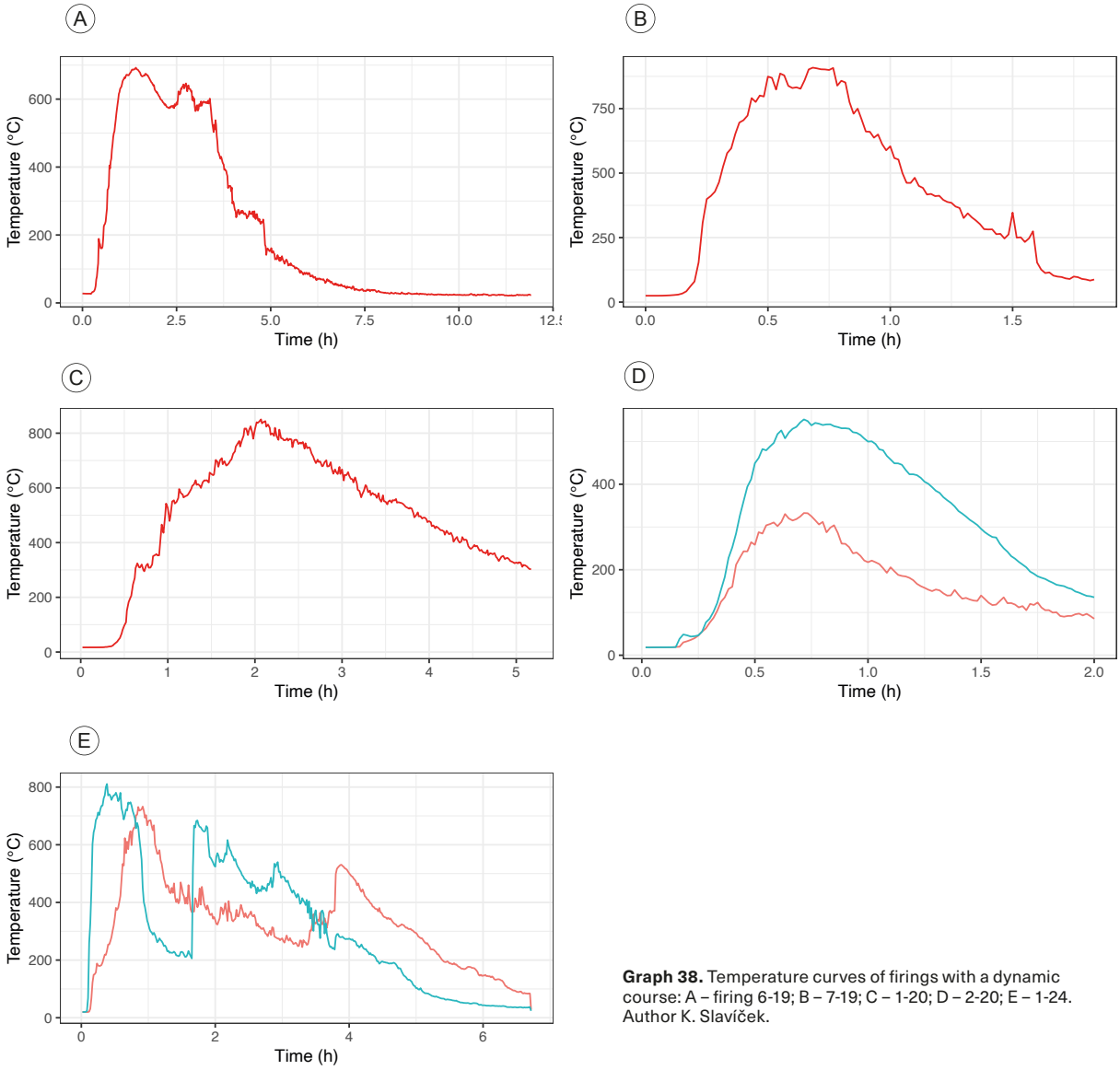


Fig. 171. Open firing with final closure (firing 5-19): A – heating around the vessels; B – intense heating near the vessels; C – heating above the vessels; D – covering the firing after the last stoking; E – the load after firing; F – the resulting ceramics show signs of a mixed firing with a predominance of oxidation. Photo by K. Těsnohlídková.

of pine and beech, this took place after 1 hour. The time that temperatures were maintained above 600°C differed the least – this was 0.7 h for pine and 1 h for beech and pine. Beech wood burns longer and maintains high temperatures better, while pine increases temperature quickly and to higher degrees.

The next two dynamic firings took place in 2020 with a larger batch volume. For firing 1-20, which had sufficient fuel volume, the temperature approached 600°C after one hour, and the maximum measured temperature of 836°C was reached after 2 hours. The 2-20 firing with a similar batch volume was insufficient, and only maximum temperatures of around 600°C were achieved with a small amount of fuel.

The last firing of this type, 1-24, was realised with a larger batch of replicas of medieval brickmaking and loess vessels including a graphite inclusion. The firing was measured with two sensors placed between vessels to show the subjectivity of measuring this type of firing: one of the sensors reached



Graph 38. Temperature curves of firings with a dynamic course: A – firing 6-19; B – 7-19; C – 1-20; D – 2-20; E – 1-24. Author K. Slavíček.

a maximum of around 810°C after 20 minutes, the other around 730°C after 60 minutes. Sawdust, wood chips and scraps from spruce and pine boards were used as fuel.

In addition to the fuel volume, the volume of the batch also affected the firing process. A larger batch accumulates heat better and faster, and it has the ability to reach higher temperatures, maintain them for a longer period of time, and cool more slowly in this type of firing.

The surface atmosphere of the fired ceramics can be described as mixed (Fig. 172: E, F). Signs of an oxidasing atmosphere predominate, with reduction stains appearing at the points of direct contact with the fuel. The larger the batch, the greater the reduction marks on the vessels. With such a fast firing process, some losses of ceramics must be anticipated, especially depending on experience with the ceramic fabric that is used. The ceramic fractures contain dark cores – this type of firing does not cause rapid combustion of the organic component.

In terms of the ceramic fabrics, local 'brickmaking' clays proved to be successful, even in versions with a graphite inclusion. If the fine industrially processed material was also fired in the grog version, the losses would probably be close to 100%. Loess proved to be unsuitable as well, although they were easy to process for wheel-thrown pottery. However, probably due to calcareous inclusions or the fineness of the material, they could not withstand the thermal shocks of the one-time firing. Loess could only cope with this kind of firing when heavily tempered with



Fig. 172. Dynamic firing process in an open fire (firing 1-24): A – stacking of vessels and samples on a base made of logs; B – vessels are covered with sawdust and wood chips and surrounded by wood; the log base is ignited; C – course of the firing; D – combustion phase when the highest temperatures are reached; E – vessels after ash is cleaned off – the surface predominantly shows mixed atmosphere effects; F – vessels mainly showing signs of reduction. Photo by K. Těsnohlídková.

organic matter, as has been demonstrated by firing replicas of prehistoric vessels. Small cracks were also found in a few cases on vessels made of other types of clays.

From ethnographic data, we know these types of firings from the F. Kalingas, where their duration is even shorter, i.e. 20–30 minutes (related to the fuel used) using a greater batch volume (30–40 medium to large vessels). Temperatures in these firings reach 500–900°C, most often 600–800°C. The hot walls of the ceramics are then treated by smearing on resin to prevent permeability (Skibo 2013, 45). A shorter period of time, i.e. around 30 minutes, was taken to fire three large vessels (the size of storage vessels) documented in Nigeria – once again, the duration was linked to the fuel that was used, i.e. predominantly straw (Perryman 1998, 20–21). The fact that it is possible to fire a relatively large volume of vessels in this way is evidenced by firing documented in the Caribbean region – a pyre is formed with five tiers of vessels of

varying sizes (roughly 100–200 vessels – the total dimensions of the batch – the diameter at the ground reaches 1.5 m and the height as well). Dry woodchips are placed lightly between the vessels, and the whole batch is lined with wood and ignited, with temperatures reaching between 600–700°C (Fay 2017, 89–91).

This type of firing is relatively quick and easy, especially because there is no need to preheat the batch. The firing can reach temperatures sufficient for ceramic firing, although it has a rapid start, shorter duration, and faster cooling. In the final phase, the firing could be filled in, thus reducing the effect of the oxidation atmosphere on the ceramics. The firing does not require a great amount of fuel, and it makes firing a large number of vessels possible. However, it requires clays resistant to temperature shocks. Regional brickmaking clays, with properties corresponding to medieval pottery, meet this requirement.

Discussion on pit firings

Open firings in pits/fireplaces are a relatively efficient type of firing. To summarise the basic specificities, it should be noted that it is partially possible to control the course of such firings, especially when striving for a gradual increase in temperature up to 500°C, after which it is possible to increase the temperature rapidly. Open firing in fireplaces is characterised by high fuel consumption with fewer vessels. The resulting batch is predominantly oxidation with reduction or mixed parts.

In closed pit firings, we tried to let the fuel burn gradually and keep the batch in a fully reduction atmosphere to obtain ceramics with black fabric and a non-combusted organic or graphite inclusion. The main difficulty with this type of firing lies in achieving sufficient temperatures, and thus it seems necessary to build outlet channels from the pit or to partially expose the firing. Although they showed signs of full reduction, the ceramics we obtained with these firings were not fired at a sufficiently high temperature.

Both of these firing procedures combine open firing with closure in the final phase. Closure takes place only after sufficient temperatures have been reached and the ceramics cool slowly in the reduction atmosphere. However, the resulting goods again show signs of a predominantly mixed atmosphere. In addition, a protective structure around the vessels was tested in one case. This may have caused a slight increase in fuel consumption, but the vessels were protected from temperature jumps in the initial stages of firing and drying took place gradually.

Dynamic firing is wholly different from the previous three types, and it has provided the most valuable data concerning the question of the beginnings of high medieval pottery production. The ceramics and fuel are assembled first, and then the resulting pyre is ignited. No additional fuel is added, and therefore temperature control is not possible and a sharp rise in temperature must be expected. Therefore, this firing is completely unsuitable for fine, wheel-throwing fabrics. However, it has proven its effectiveness when using regional brickmaking clays. The vessels made of loess were probably cracking or chipping due to their calcareous inclusion. In this firing, it is possible to burn large quantities of vessels and use any type of wood waste or combustible fuel. These dynamic firings proved to be a method of producing ceramics with dark cores, or with oxidised surfaces and preservation of the organic component in the fabric.

The advantage of one-time firings is the short amount of time needed. Unlike the other types of firings, where it is necessary to have experience with the method of heating and gradually adding fuel, all one needs to do in this case is light the fire once the pyre is built. These firings are also characterised by a significantly lower consumption of fuel.

With the exception of closed firings that strove towards full reduction, it has been confirmed that reaching sufficient temperatures is not a problem in these types of firings, even in the case of one-time firings where high temperatures are maintained for a very short time. Fine ceramic fabrics can also be successfully fired in open firings. One-time firings are suitable for lower-quality clays. In the case of the firings presented here, the percentage of mechanically damaged vessels is high. This is also due to the fact that fine ceramic fabric was predominant in the batch. One-time firings of brickmaking fabrics, which correspond macroscopically to high medieval pottery, show that when these fabrics are used, losses in open firings are considerably lower. At the same time, the use of these clays can make firing less demanding in terms of the requirements for a gradual rise in temperature during the vessel drying process.

6.4.11 Comparison of pit and kiln firings

A pottery kiln requires an initial investment in time and materials for the construction itself, whereas firing in pits or fireplaces can be carried out almost spontaneously after only minor adjustments to the site are made and vessels and fuel are prepared. Kiln firings are safer than fireplaces in terms of

the unwanted spread of fire and are therefore more suitable, e.g. in built-up areas. They are also less dependent on the weather, especially when a shelter is built over them (Gregerová et al. 2010, 29).

The implemented pit firings show that certain procedures can be used to achieve a firing process that is very similar to those in the pottery kiln. This applies in particular to open pit firing or open firing that is covered in the final phase (cf. Thér 2009).

The temperature rise in the kiln is easy to control. In addition, the temperature in closed kilns accumulates better during firing and heats the vessels more evenly. The firings carried out here were characterised by a slow temperature rise, with a maximum of 100°C per hour in the initial stages of firing up to 500°C and temperatures remaining above 800°C for at least 1 hour at the end. During pit firings (with the exception of dynamic types of firings), the aim was to gradually increase the temperature to 800°C. Results show that the range of maximum temperatures can be similar for kiln and pit firings (Tab. 40). Sufficient temperatures could not be reached in the case of closed pit firings aiming for full reduction, nor could they in the case of one-time firings, which are greatly influenced by the amount and type of wood. Maintaining temperatures at the required values is relatively easy when using kilns, and relatively long durations can be achieved even with open firings or pit firings that are closed in their final stage. Maintaining stable temperatures in one-time firings is again limited by the type and quantity of wood, and it may be possible to add fuel towards the end of the process.

The maximum temperature reached in the kiln was close to 1100°C. Temperatures above 900°C were achieved in pit firings. The results of the experimental firings confirm that it is impossible to distinguish firing in a kiln from firing in a fireplace according to the maximum temperatures reached (cf. Thér 2008, 138–139). In addition to the firings presented here, other published experiments confirm this. Generally speaking, higher temperatures or longer durations can be achieved in kilns if this is required for the ceramics being produced. For example, in Poland, maximum temperatures of up to 1250°C are listed for kiln firing and 1000°C for open firing (Wasilczyk, Wasilczyk 2014, 35). Richard Thér gives an optimum value of 1000°C for kilns. In the 1980s, experimental kiln firings in the UK reached maximum temperatures of around 1150°C (Dawson, Kent 1984, 75–77). Other experiments in Poland achieved temperatures in fireplaces at various firing points ranging from 600–920°C (Mogielnicka 1974, 531–537). Open ground-level firings carried out by local potters in the Balkans in villages with a surviving tradition of profile-coiling pottery reached temperatures close to 840°C; higher temperatures were undesirable, as the fabric would be overfired (Carlton 1990, 65).

Temperatures of 1050°C were achieved in open fireplaces using fuels such as charcoal, dried cow and donkey dung, dry branches, or grass (Daszkiewicz, Wetendorf 2017, 11).

Fuel consumption during pit firings was similar, again with the exception of one-time firings, where it was lower (Tab. 40). If we compare the amount of

	Firing duration (stoking, hours)	Maximum temperature (°C)	Duration above 800°C (hours)	Duration above 700°C (hours)	Duration above 600°C (hours)	Fuel consumption (m²)	Number of vessels	Vessels damage (%)
Kiln 1	8.5–14.5	850–1024	1–2	2–5.25	3–7	0.3–0.6	108–140	6–13
Kiln 2	7–14.25	840–880	1–2	3–5	5–8	0.7	54–68	2–4
Kiln 3	11-12.0	1065-1090	1–2	2.5-4	4.5-5	0.5	200-220	5–10
Kiln 4 smoked pottery	15	811	1	7	8	-	90	5
Kiln 4 dynamic firing	0	793	0	0,5	1	-	21	5
Open pit firing	4–5	815–905	0.25–1.25	1–1.75	1.75–2.25	0.5–0.75	13–21	20–40
Closed pit firing	2.75–4.5	180–476	0	0	0	0.3	14–25	48
Open pit firing with final closed	1.5–4	730–911	0–1	0.25–1.5	0.75–2.25	0.5	11–21	9–14
Dynamic firing	0	690–909	0–0.5	0–1.25	0.75–2	0.2-0.4	9–29	20–30

Tab. 40. Basic comparative criteria for different types of firings in kilns and pits carried out during experiments (data from the results of experimental firings, time data in hours). For open firings with closing at the end, data from firing 2-16 were omitted due to uncontrollable flare-up and temperature increase. For kilns, data from firings of smoke-fired pottery were used. Vessel loss occurred mainly when using predominantly fine potter's clays; coarse clays were used only in dynamic firings, including those in kilns (with fine clays, this type of firing would likely show nearly 100% loss).

fired ceramics to fuel consumption, we find in our case that firing in kilns is much more economical. This is due to the fact that we fired fewer vessels in pits. According to ethnographic parallels, the number of vessels could have been even higher. It can be assumed that firing a higher volume of ceramics would not increase fuel consumption or would increase it only slightly, since the vessels would partially transfer heat to each other and the heat energy would be used more efficiently. Ethnographic analogies suggest that fuel consumption for hearth firing may be lower (Roux 2019). It can thus be assumed that this factor is greatly influenced by the firing technology.

Open firings had higher vessel losses than kiln firings (Tab. 40). For kilns, losses were generally in the single percentages; for pit firings, around one third of the vessels were lost. In pit firings, the batch can be protected by using an auxiliary structure, e.g. placing old potsherds between the batch and the fuel. In addition to temperature jumps, however, the percentage of damaged vessels is also determined by the properties of the ceramic fabric. Here it is generally true that coarser ceramic fabrics are more resistant to temperature jumps than fine ones. Except for one-time firings, mostly fine ceramic fabrics were fired, and thus the data between the other types of firings are comparable. If coarser ceramic fabrics that are more resistant to temperature shocks and correspond to the fabric of medieval pottery had been used, the percentage of damaged vessels would have decreased. In the case of one-time firings, brickmaking fabrics were fired, and the percentage of damaged vessels generally corresponds to the loess part of the batch, which could not withstand the sharp temperature increases, unlike the rest of the so-called non-loess brickmaking clays.

During other experimental firings, vessel losses of 20–25%, even up to 40%, have been reported for open fireplaces and losses of around 5% for kilns (Wasilczyk, Wasilczyk 2014, 35). More significant losses of vessels are reported by authors of kiln firings in the UK, between 10–40% for a batch of between 78 and 205 vessels (Bryant 1973, 156). Martin Rogier fired natural clay pottery in kilns with a loss of about 14% of the vessels (Rogier 2015). Damaged vessels were mainly located in the lower part of the kiln and were in contact with the grate (Amicone at el. 2023).

Generally speaking, the main factor influencing the firing process is not the type of firing equipment, but the intentions and experience of the one doing the firing (cf. Dawson, Kent 1984, 78).

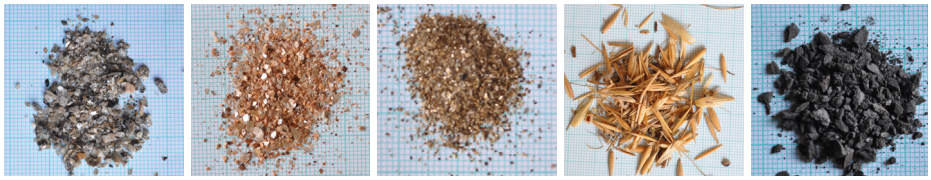
6.5 Properties of ceramic fabrics during experimental firings

This chapter is a continuation of the previous one and deals in detail with fired ceramic fabrics. In addition to vessels forming the basic volume of the batch, test tablets or small vessels made of various ceramic fabrics or with different inclusions were placed in each field firing. Test tablets were also fired in a laboratory setting. The properties of the vessels and samples were monitored with respect to their composition and firing types. The behaviour of the different inclusions was also studied. Initially, different types of firings were tested. Over the course of time, firing strategies were adjusted based on results to achieve desired objectives, such as the formation of dark cores, combustion of graphite, different surface smoking intensities, etc. Research aimed to carry out firings with resulting ceramics that would correspond in their features to high and late medieval production in the Bohemian-Moravian Highlands. The prevailing atmosphere in various types of firings and characteristics such as dark cores, oxidised surfaces or the degree of organic matter and graphite combustion were monitored. The data on smoked pottery has already been published separately (Těsnohlídková, Slavíček 2021).

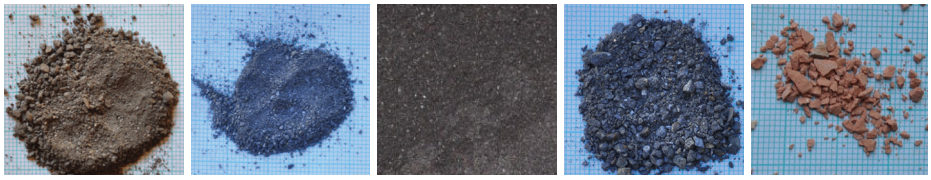
A wider range of clays with varying percentages of temper (mainly graphite) and taken from different sources were used for experiments on the behaviour of fabrics and temper during firing. In addition to vessels made from experimentally prepared clays, firings of samples produced in 2015 and fired during laboratory and field firings in 2015–2019 were essential for the firings of ceramics corresponding in composition to the ceramics from the pottery kilns in question. There are 59 sets of samples, in which 18 types of clays were represented (two clays were used in two different treatments), and three selected clays (Panská Lhota – brickyards, loess from Šlapanice, wheel-throwing clay from Hořice) were used to produce materials with 13 different inclusions (eight of which were graphite; Fig. 173, 174). In addition to regional raw materials, other clays were also used. Some were obtained through collaboration with other institutions, and others were added for their specific properties. Industrially treated wheel-throwing clay was also used as a control. Samples of industrially processed clays allowed for a comparison with local raw materials as well as the gradual acquisition of experience regarding the behaviour of different materials. A wider range of tempers including graphite from various sources and modified to different coarseness was used for similar purposes.



Fig. 173. Overview of tested ceramic clays in the first series of samples with a photograph of the surface of the dried sample (see Těsnohlídková 2021; Appendix 2 for details). Photo by P. Duffek.



Type of impurity	Pure	Mica-rich sand – grey	Mica-rich sand – red	Marly sand from disturbed bedrock at Rokštejn	Chaff	Graphite from Jevíčko
Grain size		Under 2–3 mm	Under 2–3 mm	Under 1 mm		Under 2–3 mm
Quantity (g per 1000 g of clay)	0	7	18	50	10	50



Type of impurity	Graphite from Drhovle near Písek	Graphite from Lubnice near Jemnice		Graphite from Lubnice near Jemnice	Graphite from Lubnice near Jemnice			Crashed pottery
Grain size	Under 2–3 mm	Under 1 mm		Under 0.25 mm	Under 2–3 mm			Under 2–3 mm
Quantity (g per 1000 g of clay)	50	50	100	50	50	100	150	14

Fig. 174. Overview of temper materials used in the first series of samples, including their grain size and quantity. Photo by K. Těsnohlídková.

The tablets that were produced were given a unique code to prevent potential confusion. One set was left to dry. The sample sets were field-fired in kilns or fireplaces from 2015 to 2019, and 11 sets were laboratory-fired in controlled oxidation and reducing environments. In total, over 1300 samples were obtained (Tab. 41). Later, photographic documentation was made of the surface of all samples. A cross section was then created and documented. Subsequently, a database of photographs was created for research on the macroscopic properties of individual samples during various firings and for future natural-scientific analyses.

Later, a second, smaller set of samples was created (Těsnohlídková 2021, 109–110, Appendix 5–6). For the purpose of testing the properties of the materials, vessels were also made from natural clays. Their bottoms were marked, initially only with the type of material, and from 2015 onwards with the vessel number/year code. Information on the material, forming and firing was recorded in a separate database.

6.5.1 Firing according to the prevailing atmosphere

The first characteristic we monitored in the fired ceramics was the surface colour. The composition of the fabric, temperature, and atmosphere of the firing, whether the vessel is in contact with the fuel, and possibly the fuel used, all have a major influence on the colour of the fabric and its homogeneity (Orton, Tyers, Vince 1993, 116–117). Based upon colour, medieval pottery is divided into oxidation, reduction, or mixed. This division is related to the atmosphere in the kiln during firing and cannot be determined macroscopically with absolute precision; nonetheless, these categories are used in the description of ceramics as the optimal way to characterise firing type. In field firings, both atmospheres are always present, and the firing should be described as predominantly oxidasing or predominantly reduction.

Oxidation ceramics (i.e. fired in a predominantly oxidasing atmosphere) include a wide range of colours (Fig. 175). Most of the medieval pottery is probably made of clays which are similar in their

Year	Code of firing	Sample location	Number of sample (before and after firing)	Basic firing properties (the holding time is counted from the start to the end of the fuel addition)
2015	O600	Chamotte plate	59/59	Laboratory kiln, temperature increase 100°C/hour, holding time at maximum temperature 1 hour, full oxidation
2015	O700	Chamotte plate	59/59	Laboratory kiln, temperature increase 100°C/hour, holding time at maximum temperature 1 hour, full oxidation
2015	O800	Chamotte plate	59/59	Laboratory kiln, temperature increase 100°C/hour, holding time at maximum temperature 1 hour, full oxidation
2015	O900	Chamotte plate	59/59	Laboratory kiln, temperature increase 100°C/hour, holding time at maximum temperature 1 hour, full oxidation
2015	O1000	Chamotte plate	59/58	Laboratory kiln, temperature increase 100°C/hour, holding time at maximum temperature 1 hour, full oxidation
2015	O1100	Chamotte plate	59/58	Laboratory kiln, temperature increase 100°C/hour, holding time at maximum temperature 1 hour, full oxidation
2015	O1200	Chamotte plate	59/42	Laboratory kiln, temperature increase 100°C/hour, holding time at maximum temperature 1 hour, full oxidation
2015	1-15	In the rear part of the kiln among vessels on the central pedestal	53/53	Underfired, maximum temperature reached 535°C
2015	2-15	Among vessels in the middle part of the kiln	55/53	Maximum temperature 840°C, firing duration 11 hours, smoked with bird cherry wood
2016	1-16	In the rear part of the kiln among vessels on the central pedestal	45/45	Hořice set missing, maximum temperature 1000°C, firing duration 15 hours, smoked with beech wood
2016	2-16	Inside vessels in the middle of the charge	59/53	Open firing – firing duration 2 hours, holding above 700°C about 20 minutes – cooling closed
2016	3-16	Among vessels in the middle part of the kiln	59/58	Maximum temperature 880°C, firing duration slightly over 14 hours, smoked with beech wood
2016	4-16	Inside vessels in the middle of the charge	59/58	Load protected by auxiliary structure, temperature rise to 700°C within one hour, no holding – cooling closed
2017	2-17	In the rear part of the kiln among vessels on the central pedestal	59/56	Maximum temperature 930°C, firing duration 13.5 hours, smoked with beech wood
2018	1-18	In the rear part of the kiln among vessels on the central pedestal	59/57	Maximum temperature 1024°C, firing duration 10 hours, smoked with beech wood
2018	2-18	Inside vessels and between them	59/58	Low temperatures, rapid process
2019	1-19	Inside vessels in the middle of the charge	59/58	Open, firing duration 5 hours, above 700°C for one hour, maximum slightly over 900°C – cooling open
2019	2-19	In a sealed vessel filled with sawdust in the middle of the charge	59/56	Closed, fired from the top and allowed to burn through, firing duration 3 hours, above 400°C for one hour, maximum temperature 475°C – cooling closed
2019	3-19	In 3 vessels in the middle part of the kiln	59/57	Oxidising, reaching 700°C after 7 hours and gradual cooling
2019	Josefov-pec	In the middle part of the kiln, inside vessels	39/39	Vertical kiln, A. Netopilová, temperatures up to 1000°C, smoked ceramics
2019	RO600	Chamotte plate	59/59	Laboratory kiln, simulation of fully reducing firing, temperature increase 100°C per hour, holding time 1 hour, at 600°C the gas ran out and the atmosphere changed to oxidising – the firing is mixed
2019	R700	Chamotte plate	59/59	Laboratory kiln, simulation of fully reducing firing, temperature increase 100°C per hour, holding time 1 hour
2019	R800	Chamotte plate	59/59	Laboratory kiln, simulation of fully reducing firing, temperature increase 100°C per hour, holding time 1 hour
2019	R900	Chamotte plate	59/59	Laboratory kiln, simulation of fully reducing firing, temperature increase 100°C per hour, holding time 1 hour

Tab. 41. Overview of laboratory and field firings during which experimental samples (called 'kolečko'/small solid disc/-samples) were fired, including information about the placement of samples within the firing, the number of samples obtained, and a brief description of the firings. Photo by K. Těsnohlídková.

properties to the so-called brickmaking clays and which turn red during oxidation firing due to the inclusion of iron oxides (Rada 1995, 9). We also encounter shades of orange, beige, yellow, and white, but even beige or light grey (Fig. 176).

Ceramics of black, dark or medium grey colour are most often described as reduction ceramics (i.e. fired in a predominantly reduction atmosphere). Reduction-fired ceramics can be light grey to white, depending on the presence and contact with the embers of the kiln's fuel. Occasionally, orange shades of colouration may occur (Fig. 176). Smoked ceramics, sometimes also referred to as reduction ceramics, are placed in a separate category (Fig. 175).



Fig. 175. Firing atmosphere based on vessel surface characteristics during field firings: A – colouration of surfaces of various types of industrially processed clays during oxidation firing; B – oxidation surface of vessels made from brickmaking non-loess and loess loams (firing 3-20); C – vessels with mixed surface showing predominance of oxidation (1-23); D – vessels with mixed surface showing predominance of reduction (1-24); E – vessels with reduction surface (3-24); F – smoke-fired pottery with reduction surface (1-21). Photo by K. Těsnohlídková.

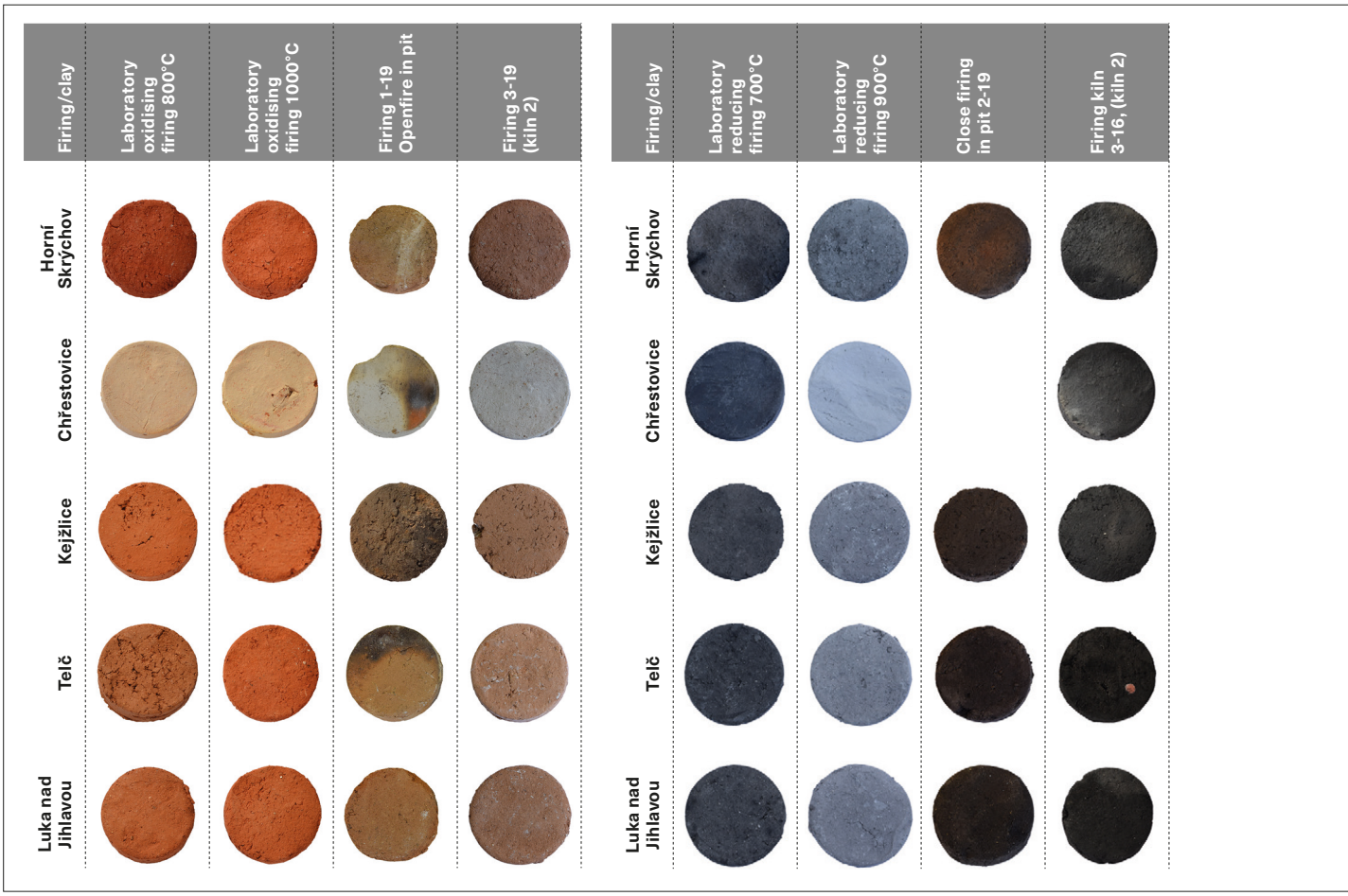


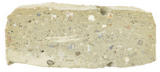
Fig. 176. Oxidation and reduction marks in selected clays and firings of test samples of natural clays on the surface (a) and on cross-sections (b). Photo by P. Duffek. Fig. 176 continues on the next page.

Mixed atmosphere ceramics show signs of oxidation and reduction, and the surface and core are inhomogeneous in colour with combinations of colours (Fig. 175). This occurs more often in open firings where temperature differences on the vessels can be expected, but it can also be encountered in kiln firings.

6.5.2 Black cores, oxidised surfaces, and full-reduction fabric

Black or dark cores and oxidised surfaces are most often caused by the imperfect combustion of organic carbon from the core of the fabric, especially during rapid firings, low-temperature firings, or short durations at higher temperatures (Fig. 177; Gregerová et al. 2010, 108–110; Gregerová 2017, 368–375). Oxidation during firing affects only the surface of the ceramics; it does not have to be present throughout the whole surface, and there is no decisive partition between oxidation and reduction areas. In this type of firing, the surface may have features characteristic of mixed firing. Oxidising phase may be caused unintentionally by a technological defect or may be the intention of the potter.

Dark cores appeared on test tablets from the first set in four field firings; this involved two firings in a fireplace and two in a kiln (Fig. 178). Most of the dark cores were formed during the failed kiln firing 1-15, when firing was halted after 5 hours and at temperatures around 500°C, when the kiln was left open to cool. This involved a total of 41% of the test tablets: 11 samples without graphite or without significant organic content; nine samples with graphite; and four samples with an organic addition. All samples with a demonstrable organic inclusion in the firing contained a black core; this number was only 40% in the case of the graphite ones. From the others, dark cores occurred in six cases in the fabric from Panská Lhota, in three cases from Šlapanice, and in fabric from Jestřebí, Chřestovice and Hořice. Except for the industrial Hořice clays and loess from Šlapanice, these were natural clays in which a natural addition of organic components can be assumed.

Mayen gelb	Kejžlice	Luka nad Jihlavou	Hořice	Telč	Šlapanice	Panská Lhota with organic temper	Panská Lhota	Firing/clay
								Laboratory oxidising firing 800°C
								Firing 1-19 Open fire in pit
								Firing 3-19 (kiln 2)

Mayen gelb	Kejžlice	Luka nad Jihlavou	Hořice	Telč	Šlapanice	Panská Lhota with organic temper	Panská Lhota	Firing/clay
								Laboratory reducing firing 700°C
								Laboratory reducing firing 800°C
								Laboratory reducing firing 900°C

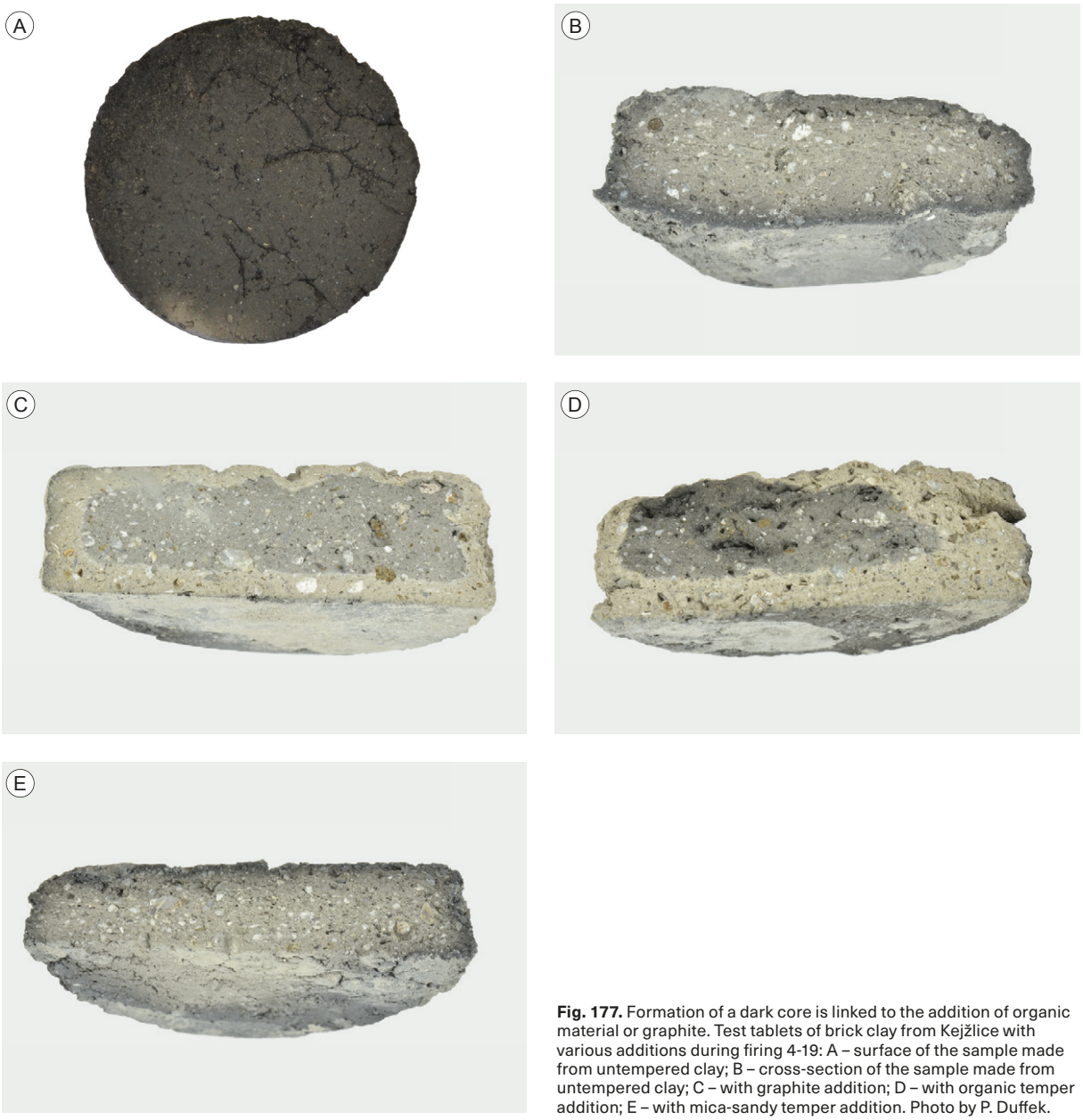


Fig. 177. Formation of a dark core is linked to the addition of organic material or graphite. Test tablets of brick clay from Kejžlice with various additions during firing 4-19: A – surface of the sample made from untempered clay; B – cross-section of the sample made from untempered clay; C – with graphite addition; D – with organic temper addition; E – with mica-sandy temper addition. Photo by P. Duffek.

After firing 1-19, 19% of the test tablets had a dark core. This involved open pit firing with a maximum temperature of around 900°C and a firing time of 5 hours. Of the 11 samples, only two were free of graphite or organic matter, specifically Hořice clay, with a sandy micaceous temper that should lack an organic component, and Tupesy clay, in which a natural organic component might also be present. The remaining nine samples were represented by four samples from Hořice and three samples from Šlapanice, both with graphite, and one sample each from Panská Lhota, also with graphite, and from Telč, with organic temper.

Three dark cores appeared in the test tablets of open pit 4-16 and in the oxidation firing in kiln 3-19. Both firings reached temperatures of around 700°C. Firing 4-16 consisted of two samples from Panská Lhota with macroscopic graphite and a 'clean' sample from the same locality. In the case of 3-19, fabrics with a natural organic component from Telč, Tupesy near Staré Město and the pond near Jestřebí were used.

The presence of dark cores in kiln and pit firings indicates that their formation was influenced more by the course of firing rather than particular type. As expected, dark cores appeared more frequently in firings with lower attained temperatures and shorter

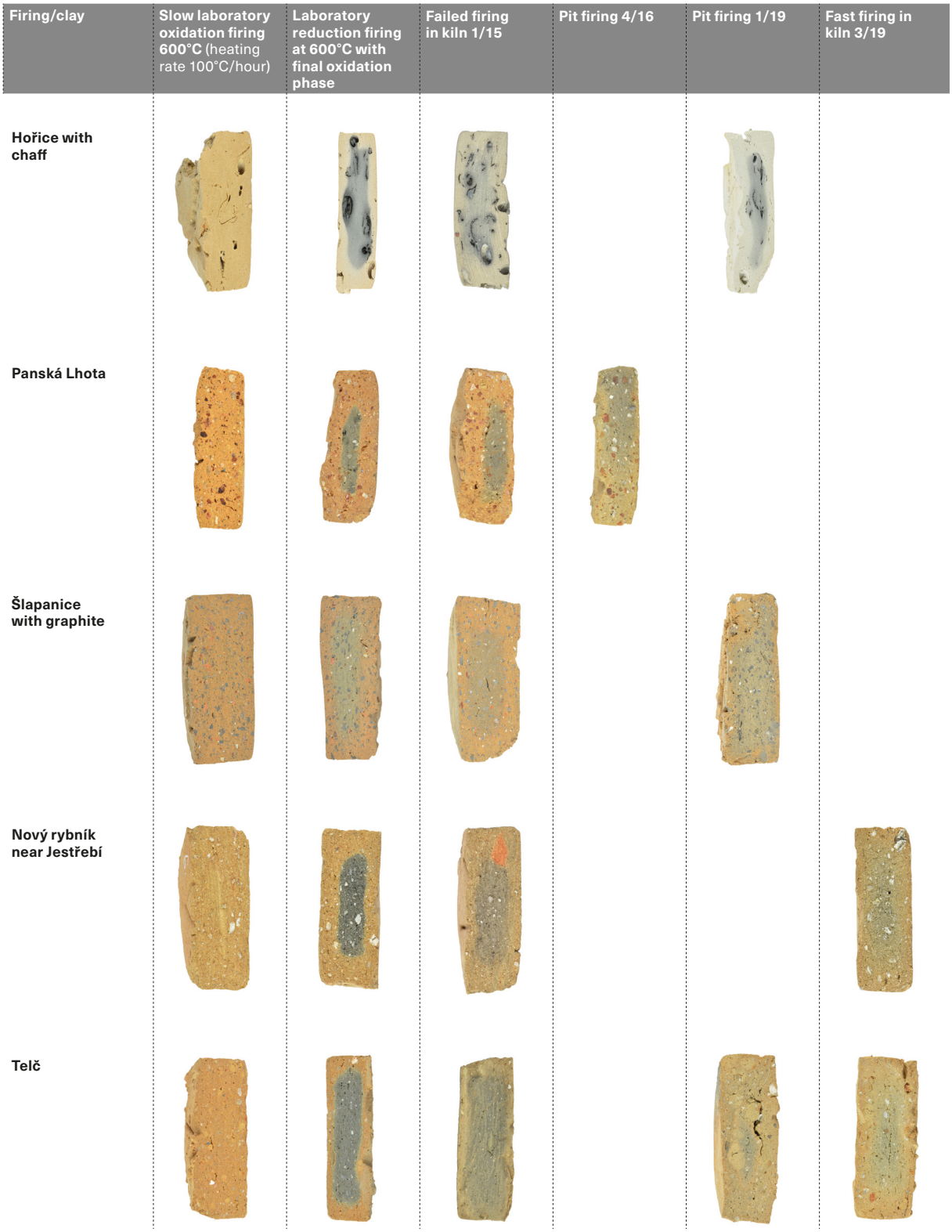


Fig. 178. Selected samples with dark cores from laboratory and field firings during firings with gradual temperature increase and fuel addition. Photo by P. Duffek.

durations. In general, it can be summarised that dark cores appear more commonly in fabrics with a higher inclusion of organic matter and graphite, and more so in coarser brickmaking or loess fabrics than in fine ones. This is also due to the fact that most brickmaking and loess fabrics were of a natural origin and contained a natural inclusion of organic components.

Dark cores were also formed in six laboratory firings (Fig. 178), specifically in the case of Hořice and Šlapanice clay with a graphite inclusion at temperatures of 800°C. In the material from Hořice, these cores occurred in samples with a higher proportion of macroscopic graphite in the same samples fired in the temperature range of 800 to 1200°C and in the material from Šlapanice in three samples fired at 800°C and five samples at 900°C. Once again, these samples had a higher proportion of macroscopic graphite. In this case, the organic component was not the cause of their dark cores. The appearance of a coloured core is influenced by graphite. The presence of a dark core is caused by a graphite admixture, but its appearance is also influenced by other properties of the ceramic fabric. These are definitely not the classic black cores that we know from 13th century pottery. Dark cores can be formed, for example, by the reduction of iron oxides at temperatures above 700°C (Gregerová 2017, 376). The highest number of dark cores was produced in the 'failed' laboratory reduction at 600°C, where oxidation firing occurred at the end; 73% of samples contained them.

One-time firings (6-19, 7-19, 1-20, 2-20, 3-24) were the ideal type of firing for the formation of dark cores and oxidised surfaces. These effects appeared on several test tablets of the second set. They could mainly be observed on the cross sections of vessels made of regional brickmaking clay. Vessels from one-time firings show signs of mixed firing, oxidised surfaces or contain dark cores; the technology above can be considered ideal for such manifestations, including oxidised surfaces (Fig. 179). Dynamic firing in the kiln, which was closed in the final stage, provided fully dark fired fabric, thus meeting the firing requirements for ceramics with properties characteristic for 13th century pottery, including graphite ware (Fig. 180).

6.5.3 The sandwich effect and the effects of alternating atmospheres during firing

The sandwich effect is encountered on ceramics that contain remnants of a dark core and a smoky surface at the same time. The colour of the shells is lighter. This attests to the alternation of atmospheres during firing.

In our experiments, the sandwich effect was not significantly related to any particular type of clay or inclusion. It occurred more commonly on brickmaking non-loess and loess clays. Only in one case did it appear on fine wheel-throwing clay from Hořice (during kiln firing 4-19). Its presence was also related to the placement of the samples in the kiln. Most of the dark cores that were observed were not very pronounced.

The greatest number of samples with the sandwich effect were produced in firing 4-19, occurring in 27% of the samples, followed by firing 2-15, where the effect was present in 17% of the samples, and firing 3-16, where it was present in 8% of the samples. The characteristics of these firings confirm the link between this effect and firings with a lower maximum temperature (840°C for 2-15 and 880°C for 3-16) in combination with the duration of firing. Firing 4-19 reached a temperature of 991°C, but its duration was much shorter than the others. In the case of firing 2-15, which produced the largest number of samples with the sandwich effect, the duration was more than 4 hours shorter than for firing 3-16. The alternation of environments during firing can also be documented in some samples of Hořice clay with graphite from firings 2-15 and 1-18, where several coloured layers were formed (Fig. 181).

If we wanted to achieve a higher occurrence of the sandwich effect, it would be advisable to fire at lower temperatures with a short duration and a final smoking, while at the same time having fabrics in the kiln with a higher organic carbon inclusion.

6.5.4 Combustion of organic matter

The organic inclusion in ceramic fabric is in many cases the cause of the presence of dark colouring of the core or the whole body. An organic inclusion can enter the ceramic fabric before firing in two ways: either it is added intentionally or it is naturally present in the clay. Furthermore, organic carbon can enter ceramics when firing, cooking in vessels and post-deposition processes (Johnson et al. 1988, 404).

For ceramics with an organic inclusion, the technology of firing is crucial. At certain temperatures and in an oxidising atmosphere, the organic temper/organic carbon combusts. The greatest losses occur as early as 200°C to 400°C (Johnson et al. 1988, 408). Whether the organic inclusion remains at least partially present in the ceramics after firing depends on firing temperatures, duration, and, above all, the atmosphere of the firing.

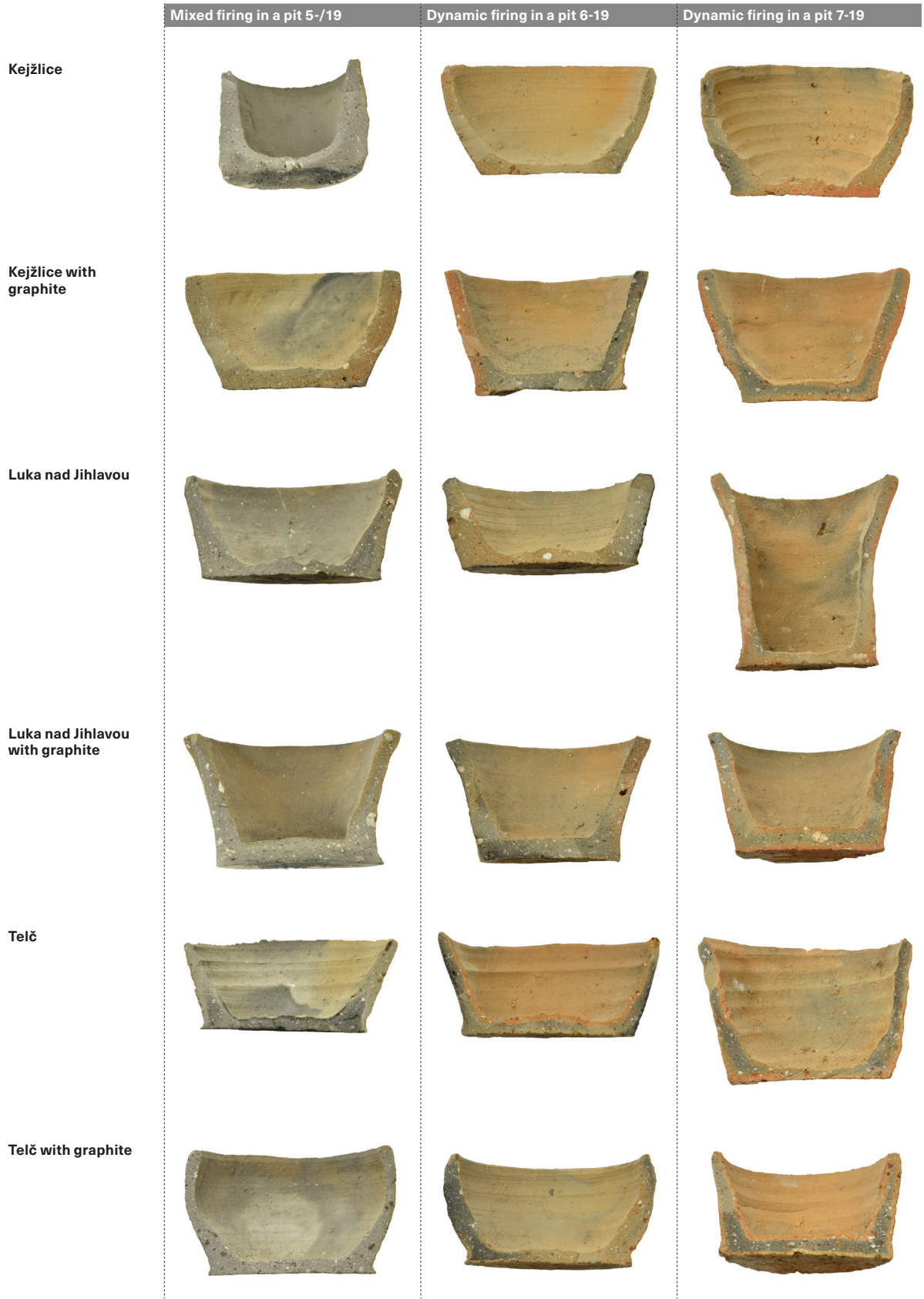


Fig. 179. Experimental vessels made from regional brickmaking clays and the formation of dark cores during field firings on cross-sections. Photo by P. Duffek.



Fig. 180. Distinct reduction pottery with preserved organic additions and graphite forms during dynamic firings with rapid progression, when the pottery remains in contact with the fuel throughout. Examples are vessels from firing 4-24: A – loess from Šlapanice with graphite addition; B – loess from Bukovsko with natural organic addition; C – non-loess potter's clay from Telč with natural organic addition. Photo by K. Těsnohlídková.

A number of experiments have focused on the organic inclusion's influence on the final appearance of the ceramics. These have mainly dealt with artificial organic inclusion and work with a wide range of materials, such as different types of manure or grass (Skibo, Schiffer, Reid 1989, 124; Abbink 1999, 126). Based on ethnographic analogies, it is also possible to observe properties of clays containing chopped straw, the seeds or fibres of various plants, animal hair, feathers, or eggs (Rye 1976, 115; Skibo, Schiffer, Reid 1989, 123). In contrast, some other experiments used only naturally occurring organic inclusions (Johnson et al. 1988, 405).

The combustion of organic substances in the fired fabric has been dealt with, for example, by M. Beránková. She concluded from experiments that organic components begin to combust at relatively low temperatures as oxygen permeates the fabric during firing. Thus, they first combust from the surface and then towards the centre. This is influenced by the thickness and porosity of the fabric, the type of organic matter, its concentration and, to some extent, the chemical composition of the clay and firing mode – the more oxygen reaches the fabric, the faster the organic matter burns (Beránková 1996, 24).

Experimental oxidation and reduction firing with ceramics containing organic substances was carried out by J. Dvorská in connection with the research of early medieval Mikulčice graphite ceramics (Dvorská 2001). During reduction firing, carbon migration from the surrounding environment into the ceramic fabric was monitored (Tab. 42).

A set of samples tempered with chaff and a second set tempered with partially decomposing fine

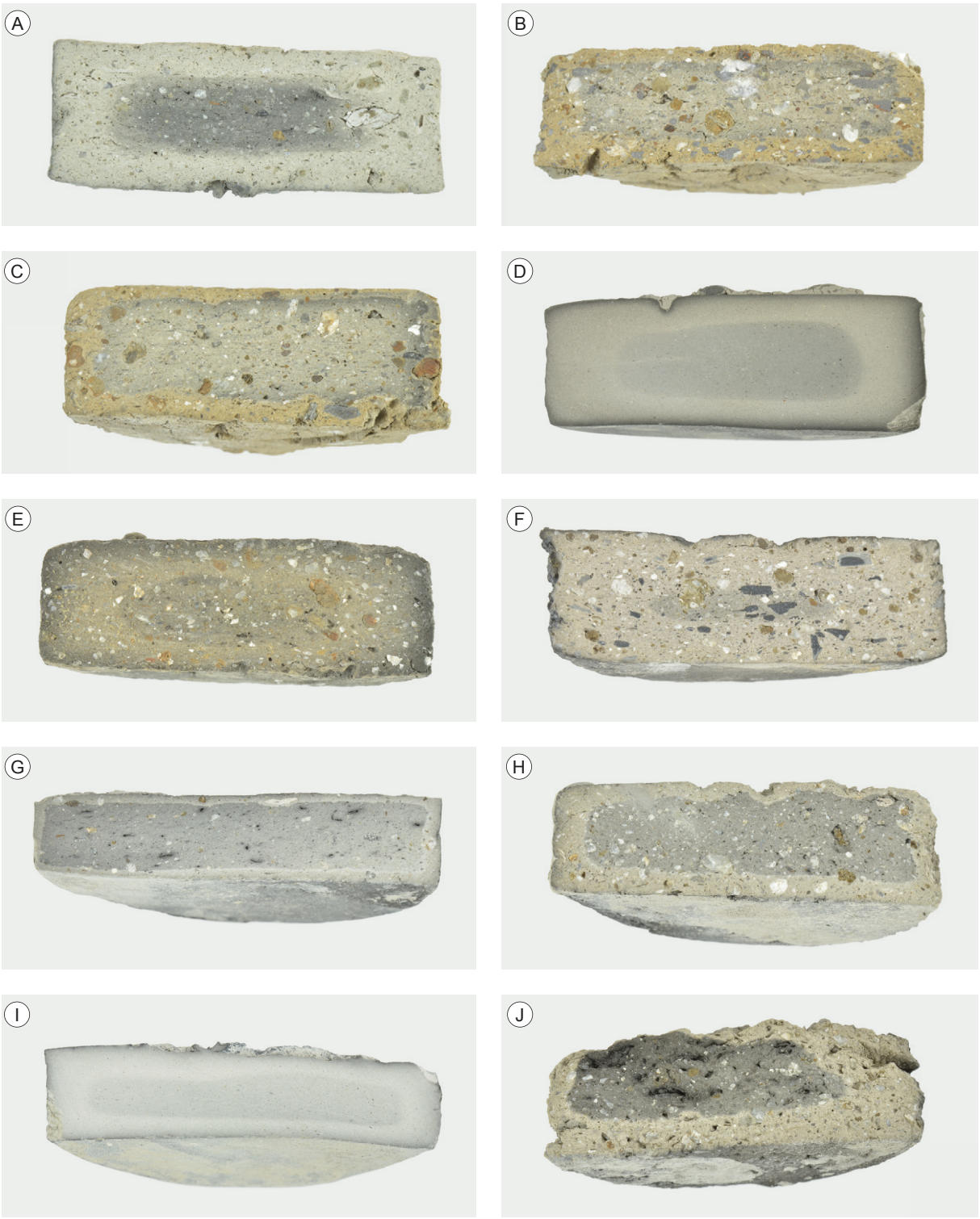


Fig. 181. Examples of samples showing signs of the sandwich effect during selected firings of smoked ceramics: A – Telč; B, C – Panská Lhota with graphite during firing 2-15; D – Tupesy near Uherské Hradiště; E – Panská Lhota with micaceous sand during firing 3-16; F – Panská Lhota with graphite during firing 1-18; G – Plzeň with graphite; H – Kejžlice with graphite; I – Hořice; J – Kejžlice with organic matter during firing 4-19. Photo by P. Duffek.

Temperature	Properties of ceramics during oxidation	Properties of ceramics during reduction
400°C	Almost original content of organic substances	No carbon migration occurs
500°C	Brick color, lightly fired ceramics	
600°C	The color is uniformly brick-red, caused by oxidation of iron into finely dispersed hematite, hardness of the ceramic increases	The reduction-fired part of the shard (in crushed charcoal) colors dark gray due to penetrating carbon
700°C		Carbon gradually penetrates the shard, expanding the reduction-fired zone even at the expense of the oxidation zone
800°C		
900°C	The core of the shard colors dark gray due to magnetite, partial sintering of the binder occurs	It is no longer possible to precisely determine where the reduction firing advanced and where oxidation firing occurred, during which dark gray magnetite forms
1000°C	The core is gray-black – magnetite forms in the core of the shard, where carbon dioxide escaping from the decomposition of carbonates lowers the partial oxygen pressure, causing a reducing environment; the binder is already sintered	

Tab. 42. Results of experimental firings tracking carbon migration from fuel (during oxidation) or from the surrounding environment (during reduction) into the pottery. After Dvorská 2001, 57.

grass were produced as part of the experimental samples/rounds. Most 'natural' materials could also be assumed to contain some naturally occurring organic inclusion. Its presence was evident during 'maturation', e.g. in the fabric from Telč.

In all cases, field firings (in which firings that reached temperatures of around 500°C and above were assumed) resulted in the combustion of the macroscopic organic temper. Like the studies mentioned above, the presence of organic temper also had an effect in this case on the frequency and appearance of the dark core.

Samples with organic matter in unfinished firing 1-15, where the highest temperatures were around 500°C, had the most distinct dark cores. Samples with organic matter from kiln 2-15 fired at 840°C for 11 hours and cooled in a reduction atmosphere also showed colour changes due to the organic inclusion. In the other kiln firings, which took place at higher temperatures, the organic inclusion had already fully combusted, as was the case with the pit firings. The organic component was partially preserved in products from rapid, one-time firings (Fig. 182).

Laboratory firings have also demonstrated that, in addition to temperature, the duration of firing affects the organic component. In laboratory oxidation firings with longer durations, the organic matter had already fully combusted at 600°C (i.e. a 100°C increase per hour), but during the fast duration, at 600°C and 700°C, a remnant of the dark core remained in the fabric with a fine organic inclusion; the required temperature was reached in one hour. In the laboratory reduction firings, even at 900°C, it was possible to observe the remnants of charred temper in the pores and also a noticeable 'staining' of part of the fabric to a dark colour due to the action of carbon from the temper (Fig. 182).

Additional firings have shown that ceramics with non-combusted organic matter in the core of the fired fabric are formed mainly in rapid firings, and dynamic firings are ideal. Dynamic firing in a bonfire-like clamp kiln, accompanied by closing in the final stage, can achieve full-reduction fabric (Fig. 180, 182).

6.5.5 Graphite combustion

Graphite is undoubtedly the most widely debated inclusion in high and late medieval pottery. Its influence on the ceramic fabric during vessel formation has already been mentioned in this work. During the firing process, graphite's main property – maintaining a reducing environment in the fabric – becomes apparent. At certain temperatures, it begins to combust in reaction with oxygen. Graphite combustion can cause a higher porosity of the walls and therefore higher absorption or even permeability of the vessel walls.

Graphite combustion was dealt with using experimental samples in the form of pure graphite or ceramic fabrics with a graphite inclusion (e.g. Beránková 1996, 65; Fusek, Spišiak 2005, 291; Gregerová et al. 2010, 114–122; Rzeźnik, Stoksik 2004, 255). The macroscopic recognition of graphite or organic impurities in the ceramic fabric or the relative proportions of these impurities can be problematic (Gregerová 2017, 375–379).



Fig. 182. Selected firings of samples with natural or added organic temper. Photo by P. Duffek.

In oxidation-fired ceramics, graphite transformations may indicate the approximate firing temperature – the presence of graphite exclusively in macrocrystalline form indicates firing temperature between 500–700°C. In controlled laboratory experiments with graphite ceramics, the first traces of disintegration occurred at 700°C, when porosity increased – this temperature should be seen as a certain threshold for firing graphite ceramics. Fine graphite combusted in oxidising conditions at 510–550°C, and macroscopic graphite grains reacted only at temperatures of 700–730°C. The situation is more complex with reduction-fired pottery (Beránková 1996, 65; Gregerová et al. 2010, 114–122).

The aim of our experiments was to focus on the behaviour of different forms and contents of graphite directly in the ceramic fabric and determine whether different ceramic fabrics influence graphite combustion. The experiment used three different sources, three different grain sizes and three different proportions of graphite. Graphite inclusions were used in three clays with differing properties (Fig. 172, 173).

The table shows the combustion of graphite from samples in laboratory oxidations with a slow duration, i.e. with a rise of 100°C per hour and maintaining the maximum temperature for one hour (Tab. 43; Fig. 183). At 600 and 700°C, graphite is observable in all the samples. At 800°C, it ceases to be visible in part of the brickmaking clay samples from Panská Lhota (fine graphite and graphite from Drhovle and Jevíčko are not observable). At a temperature of 900°C, graphite is no longer visible in over half of the samples from Panská Lhota, while in clays from Šlapanice and Hořice there is only one such case, namely in the case of the added graphite from Drhovle near Písek.

At 1000°C, graphite combusted from all samples from Panská Lhota and more than half from Šlapanice; graphite remains only in samples with the highest content of coarse graphite. In terms of clay from Hořice, graphite is no longer observable at 1000°C only in the case of the inclusion from Drhovle and Jevíčko; in the other samples, its presence is visible on the dark core including macroscopic grains. The fine wheel-throwing clay from Hořice retains graphite in this form even at 1100°C and 1200°C, when graphite is no longer visible in the material from Panská Lhota or Šlapanice. Graphite does not combust during reduction firings up to temperatures of 700°C, 800°C and 900°C.

In terms of the connection between graphite and black core formation in ceramics, samples showed that the brickmaking clay from Panská Lhota with graphite does not form a dark core in laboratory oxidations contrary to the Šlapanice clay, where a dark core appears depending on the form of graphite at temperatures of 800–900°C. In the case of the Hořice clay, a dark core forms from 800°C.

Graphite combustion was monitored in seven field firings. In none of them did the graphite component combust in all samples. Most often, the fine component or graphite from the surface layer combusted (Tab. 43; Fig. 184, 185).

In the unfinished firing in the large kiln (1-15) and in the closed pit (2-19), where temperatures were around 500°C, graphite remained present in all samples, as well as in the bonfire-like clamp kiln

	Panská Lhota with graphite	Šlapanice with graphite	Hořice with graphite
Laboratory oxidation firing at 600°C (heating rate 100°C/h)	8	8	8
Laboratory oxidation firing at 700°C (heating rate 100°C/h)	8	8	8
Laboratory oxidation firing at 800°C (heating rate 100°C/h)	5	8	8
Laboratory oxidation firing at 900°C (heating rate 100°C/h)	3	7	7
Laboratory oxidation firing at 1000°C (heating rate 100°C/h)	0	3	6
Laboratory oxidation firing at 1100°C (heating rate 100°C/h)	0	0	6
Laboratory oxidation firing at 1200°C (heating rate 100°C/h)	0	0	6
Failed firing in kiln 1-15	8	8	8
Smoked pottery firing in kiln 2-15	8	8	8
Smoked pottery firing in kiln 2-17	1	1	5
Smoked pottery firing in kiln 1-18	3	8	8
Mixed atmosphere firing in pit 1-19	7	7	8
Mixed atmosphere firing in pit 2-19	8	8	8
Oxidation firing in kiln 3-19	8	8	8

Tab. 43. Number of samples with unfired graphite in various ceramic clays during laboratory oxidation firings and field firings. Each clay sample contained eight different variants of graphite – thus, 24 graphite samples were included in each firing (3 sets of 8 pieces each).



Fig. 183. Combustion of graphite in ceramic samples made from clay from Panská Lhota, Šlapanice, and Hořice during laboratory firings. The graphite content in sample 1 is graphite up to 0.25 mm – 9% in the clay body; in sample 2, graphite up to 1 mm – 17% in the clay body; and in sample 3, graphite up to 2–3 mm – 23%. The laboratory oxidation firings involved a temperature increase of 100°C per hour with a one-hour hold at the maximum temperature. Photo by P. Duffek.

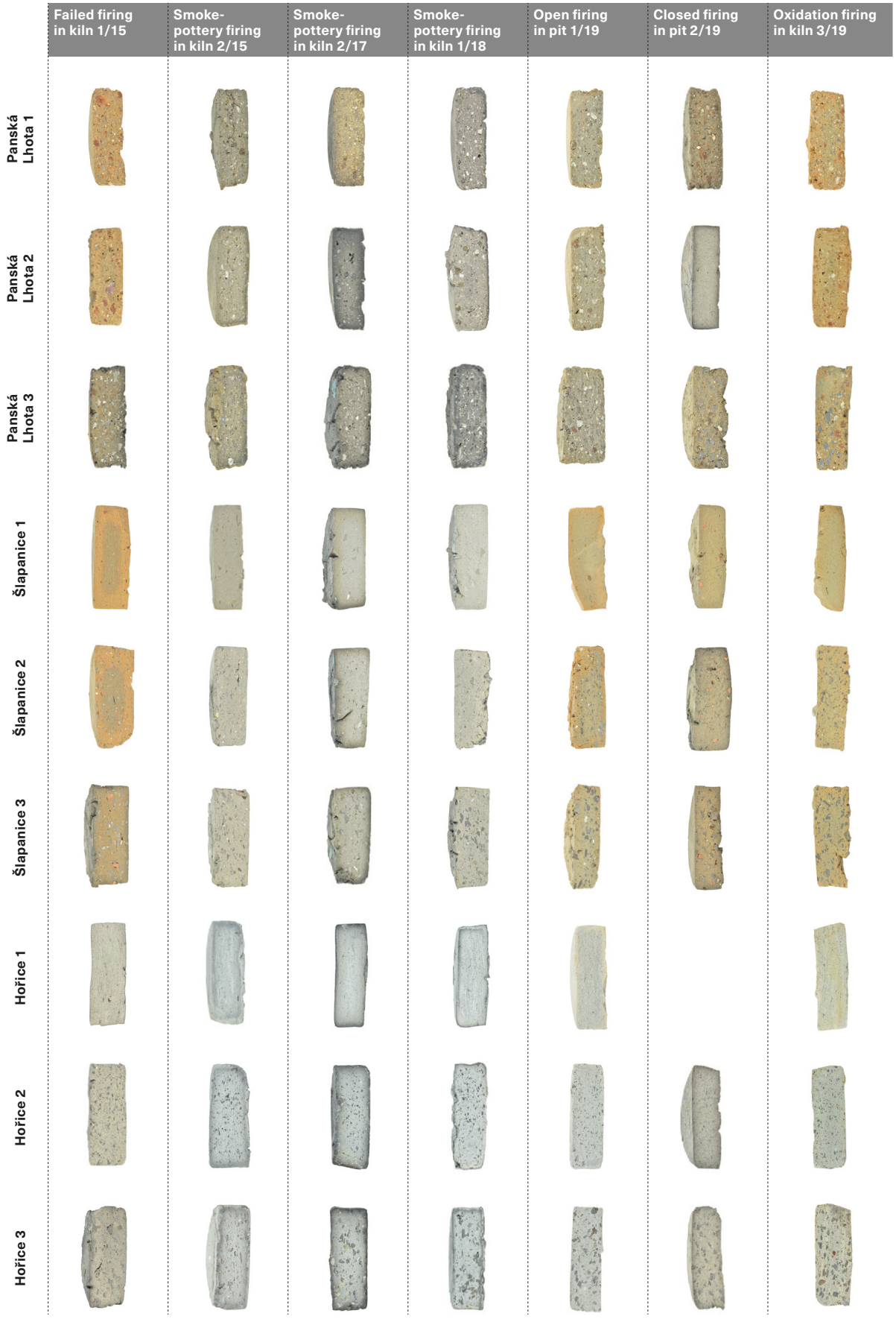


Fig. 184. Combustion of graphite in ceramic samples made from clay from Panská Lhota, Šlapanice, and Hořice during open-air (field) firings. The graphite content in sample 1 is graphite up to 0.25 mm – 9% in the clay body; in sample 2, graphite up to 1 mm – 17% in the clay body; and in sample 3, graphite up to 2–3 mm – 23%. Photo by P. Duffek.



Fig. 185. Combustion of graphite in ceramic samples during rapid firings. The graphite additive had a grain size of up to 2 mm. Photo by P. Duffek.

with temperatures around 840°C and a firing time of 11 hours (2-19), which was left to cool in a closed state, and in the kiln fired at 700°C with cooling in an oxidasing atmosphere (3-19).

In two samples with a fine graphite inclusion from Panská Lhota and Šlapanice, graphite was macroscopically determined to have combusted when fired in an open hearth with a duration of 5 hours and maximum temperatures of around 900°C.

More than half of the graphite samples from Panská Lhota lost graphite during the firing of smoked ceramics in the large kiln (1-18) with a temperature above 1000°C and a firing time of 10 hours; graphite remained in the Šlapanice and Hořice clay. Most of the samples lost their graphite inclusion when fired in the large kiln 2-17 (maximum temperature 930°C, firing time 13.5 hours). Graphite remained only in one case in the fabric from Panská Lhota and Šlapanice and in five samples from Hořice.

In terms of field firings of ceramics while monitoring the firing of ceramics and comparing the results to similar temperatures in laboratory firings, it must be taken into account that the temperature at the measurement site and the temperature of the samples may differ, and also that field firings take place under alternating reduction and oxidising atmospheres.

Field firings have confirmed the fact that graphite combusts earlier from some clays, especially from coarse regional brickmaking (non-loess) fabrics, then loess, and persists the longest in finer fabrics. In medieval pottery, however, the use of brickmaking clay can be assumed to have been most common. The finer component of the graphite combusts first. Macroscopic observation demonstrated that graphite from different sources combusted at different temperatures. The tendency of the fabrics to form dark cores with graphite was observed more frequently in the loess material from Šlapanice and fine material from Hořice; this manifestation was not observed in the brickmaking clay from Panská Lhota. The clay from Hořice apparently retains its graphite inclusion up to high temperatures, since the surface of the fine material sinters at certain temperatures and then no longer allows the oxygen needed for graphite combustion into the fabric.

The presence of graphite in smoked ceramics fired at relatively high temperatures with long durations (firings 3-16 and 1-18) confirms that a number of reduction phases take place when firing in a kiln at temperatures above 500°C.

To complement the findings from the firings of the first set of test samples, the behaviour of the graphite inclusions was further studied, especially the observation of fast-duration firings and dynamic firings. In the laboratory, these samples were fired ‘rapidly’ with a rise to maximum temperatures in 1–2 hours without holding steady temperature durations. This confirmed that even at

higher temperatures but with shorter durations of steady temperatures, graphite or organic impurities especially from the core of the fabric combust more slowly. Dynamic firings of the second set of samples and the graphite-mixed vessels retained non-combusted graphite in all cases, except for the oxidised areas of the surface.

6.5.6 Over-firing ceramic fabric

Another group of macroscopically observed features on ceramics involves the effects caused by high temperatures. At this point, we will only be dealing with the over-firing of ceramic fabric, which may serve as an analogy for vessels found in the relics of pottery kilns.

In terms of medieval ceramics, stoneware has the highest sintering temperature. The production of stoneware is linked to special 'stoneware clays' for which the firing temperature is above 1000°C. Partially sintered pottery may be referred to as 'semi-stoneware'. In the Czech Republic, Loštice pottery was fired at temperatures above 1000°C (Gregerová el al. 2010, 159).

Regional brickmaking clays did not sinter during the experiments, but due to the low content of clay minerals, they began to over-fire relatively early. Based on laboratory firings, it can be subjectively determined that at temperatures of around 1000°C, the structure of ceramic fabrics still remains unchanged. At 1100°C, especially in samples of brickmaking clay, it is possible to observe melted grains of quartz or other inclusions; at 1200°C, samples are already over-fired. The over-firing of brickmaking fabrics is observable in the following: crumbling, fine cracks, melted grains of temper, and melted or highly porous to pumice-like fabric. However, field firings of vessels made from these materials showed that over-firing could have occurred in these fabrics already during kiln firings when maintaining temperatures above 800°C for an hour and with peaks of around 900°C (Fig. 186).

As expected, kaolin and fine wheel-throwing fabrics sintered well in the experiments. Loess behaves specifically at high temperatures, melting at temperatures between 1100–1200°C and then solidifying into a glassy material.

6.5.7 The range of firing types in ceramics from individual firings

The test tablet samples were used to observe the types of firing occurring in the different firing devices and the strategies used in field firings. This part of the research was conducted only for the duration of the use of the test tablets from experimental clays, i.e. until 2019.

For smoked pottery, the firing was very homogeneous, as demonstrated by the graph (Graph 39). The five smoked pottery firings mostly contained only samples with smoky surfaces, a minority of which had dark cores, most notably in the fastest firing 4-19. Firing 2-15 was an exception, as the smoking was of poor quality due to the use of elder branches; for this firing, some samples were classified as mixed-firing pottery. Samples exhibiting a mixed atmosphere were also identified in a firing of smoked ceramics by A. Netopilová in Josefov, and in this case their placement in the kiln probably played a role. A small number of samples (up to four pieces for different firings) were damaged or destroyed, and firing type was not determined. This mostly involved specific fine clay material from the River Brtnička and fine Hořice clay with an inclusion of unsuitable sandy temper.

We should also mention three more firings in which the kiln was left to cool in an open position. Firing 1-15 was a failed attempt at smoking ceramics in a large kiln – the firing was halted at a temperature of around 500°C. This value represented the minimal limit of firing, and ceramic vessels made of industrially prepared wheel-throwing clay were not fired successfully. In the cases of samples from coarser materials, minimal successful firing can be said to have taken place. Here, 40% of the samples were identified as oxidation, 10% with mixed firing, and 45% with the presence of dark cores (Graph 40).

Firing 3-19 was conducted intentionally so as to produce oxidation ceramics fired at lower temperatures, i.e. at around 700°C while maintaining one hour at this temperature. Here, the proportion of dark cores was much lower, i.e. around 5%; almost three-quarters of the samples showed signs of an oxidasing atmosphere, and one-tenth showed signs of a mixed atmosphere.

An extreme case was the firing of samples in a glass-maker's kiln, where a maximum temperature of 1200°C was reached while keeping a long stable temperature of 1100°C. Three-fifths of the samples were noted to have over-firing damage, and the rest did not survive at all, as they were likely to have been destroyed by the heat.

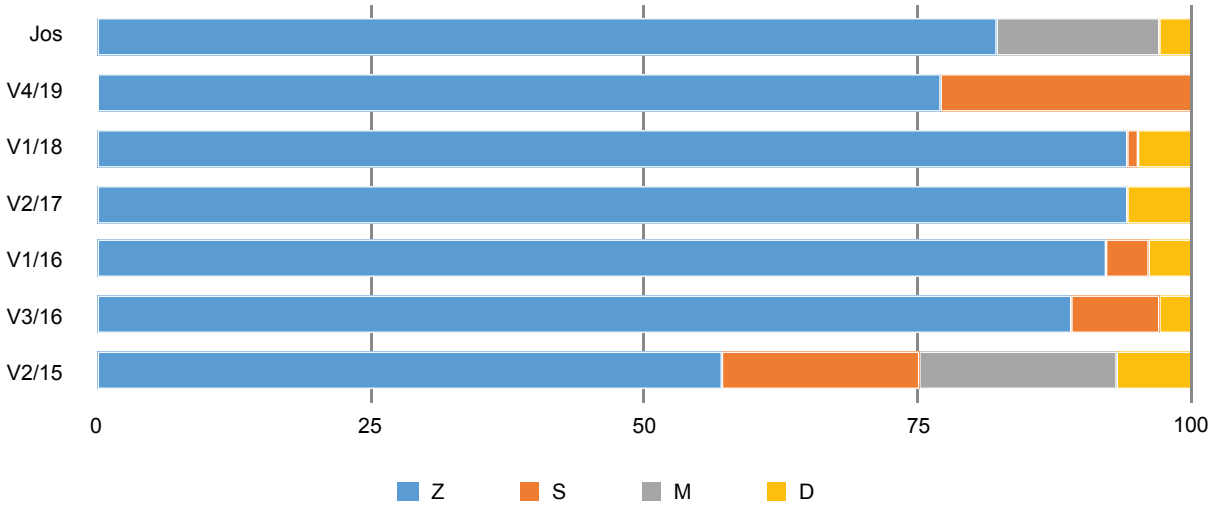
Samples fired in pits and hearths confirm the fact that these firings are less homogeneous and show a wider range of manifestations on the pottery. This is despite the fact that these were small samples that were always placed in a small area in



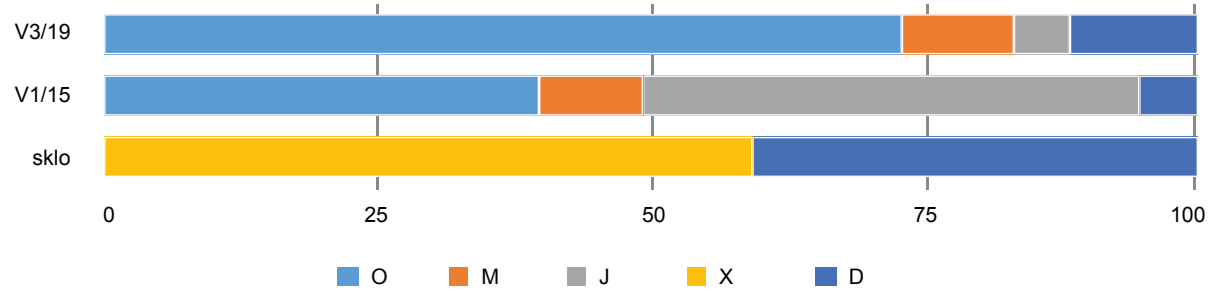
Fig. 186. Firings of various ceramic clays at high temperatures during laboratory and field firings. Photo by P. Duffek.

the core of the firing. These firings also produced higher losses of samples due to higher temperature jumps (3–6 pieces; Graph 41).

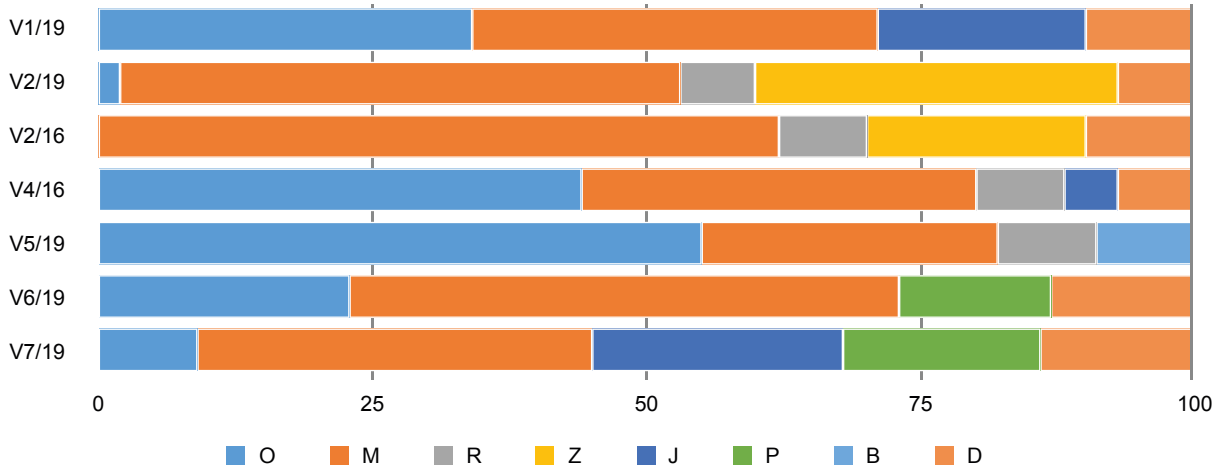
The open firing in a fireplace produced 34% of samples with predominant oxidation and another 19% oxidation with a dark core. The remaining 37% of the fired samples bore traces of mixed firing. Compared to the firing in a kiln 3-19, which maintained the same temperature of over 700°C, the same types of firings occur here, but the percentage of samples that can be identified as oxidation is only approximately half as high.



Graph 39. Proportion of firing types identified on samples during firings of smoke-fired pottery in kilns: Z – smoke-fired pottery; S – sandwich effect; M – mixed firing; D – damaged/destroyed samples without identification of the firing type. Number of samples in individual firings: 2-15 – 55 pcs; 1-16 – 45 pcs; 3-16, 2-17, and 1-18 – 59 pcs; Jos – 39 pcs. Author K. Těsnohlídková.



Graph 40. Proportion of firing types identified on samples during other kiln firings: O – oxidation firing; M – mixed firing; J – dark core; X – overfired pottery; D – damaged/destroyed samples without identification of firing type. Number of samples in individual firings: 1-15 – 53 pcs; 3-19 – 59 pcs; glass – 22 pcs. Author K. Těsnohlídková.



Graph 41. Proportion of firing types identified on samples during various types of firings in open fires and pits: O – oxidation firing; M – mixed firing; R – reduction firing; Z – smoke-fired pottery; J – dark core; P – oxidation overfiring; B – white core; D – damaged/destroyed samples without identification of the firing type. Author K. Těsnohlídková.

During the firing in the closed pit, which strove towards a gradual firing and full reduction, 53% of mixed-atmosphere ceramics were obtained, while another 7% of the samples were reduction. The remaining 33% had signs of smoked pottery with centres mostly bearing marks of a mixed atmosphere. Due to the relatively low temperatures reached by this firing, samples can be considered to be only partially dried.

Additional types of firing involve different variations of fireplaces with partial or complete closure at the end of firing. Firing 2-16 was fully closed at the end; firings 4-16 and 5-19 were also partially filled in while leaving two to three small holes for the burning process. In addition, a protective structure around the vessels was used in firing 4-16 to partially insulate them from contact with the fuel, but because this structure collapsed, this condition was not fully met.

Firing 2-16 achieved very similar results to firing 2-19 with an attempt at a gradual firing process. Pottery with signs of mixed atmosphere was predominant (62%), 20% showed signs of smoking, and 8% signs of reduction ware. This is probably also due to the fact that the open phase had a relatively fast duration.

Firings 4-16 and 5-19 show similar results. Approximately half of the samples (44% and 55%) were oxidation fired, with slightly smaller numbers showing signs of mixed firing (36 and 27%). A few pieces could be identified as reduction pottery (8% and 9%). In firing 4-16, a dark core remained in three samples. In the case of firing 5-19, two samples showed a white core – this was found on loess from Pilsen in pure form and with a graphite inclusion.

The one-time firings 6-19 and 7-19 were specific for their higher occurrence of oxidised surfaces and dark cores. Oxidised surface was found in 14% and 18% of the samples, and dark cores were observed only for the faster firing 7-19, specifically in 23% of cases. These effects are more pronounced on vessels that have a larger surface area (Chapter 6.5.2). Mixed-atmosphere ceramics predominated in these firings (50% and 36%). There were samples identifiable as oxidation (23% and 9%).

6.5.8 Defects of ceramic fabric and vessels during firing and signs related to vessel arrangement in the kiln

Improper choice of ceramic fabric, inclusion or method of firing can result in damage to the fired fabric. Here are examples of similar phenomena observed in experimental pottery firings that can serve as analogies for pottery from archaeological finds (Tab. 44).

We monitored the combustion of the organic temper or graphite, which resulted in vessel permeability. Surface chipping over large grains of temper in the ceramic fabric, e.g. in mica, was a minor defect. Vessels that were mostly unusable contained an inappropriate sandy inclusion with a higher content of fine mica, which caused the general disintegration of the vessel wall in the direction in which the mica scales were arranged. A precise analysis of the composition of the temper would reveal the cause. In clay with a very low content of clay minerals, crumbling of the fabric may occur. High temperatures can also lead to the melting of temper grains or the over-firing of the complete fabric in brickmaking clays (Fig. 187).

A range of defects wider than in the case of the small samples could be observed on the ceramic vessels. These are listed separately for pit firings and kiln firings. The features presented here are based on typical firing patterns. In a fireplace, temperatures generally rise faster and direct contact with the fuel is more frequent than in the kiln.

The most common defects on ceramic vessels during open firings are caused by the poor resistance of some ceramic fabrics to the temperature jumps common for these firings. Fine clays and loess or loess loam containing calcareous impurities are more susceptible to damage. This includes various

Firing number/ defect	Shape deformation	Crack through the entire vessel	Cracks around and in the bottom	Edge cracks	Breakage of the edge	Fine cracks in the body	Warping due to heat
1-15	5				10		
1-16	3	1	3	2	2		4
3-16	1						
2-17					3	4	
1-18		3		7			1
4-19			4		1	3	

Tab. 44. Types of defects on kiln-fired ceramics and their frequency of occurrence during kiln firings carried out between 2015 and 2019.

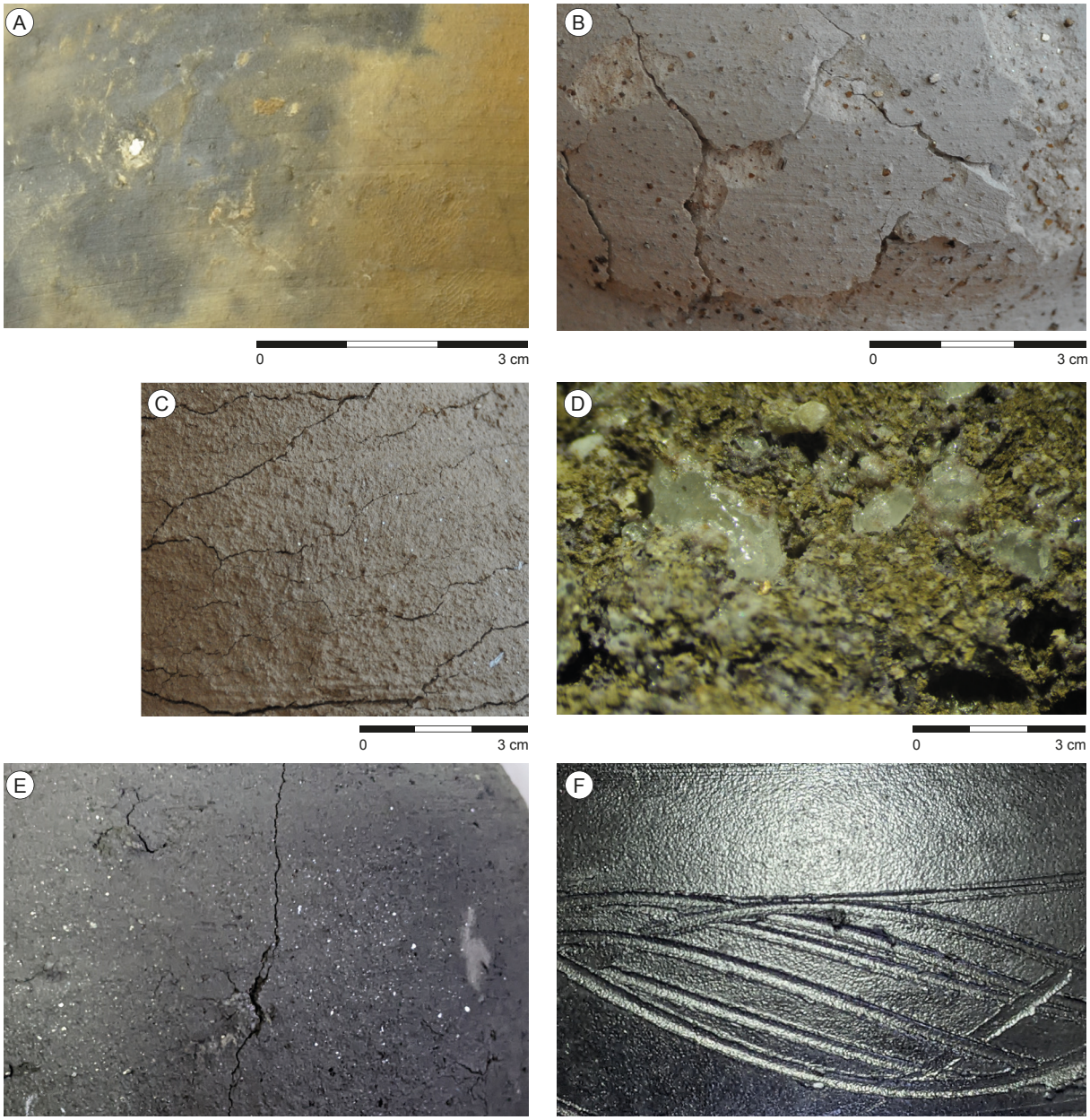


Fig. 187. Various 'defects' caused by the composition of the ceramic clay on the surface of ceramic vessels during field firings: A – flaking of the surface above mica grains; B – surface flaking due to the use of unsuitable temper; C – surface cracking and crumbling of the body in very low quality clay; D – melted quartz grains at high temperatures; E – overfiring of brick clay during smoke-fired pottery firing; F – vitrification of the ceramic surface at high temperatures and during smoke-fired pottery firing. Photo by K. Těsnohlídková.

cracks and the chipping-off of the surface layers of the vessels. Vessel shapes with a large surface area are more susceptible to cracking, as there may be high temperature differences between the different parts of a single vessel and in their bottoms or the transitions from bottom to body. The vessel shape can also be completely destroyed (Fig. 188).

The defects we encountered in kiln-fired vessels can be linked to high temperatures or temperature jumps in certain parts of the kiln in which the vessels were not properly aligned. These defects are more common in fine kaolin materials susceptible to temperature increases. In several firings, it was possible to detect a concentration of damaged vessels in a certain part of the kiln. This occurred in large kiln firings: 1-16, 1-18 and 4-19. In firing 1-16, several vessels above the middle part of the right channel on the lower and middle tiers cracked – apparently a large amount of free space was left here and the flame quickly penetrated in the early phases of firing, causing a jump in temperature. In firings 1-18 and 4-19, cracked



Fig. 188. Typical defects during open firings with rapid temperature increases: A – loess from Plzeň with graphite and likely containing a calcareous component during firing 6-19; B – fine potter's clay during firing 1-19; C – fine potter's clay with graphite during firing 4-14; D – Šlapanice – loess during firing 2-16; E, F – fine potter's clays during firing 2-19. Photo by K. Těsnohlídková.

vessels were concentrated on the lower tier and more in the front above the firebox. In these two firings, the initial stages of temperature increase were accelerated compared to the others. Due to kiln design or improper alignment of the batch, vessels in a part of the kiln may be insufficiently fired, as in the case of firings 4-20 and 1-21.

Cracks were more likely to occur where the walls were thicker, e.g. at the transition from bottom to body or in the bottom (Fig. 189: A–C). Here, cracks are often annular (ring-like) in character (Fig. 189: A). Typical for the bottom is also an S-shaped crack, which is formed as the vessel dries or during the final drying stage in the kiln due to shrinkage of the fabric (Fig. 189: B). Another common place for cracks were the edges of the vessels (Fig. 189: D, E). Cracking of the entire shape occurred only sporadically (Fig. 189: D). Defects could be observed on unfired ceramics in cases of failed firings (Fig. 189: F). Cracks are more likely to occur in vessels with a large bottom area, such as tripod vessels, bowls, or large lids (Fig. 189).

High temperatures can cause the rims of vessels to bend and even break. This was most common in vessels at the front of the kiln or directly above the heating hole, where the highest temperatures were reached. The most pronounced bends in the vessels at the front of the kiln were noted in firings 1-16 and 1-18 – these firings were the only ones to reach temperatures of 1000°C, with more bends in firing 1-16, which had a longer duration with high temperatures that were maintained for a longer period of time (Fig. 189).

Damage to vessels can also occur while arranged the loading – if the weight of the vessels in the upper part of the kiln is too great, the edges of the vessels in the lower part of the kiln can collapse, as in the case of firings 4-20 and 1-21 (Fig. 189: F).

In addition to vessel damage significantly affecting subsequent functionality, it is also necessary to take into account the markings that are left on the vessels according to how they are arranged in the kiln. These affect the aesthetic appearance of the vessel, but not its resulting usability. They are especially evident when firing smoked pottery, where we can find on some vessels impressions of their being placed against the walls or touching other vessels, or traces of the draught of the flame between vessels (see Těsnohlídková, Slavíček 2021).



Fig. 189. Most common defects observed on vessels fired in kilns: A – ring-shaped crack along the base (fine potter's clay, firing 1-14); B – S-shaped crack in the base (fine potter's clay, firing 1-14); C – chipping of the base; D – overall damage to the vessel made from very fine kaolin clay in the kiln area where rapid temperature increase occurred due to the stacking of vessels (ceramic clays from Mayen, 1-16); E – radial crack on the rim caused by thermal shock (fine potter's clay, 1-18); F – breakage of the rim of an underfired vessel after collapse of part of the kiln loading during an unsuccessful firing (fine potter's clay, 1-15); G – jug placed upside down over the firebox damaged by thermal shocks (fine potter's clay, 1-22); H – deformation of a lid shape and its adhesion to a glazed tripod during firing in a large kiln 1-16 (fine potter's clay); I – deformation of the rim of a pot due to high temperatures in the front part of the kiln (fine potter's clay, 1-22); J – deformation and splitting of the rim due to high temperatures (fine potter's clay, 1-22). Photo by K. Těsnohlídková.

7

From clay to kiln: Interdisciplinary insights into medieval pottery production and the use of kilns

7.1 Pottery production centres in their spatial and social context

According to current knowledge, it seems that pottery workshops in the Czech lands were located primarily in cities and towns in the High Middle Ages, i.e. in settlements containing a market. Village workshops operated on a rather temporary basis, and we possess only fragmentary knowledge, mostly obtained through archaeological research, of their share in the production and distribution of ceramics. A common feature was the use of nearby, average-quality raw materials, which mostly predetermined a small distribution range.

However, the concentration of production workshops in some sites exceeding the needs of the given settlement suggests a somewhat larger distribution range, which would be appropriate to specify using archaeometric research (Ivančice, Česká Lípa, Domažlice, Sezimovo Ústí). It is likely that the increase in the export possibilities of some workshops increased the introduction of the technology of full throwing from one piece of clay at the end of the Middle Ages. This was also associated with the search for high-quality clay raw materials. These trends fully established themselves only in the modern era, when pottery production was favourably influenced by the technological skills of the Anabaptists (Černohorský 1941, 16–94; Pražák 1961; Scheufler 1972, 72, 86; Pajer 2010). An exception with an extensive distribution network is Loštice, where the use of high-quality clays managed to develop a specific variation of stoneware, i.e. goods that deviate from the usual domestic production not only in the quality of the material but also in aesthetics (especially Měřínský 1969). In terms of smoked ceramics with white core and stamped decoration, we also see a relatively large distribution range, although we cannot confidently identify the production centre (see Chapter 2). It cannot be ruled out that production took place in several centres. There is also a large scope for further research here.

Research confirmed the well-known assumption that pottery workshops in cities and towns were usually located in the suburbs or in the peripheral parts of fortified town centres. Workshops were probably located on potters' house plots in the vast majority of cases, but there were apparently also workshops outside the residential area, as the example of the unfortunately insufficiently analysed site in Kroměříž and some rural examples (Kostelec, Staré Město near Uherské Hradiště) apparently suggest.

Western Europe presents a more complex picture of pottery production centres in the Middle Ages. Numerous studies in present-day France, Belgium, and the German Rhineland, i.e. in territories that were part of the Roman Empire, show that wheel-made and kiln-fired pottery production continued uninterrupted even in the Early Middle Ages, although in the 6th–7th centuries in rural areas we encounter pottery made without the use of rapid rotation. In former Gaul and Gallia Belgica, production centres were often dominant on the outskirts of large towns during the Carolingian period (here until the 10th century), which were generally tied to high-quality clay raw materials, sometimes continuing without interruption in the following centuries. However, smaller rural workshops did not

completely disappear (Carme, Guionova, Cloarec-Quillon 2020; Compagnon, Séverin 2015; Chapelot, Chapelot 2020; Jesset, Roy 2015). In the Meuse basin, an important centre in Andenne took over from older centres in the 11th century (Van Wersch et al. 2020; Longueville, Challe 2010). In the Rhineland, we observe the long-term parallel existence of coarse pottery made by hand and fired on fireplaces, pits or perhaps in simple kilns alongside high-quality wheel-thrown goods of the Mayen or Pingsdorf type. The structure of rural production is firmly embedded in the system of 'Grundherrschaft', i.e. dependent, most likely already specialized craftsmen within the economy of the rulers' manorial farms (Von Bock, Jürgens 1985; Sanke 2002; Hanauska 2012; Grunwald 2022; Weiler-Rahnfeld 2012; 2015). A similar situation is found in the Carolingian centres in Hessen (Stephan 2000). Pottery workshops are mostly evidenced by kilns, waste pits, and, more rarely, clay storages. We know much less about the dwellings of the potters concerned, as they were often located in separate areas (e.g. Mayen, La Fontaine aux Linottes, Grunwald 2022; Thullier et al. 2015). A possible analogy could be the workshop area in Nitra-Lupka in the 9th century, where, unfortunately, we have no knowledge of the further settlement context (see Chapter 2.2).

In the Late Middle Ages, we find pottery production in cities, similarly to the Central European environment. In addition, however, rural production centres near high-quality raw materials are also significantly more prevalent in Western Europe than in Central Europe, e.g. they even predominated in Brittany (Beuchet, Fichet de Clairfontaine 1996; Mani, Simonin, Peter 2015; Flambard Héricher 2020; Georges- Leroy et al. 2002; Giot, Fichet de Clairfontaine 2022). A similar picture is presented, for example, by a large part of Lower Saxony or Hessen in areas with high-quality clays. At the same time, the possibility of the contemporaneous agricultural activity of potters is acknowledged (e.g. Coppengrave, Bengerode, Knechtsbach Stephan et al. 1981; 1991; Grote 1976; König, Götz 2005; Dürr et al. 2020). Similar settlements are also found in Bavaria or the Upper Palatinate (Großmann 2000; Losert 1993, 73, 174), and also in England (Mayes, Scott, Johnson 1984; Wilson 2015; Moorhouse 1987). Urban export centres also utilized high-quality raw materials (Siegburg, Mayen; Grunwald 2022). In cities, there appear to be no significant differences in the distribution and mobility of pottery workshops compared to the Czech lands, as examples show in places such as Paris, Metz, Siegburg, Belzig, Mayen, Leipzig, Dresden and many others, where potters are often found in the suburbs, but also quite regularly within the city's walls (Georges-Leroy et al. 2009; Ravoire 2007; Biermann et al. 2001; Korte-Börger, Hellenkemper-Salies eds. 1991; Döhner, Grunwald 2022; Kluttig, Altmann, 2006; Hemker 2012). This also applies to neighbouring Lower Austria, which is akin to the Czech lands in terms of the organization of pottery production, as shown by examples from St. Pölten or Tulln (Scharrer-Liška, Scherrer 2010; cf. Chapter 5, in this book). The Austrian and Czech lands show similar features in terms of the late emergence of pottery guilds (Kraschitzer 2019, 46). In some cases, as in the Czech lands, we can consider the possibility of production areas located outside the continuous built-up area, which may perhaps be indicated by the example of the Negerborner Weg site about 1.5 km from the town of Einbeck from the second half of the 12th century (Heidrich, Kamphowe, Leers 1998; Heege 1998).

It seems that the often long-term existence of 'potter's villages' under the protection of various rulers is what distinguishes many French or German regions from Bohemian or Moravian ones, where village potters operate rather exceptionally and mainly in the short-term. The change occurred only in the modern era, but even then, small towns of the Levín or Ivančice type prevailed, not villages incorporated into the nobility's economy with a significant proportion of serf labour (Scheufler 1972, 97–99). In Central and Eastern Europe, where the 13th century was marked by a major societal change, including the emergence of institutional towns, pottery was primarily an urban craft, although in some areas it did establish itself in seigneurial villages, e.g. in Brandenburg (e.g. Mangelsdorf 1990, 272).

With the exception of Loštice ceramics, it is not possible in the Czech lands during the Middle Ages to document long-distance trade in ceramics, which was widely practiced between France, England, Belgium (Flanders), and Rhineland workshops in Germany (e.g. Jervis 2017; Keller 2022). Outside of the Czech lands, Loštice stoneware was perhaps more of a curiosity sought out only occasionally, as it could hardly compete with the large centres producing stoneware. A greater degree of export from the Czech lands is known to have been generally hindered by the average quality of goods, the staple right applied by some cities, customs barriers, and

the dependence on poor inland communications in the absence of adequate waterways. The organization of medieval crafts effectively prevented investments, and thus monetary surpluses of producers and merchants were invested more commonly in land. In the Late Middle Ages, urban production came under additional pressure by the noble estate (e.g. Graus 1960; Marek 1965, 112–128; Macek 1998; Mezník 1999, 82–87, 7–318). The socio-economic or political status of potters also offers a certain, albeit limited, field for research, especially in cities, where we have access to a relatively broad, albeit fragmented and mainly unevenly represented, collection of sources. In order to deepen our knowledge, further comparative research on various written sources will be necessary (see Chapter 2.3). Here we might highlight some intriguing topics such as the contribution of agriculture to the livelihood of potters, their investment strategies, the representation of potters in the leadership of some cities, as well as social and spatial mobility. A relatively considerable field of research is offered by unpublished sources, especially tax records, from the Late Middle Ages and Early Modern period in Jihlava and Znojmo (Nekuda, Reichertová 1968, 24–28; Hoffmann 2004b; Svoboda 1927, 43–44). The relationship between medieval and early modern pottery, e.g. in terms of the emergence of export centres, is also a major topic. In principle, however, representatives of the specialization in question can be said to have belonged to the poorer segment of urban crafts. The reason for this was relatively high production complexity, especially in the area of material preparation and firing, with the relatively high availability of raw materials of moderate quality, which reduced the possibilities of increasing the added value of the resulting products. It seems that the position of potters in the high and late medieval towns of Western Europe and eventually also in Central and Eastern Europe did not fundamentally differ, judging at least from individual records (e.g. Mangelsdorf 1990, 269–270; Schweitz 1981, 66–67; Le Patourel 1968). Pottery villages were characterized by some specificities, e.g. in Provence, France, we have proof of shared kilns. In some places in Lower Saxony, we find pottery kilns in separate areas outside of settlements (Stephan 1981, 25). Pottery wheels were often subject to taxation in France and England, which is not documented in the Czech lands. Sources also attest to the involvement of women in production (Chapelot, Chapelot 2020, 84, 91, 94, 104).

7.2 The contribution of ceramic fabric research to the understanding of medieval pottery

A specific feature of the ceramic production research presented in this book is the focus on pottery kiln finds. A variable part of their content usually consists of whole or reconstructable shapes and large parts of vessels. These probably represent the remains of the final batch. It is precisely this degree of homogeneity that is characteristic of these finds and distinguishes them from the usually fragmentary assemblages from settlement situations, which are the result of various processes taking place over a longer period of time and may include pottery from multiple workshops. However, a detailed analysis of finds from pottery kilns and their petrographic analysis mostly fail to provide a uniform picture. In addition to the remains of the final batch, parts of older batches or even common settlement waste from the surrounding areas (which entered into the already non-functional, more or less destroyed kilns as secondary filling) are often represented here. Therefore, we can often distinguish more than one type of ceramic fabric in this context.

In terms of the composition of ceramic fabric, especially with regard to the search for and preparation of raw materials, the following questions can be asked:

1. What are the possibilities and limitations of integrating macroscopic, petrographic, and chemical analysis for the research of medieval pottery?
2. What is the significance of the identified fabrics and their subgroups for assessing the preparation of raw materials by the potter? What does the possible variability of raw materials within the vessels found in the fill of the pottery kiln relic indicate? When does it represent a) an intrusion or the mixing of different batches, b) the inhomogeneity of the source/s, and/or c) the deliberate use of various clay sources by the potter?
3. What is the significance of the composition of a specific ceramic fabric for the course of the subsequent stages of the production process (shaping, firing) and how did the potter influence this?

7.2.1 What are the possibilities and limitations of integrating macroscopic, petrographic, and chemical analysis for the research of medieval pottery?

When evaluating current approaches to the analysis of ceramic artefacts in the context of international science, several challenges must be taken

into account. Each research is – or should be – optimally designed with regard to the nature of the specific material and related research questions. Its outputs should be the result of the synergistic cooperation of specialists from various fields and, ideally, their findings should be interconnected into a unified text that presents a consistent interpretation – which, however, is not always the case. In the past, analytical results were often attached to archaeological elaborations concerning ceramics merely in the form of an appendix (e.g. Hanykýř, Nováček 2010; Gregerová 2022). A step in the right direction can be found in interdisciplinary cooperation, such as verifying the macroscopic classification of ceramics with scientific analyses (e.g. Hanykýř, Maryška, Brůček 2002; Dvorská 2003; Gregerová, Procházka 2007). This has made it possible to create the foundations of the study of provenance and distribution that is being developed by other researchers (Varadzin 2010; Zavřel 2024). In exceptional cases, the results of long-term research on the archaeometry of ceramics were published separately in the form of a monograph (Stoksik 2007; Gregerová et al. 2010). However, the specific character of the assemblages we worked with in this book allowed us to deepen our knowledge of the entire process of medieval ceramics production and some related topics using archaeometry.

The work of I. K. Whitbread (1995) is considered to be an internationally recognized methodological standard for ceramic petrography and standardized the procedure for describing thin sample sections, categorizing ceramic fabrics, and evaluating them in relation to regional geology. His methodology includes a detailed description of microstructure, basic fabric, inclusions, and their quantitative ratios (c:f:v, or the ratio of coarse:fine:voids), as well as a record of other diagnostic features, such as clay pellets or various forms of concentration and depletion structures. Patrick Sean Quinn (2013) built upon Whitbread's approach, as he systematically explained individual concepts and the procedures for determining them in his textbook. The methodology of M. Gregerová is based on a precise petrographic description of mineral and rock components; the evaluation of temper, pore and matrix ratios; the determination of firing conditions; and connection with chemical analysis. A distinctive feature of her work is the use of normative recalculations and their visualization in ternary diagrams, which allows for a comparison of relationships between clay minerals, quartz, carbonates, or feldspars (Gregerová 2017; Gregerová, Procházka 1998; 2007; collectively Gregerová et al. 2010, for further detail, e.g. Gregerová 2022). The refinement of quantitative ratios in ceramic petrography can be achieved using the method of point counting, which is a method by which predefined features such as basic fabric, temper, natural non-plastic component, pores, or custom categories and specific minerals are classified in a strictly defined span of distance (e.g. Garret 1980; Stoltman 1989). However, this procedure is significantly more time-consuming than the more frequently used method of quantification based on comparison with a quantitative scale, which is more efficient, but is burdened by the observer's experience and subjectivity. Further developments in quantification methodology are moving towards automation via digital image analysis (Reedy et al. 2014; Puglisi et al. 2015).

The methodology applied in this book aims to describe all the key features in the context of the ceramic production chain. Unlike Whitbread's detailed classification of fabrics, the result of our chosen methodology is closer to a condensed description focused on provenance, raw material preparation, shaping technology, and firing (see the Methodology chapter). The chosen approach uses methods that are sufficient given the nature of the material under examination, and leaves room for future refinement, particularly through chemical analyses focusing on elements whose determination is beyond the capabilities of the ED-XRF spectrometer used. The analysis of the chemical composition using the chosen methodology allowed for the interconnection of petrographically distinguished fabrics and their precise identification via the statistical analysis of main components (PCA) as well as the mutual comparison of ceramics from regionally contiguous sites. The provided results thus represent a reference base for further research.

Despite the invasiveness of ceramic petrography, it is evident that the amount of information gained is higher when sampling larger fragments or even nearly-complete vessels. Damage to the artefact when collecting a sample can be limited, for example, with the use of sampling via core drilling. If it is not possible to take samples from larger pieces, then it is appropriate to select smaller fragments, the fabric of which corresponds to larger vessels. This means that macroscopic processing – i.e. both morphological and material classification and quantification – should precede the selection of samples (Travé Allepuz, Quinn, López Pérez 2014; Perry 2016; Ferreira et al. 2018). Similar informational value can be provided

by secondary deposits of ceramics or ceramic waste in production sites (Biermann 1998; Biermann et al. 2001; Römer-Strehl et al. 2004). Strengthening the interpretative base of research on production centres and regions should be supplemented by sampling available raw materials in the field (or in the rare cases of preserved deposits), analysing them, and potentially also via experimental firings (De Bonis et al. 2013; Neral et al. 2023). This procedure is a logical continuation of research into the origins of pottery and ceramic production, especially in the Czech-Moravian Highlands, given the number of finds of medieval kilns and the current state of knowledge. Foreign examples that can be noted here include research on the pottery site of Einbeck – Negernborner Weg, where, among other things, the analysis of production waste and clays in the immediate vicinity of the workshop from the second half of the 12th century to the beginning of the 13th century proved the local origin of the raw material (Heidrich, Kamphowe, Leers 1998). The same was true for the 9th century Anglo-Viking pottery site at Torksey in Lincolnshire, where a holistic approach was taken to research the entire operational chain (Perry 2016). Raw materials were extensively tested in relation to specific medieval workshops in Picardy, France, where differences between different levels of the same site were sometimes evident in the products (Mouny 2013, 240).

The analysis of ceramic samples from several kilns showed that the macroscopic categorization of ceramics based on visual characteristics may not always coincide with the results of archaeometric analyses. This contradiction was evident in several cases. In the assemblage from the kiln in the U Skály Street, Jihlava, graphite ceramics were mistakenly identified in samples which did not contain graphite and, on the contrary, the presence of graphite was not detected in ceramics that did in fact contain it. Furthermore, micaceous and sandy ceramic paste was macroscopically distinguished here, while the analysis results revealed only one petrographic group (or fabric) – sandy ceramics with a natural mica content. This discrepancy can be explained by the fact that macroscopic evaluation is based mainly on observing the surface and fracture. The condition and degree of preservation of the surface may affect the visibility of mica flakes. Examination of the fracture also presents limitations, which should ideally be evaluated 'fresh' after cutting or snapping off with pliers, which is often not a viable option. In the ceramics from Jihlava's Křížová Street, a category of so-called 'overfired' ceramics was also macroscopically distinguished among other classes. However, this classification did not fully coincide with the results of the analyses, which did not record extreme firings. The highest determined firing temperatures did not exceed 950°C. This may indicate two facts. Firstly, that either a lower-quality raw material that could not withstand even these relatively low temperatures was used; or secondly, that repeated exposure to firing took place when, for example, the vessels were used as kiln furniture ('kabáty' in Czech) that covered the heating chambers. In the kilns from Mstěnice, the macroscopic determination of graphite ceramics was similarly inaccurate, as the presence of graphite was not analytically confirmed. A variability in mica content was also recorded here, which was confirmed in the analyses, but the determination of individual fabrics only partially coincided with the macroscopic determination. This phenomenon is comparable to the situation in the U Skály kiln and probably has similar causes. In the case of the kilns from Žďár nad Sázavou, medium and fine-grained sandy ceramics were macroscopically distinguished, but this differentiation did not manifest itself in any way in the results of analysis. A specific example are the kilns from Staré Město, where the macroscopic classification was primarily based on the colour differences on the surface of the ceramics observed in assemblages from waste pits containing the so-called ceramics of the early medieval tradition as in the older kiln. However, this division was not confirmed by analyses, as uniform colouring is not achieved on a single vessel during firing, let alone in an entire batch. It is therefore only a visual, surface manifestation without a connection to the composition of the paste. Nevertheless, analytical methods allowed for the identification of several distinct petrographic groups within these sand classes.

The macroscopic classification of ceramics has proven to possess significant limitations. One of the main pitfalls of this method is its partial subjectivity. The evaluation of ceramics depends on the experience and perception of the specific observer. Another problematic aspect is the fact that a ceramic class is often determined for each fragment. This fragment may not necessarily reflect the true variability of a given vessel, especially when differences in the degree of surface wear or fluctuations in the content of certain inclusions are involved. In the case of evaluating entire vessels, we also encounter the limitations of macroscopic observation due to the fact that we only have access to their outer surface.

The internal structure of the ceramic paste cannot be assessed without collecting a sample or damaging the vessel. The ability to recognize the structure of ceramic fabric is where archaeometric methods are irreplaceable, and they should be used to validate preliminary macroscopic assessments. These methods allow for an objective and detailed evaluation of the mineral composition, technological characteristics, and possible production variations to a degree that is not possible via macroscopic study.

Ceramic classes for material classification should be based on a description of the paste with the distinction of notable additions. Subsequently, groups formed in such a way should be compared with technological characteristics, such as traces of forming or firing. The third step should be the validation of the aforementioned groups via archaeometric analysis, resulting in the division of the studied assemblage into production-technological groups (cf. Dvorská 2003; Čapek et al. 2022, 191–205). However, ceramic classes should primarily be petrographic. As we have demonstrated, macroscopic classification can lead to incorrect results when carried out in excessive detail. A problem, for instance, lies in the objective differentiation of subclasses according to the size of temper if we wish to quantify size groups on a large scale according to M. Gregerová's methodology; this is only possible on a properly prepared sample (Gregerová, Procházka 2007, 276, 283; Gregerová 2017, 368; Procházka et al. 2024, 135–136).

Assemblages with entire preserved vessels such as the remains of kiln batches in the relics of kilns processed in this study are ideal for precisely defining ceramic classes, including the determination of firing properties and forming techniques. Unfortunately, only in exceptional cases was it possible to take samples from entire vessels or large parts of them that were highly likely to have come from the last batch (Jihlava – U Skály Street, Žďár nad Sázavou, Staré Město). On the other hand, a larger dispersion of selected samples also including fragmentary ceramics provides evidence of a workshop's activity over a longer period of time. However, the findings presented above in Chapter 4 show that in the assemblages studied, one distinct material group often dominates and is accompanied by subgroups represented by individual samples. Thus, the question of the representativeness of the analyses arises. It is evident that the more samples that were analysed, the greater the objectivity of the presented classification.

7.2.2 What significance do the identified fabrics and their subgroups have for assessing the potter's preparation of raw materials? What does the possible variability of raw materials within the vessels found in the fill of the pottery kiln relic indicate? When does it represent a) an intrusion or the mixing of different batches, b) the inhomogeneity of the source/s, and/or c) the deliberate use of various clay sources by the potter?

Archaeometric analysis showed that the raw materials needed for the production of ceramics were mostly obtained from near the studied pottery workshops. In terms of the rock composition in relation to a specific location, five areas can be distinguished. The first includes Jihlava and Kostelec near Jihlava, the second Žďár nad Sázavou, the third Mstěnice, the fourth Staré Město near Uherské Hradiště, and the last St. Pölten.

The study sites are located in four geologically diverse areas. The first of these are sites in the Czech-Moravian Highlands. Jihlava, Kostelec, Žďár nad Sázavou and Mstěnice are in the area of crystalline rocks of the Moldanubian. Jihlava is located in the Moldanubian variegated series, consisting mainly of migmatite, with sporadic outcrops of granite. From the northeast, the city is affected by the remains of freshwater Tertiary sediments of the Jihlava Furrow. In the same direction, there are loess loam deposits, which also outcrop directly in the city and continue for approximately 15 km to the north. West of Jihlava, at the point of contact with the central Moldanubian pluton, the bedrock is formed by granulite. Kostelec, which lies in this direction at a distance of only 8 km, has a bedrock formed by paragneiss and migmatite. Serpentinite, dolomite and amphibolite are found locally. Žďár nad Sázavou falls within the Strážek Moldanubicum, a sub-unit of the variegated series. Its bedrock is mainly composed of migmatite to orthogneiss, with less paragneiss, granite and granodiorite. Two kilometres to the west, there are outcrops of erlan and crystalline limestone. These rocks are found in the wider surroundings in the form of smaller bodies along with small bodies of amphibolite, serpentinite, skarn and quartzite. Less than 10 km northeast, the bedrock is formed by the Kutná Hora-Svratka crystalline complex, the rock composition of which is represented by two-mica paragneiss and schist, orthogneiss with small bodies of amphibolite, carbonate rocks and quartzites. The bedrock of Mstěnice and the nearby area consists of strongly metamorphosed rocks of the western Moravian Moldanubian Zone.

They are mainly serpentinized peridotites, migmatites and migmatitic biotite gneisses. East of the site, granulites and amphibolites outcrop. Part of the Quaternary cover in the vicinity is formed by loess and loess loam. Alluvial sediments accompanying local watercourses can be found at all sites (Mísař 1983; Francírek, Nehyba 2019; ČGS 2025).

Staré Město is located in a completely different geomorphological environment of the Lower Morava River Basin. It lies on the western edge of the wide alluvium of the River Morava with thick fluvial sediments from the Quaternary. The Quaternary cover between the alluvium and the slopes of moderate hills formed by sandstone and claystone of the Carpathian Flysch is formed by loess and loess loam. Neogene strata of the Vienna Basin are found locally in the Quaternary bedrock and outcrop. Their lithological content is formed by clay, silty clay, silt, and silty sand. The area to the southeast is characterized by fairly inextensive limestone from the Hluk Development (Buchta et al. 2021, ČGS 2025).

The Austrian site of St. Pölten, which is located in the area of the autochthonous molasse between the crystalline units of the Moldanubian and the thrust sedimentary units of the Subalpine molasse and the Alpine Flysch, has a significantly different geological context. The bedrock here consists of detrital sediments from the late Eocene to the middle Miocene, covered by loess and loess loam. From the point of view of ceramic raw materials, the following are particularly significant: refractory clays of the Egerian (Pielach formation), above which are layers of sands rich in feldspar (Melk sands) and carbonate clays ('Schlier'). The valley terrace of the River Traisen, which brings sediments from the flysch zone, represents another potential source of fine-grained raw materials, while outcrops of the crystalline basement with granulite and serpentinite are found northwest of the city. Granulites are locally kaolinitised and represent another possible source of raw pottery material (Janoschek, Matura 1980; Müller, Schermann, Schwaighofer 1983; Geologische Bundesanstalt 2002; Roetzel 2002).

The geological bedrock fundamentally determined the possibilities of medieval and modern potters in their selection of raw materials. Archaeometric analyses have shown that potters made a certain targeted selection, focusing on clayey and silty soils and clays, while their diversity in individual microregions did not always require tempering (fabric A in Jihlava – the Křížová and U Skály streets including sub-groups, fabric A in Kostelec, sub-groups A1, A2, B2 and B3. Mstěnice, or A2 in Žďár nad Sázavou, or fabrics A in Staré Město and in St. Pölten). The most frequent fabric A1 in Žďár nad Sázavou was intentionally tempered, as is probably the case of part of the raw material in fabric B in Staré Město, although here it may be a naturally heterolithic sediment. The percentage of temper ranged up to 30 vol.% (Tab. 45). The purpose of tempering was to increase the proportion of the sandy fraction in clay that was too fine. The average proportion of the non-plastic component of either tempered or untempered pottery was 20 vol.% (15 and 26% in the second and third quartile, with a maximum of 40%). Interestingly, in Mstěnice, Jihlava, and Staré Město, potters avoided loess and loess loam, which were commonly used later by local brickyards. These clays may be problematic in their excessive fineness, which could lead to the cracking of vessels during the drying process (Towner 1988; Zaccaron et al. 2024), or in the content of carbonates (usually reduced in loess loam), which decompose at temperatures commonly reached in medieval kilns (Shoval et al. 1993; Gregerová et al. 2010, 32). This could compromise the stability of vessels during firing. It should be taken into account that most of the ceramics produced during this time were cookware – that is, the walls of the pot were repeatedly exposed to direct flame. It is evident that medieval potters took this fact into consideration. However, it is certain that they were able to distinguish between loess and clay deposits and, for some reason, preferred the latter type of raw material for pottery production. Precise determination of sources is not possible without extensive research and subsequent analysis of material from selected sites. Moreover, research into this matter is limited by the existing built-up area. St. Pölten, where we possess data from written sources, is an exception. Due to the narrow range of possible sources, it was also possible to achieve considerable specification in Staré Město near Uherské Hradiště. In contrast, the diverse sources of clays and clayey soils from the Tertiary and Quaternary Age in Jihlava offer a wide range of localization possibilities, but these are not always accessible on the surface. One of the likely possibilities is the origin of the raw material from limonitised tectonic clays filling the dislocation zones of the Jihlava ore area.

According to some documents, in the Late Middle Ages, the procurement of clay was already regulated and taxed by landowners, especially by municipalities or rulers, as shown in the examples from Žďár nad Sázavou (1407) or Rakovník (1436)

Site	Ceramic pastes and fabrics					
	Sandy		Graphitic	Micaceous	Glazed	Loess
	Non-tempered	Tempered				
Jihlava – U Skály Street	**A2 (with mica), 3**	**A1 (with mica)**	**B1, 2**			
	15–25 %	1/10–30 %	15–20 %			
	<700/750 °C (<1000 °C)	700/750 °C	<800–850 °C			
	Mixed atmosphere, often reduced core	Mixed atmosphere, often reduced core	Mostly oxidised			
Jihlava – Křížová Street	**A**		**B**	**C**	**D (intrusion)**	
	15–20 %		25–35 %	1/15 %	15 %	
	<850–950 °C		<800–900 °C	<800 °C	<1000 °C	
	Mixed atmosphere, often reduced core		Mostly oxidised	Oxidised	Reduced	
Kostelec near Jihlava	**Mica content variable**					
	5–20 %					
	<700–850 °C					
	Weakly oxidised marings, reduced core					
Mstěnice	**A1, 2 (with mica both), B2, 3 (less mica)**	**B1, 4**		**C1, 2 (muscovitic)**		**D (intrusion) loess derivated**
	15–30 %	1, 5/25, 15 %		15, 30 %		15 %
	<700–850 (~900, ~950) °C	<700 °C		<800, <700 °C		<750 °C
	Mixed atmosphere	Weakly oxidised		Weakly oxidised, weakly reduced		Reduced margins, weakly oxidised core
Žďár n. Sázavou	**A2**	**A1**	**B**			
	30 %	5/5–15 %	5/20 %			
	<700 %	<700–800 °C	<850 °C			
	Oxidised margins, reduced core	Oxidised margins, reduced core	Oxidised margins, reduced core			
Staré Město near Uherské Hradiště	**A**	**B1, 3**	**SM3 (intrusion)**	**SM4 (intrusion)**		
	20–40 %	1–5, 1–15, 15/20–30, 10–30, 1 %	<5/10-25 %	<5/35		
	750–900 (<1050, <1100) °C	750–900 (<1100) °C	950–1050 °C	<900 °C		
	Mostly oxidised, minority reduced, several reduced cores	Mostly oxidised, minority reduced, several reduced cores	Weakly oxidised, reduced core	Mixed		
St. Pölten	**A (kaoline)**	**B (kaoline)**				
	15–30 (40) %	10/20 %				
	800–900 (1000) °C	1000–1100 °C				
	Most completely oxidised, some completely redcued	Oxidised				

Tab. 45. Ceramic pastes and the fabrics distinguished among them – summary of selected technological features (volume of aplastic inclusions – in tempered fabrics divided into natural aplastics / added temper; firing temperature – outliers in parentheses; oxidation–reduction effects).

cited in Chapter 2. The example of Loštice, although from the Early Modern period, gives evidence of the free traditional use of land that was later confirmed by privilege (see Chapter 2.3.4). This may have forced the potter to concentrate, if possible, on a single deposit. However, this assumption cannot be made absolutely (e.g. Arnold 1985). In the 13th century, especially in places like Mstěnice, we can assume that multiple sources were tested, still without significant regulation. Efforts to optimize the availability of the resource, influenced by the transportation possibilities of the time, were of paramount importance,

forcing potters to work as close as possible to the site of usable clays, as shown by numerous studies (e.g. Heege 1998, 15–16; Heidrich, Kamphowe, Leers 1998, 28–29; Stephan 1981; Carme, Guionova, Cloarec-Quillon 2020, 309). The still insufficiently clarified distribution of graphite, where relatively larger import distances can be considered, still represents a certain exception (e.g. Gregerová et al. 2010, 135).

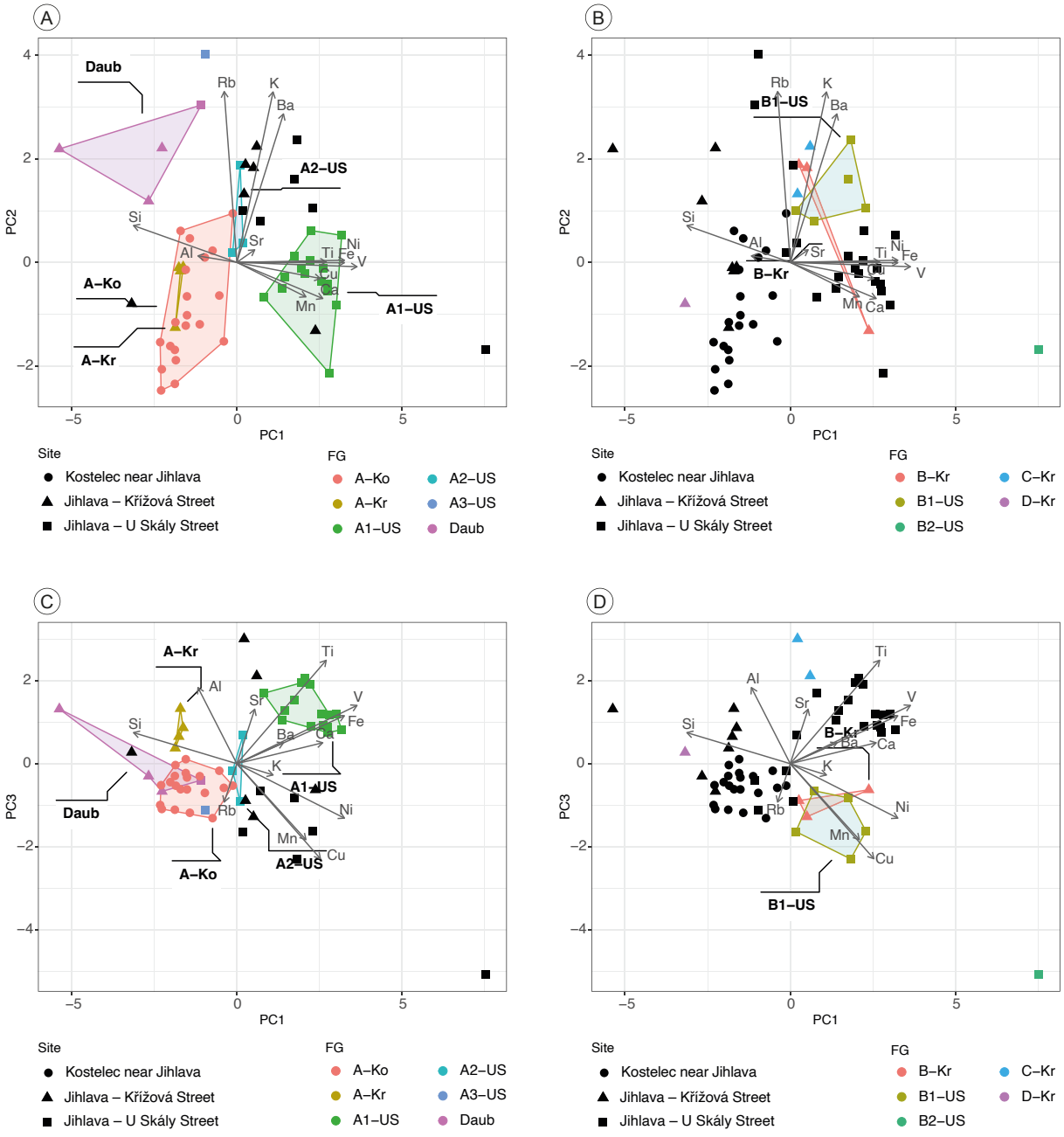
So-called sandy ceramics, which have been defined in all assemblages, clearly come from local sources. Their basis is formed by clays and clay loam with rather average properties, especially in terms of resistance to temperatures above 900–1000°C, as shown, for example, by the deformed fragments from kiln 11 from Staré Město or 'overfired' vessels from the kilns in Jihlava. Pottery was significantly homogeneous in Kostelec and in Jihlava – Křížová Street. In Staré Město, Žďár nad Sázavou, Mstěnice and Jihlava – U Skály Street, further subgroups differing in various proportions of the specific elements or minerals, or in the modality and shape of the grains of the clastic component, were distinguished within sandy paste ceramics. This variability may reflect both internal structural differences within one layer and differences between several nearby layers. Some clays and loams had to be tempered, while others did not. Mstěnice is characterized by a relatively considerable diversity in terms of macroscopic homogeneity, where differences between subgroups in both fabric A and B also suggest dissimilar sources. Moreover, there is also the strongly muscovite-tempered and biotite-tempered fabric C – the mica temper may or may not be of local origin and was apparently added intentionally, perhaps reflecting the popularity of micaceous ceramics in the neighbouring Brno region. Given the lack of knowledge concerning the detailed composition or the thickness of suitable sediments in the Mstěnice area, we can hypothetically assume that the potter tested several sources in the immediate vicinity over the course of, say, two decades, and the naturally sandy fabric A1 seems to have suited him best. At the same time, it would be necessary to verify the actual proportion of the fabrics represented individually (B1 and B4): In the case of fabric C, this would constitute single-digit percentages. Their macroscopic differentiation, which appears to be very problematic, still remains a question.

Nearly identical sources can be noted in the case of ceramics from the kilns in Jihlava. The main sandy-mica fabric A1 (U Skály Street) shows similarity to the dominant fabric A in the assemblage from Křížová Street, especially in the matrix, which has a distinctly clayey character and thus is of good quality. The difference is found in the non-plastic component: fabric A1 (U Skály Street) had to be intentionally tempered, while fabric A (Křížová Street) – similarly to fabric A2 from the U Skály kiln was not tempered. The single sample in fabric A3 stands out distinctly, suggesting a mixture of multiple clay sources.

An interesting comparison can be made with the kilns from Jihlava and Kostelec, which are located in close geographical proximity (distance of 8 km) and share a similar geological bedrock. The dominant sandy fabric A from Kostelec corresponds to the similarly labelled fabric from Křížová Street and subgroup A2 from U Skály Street – all had a common abundance of natural temper. However, we observe certain petrographic differences with a very similar chemical composition (Graph 42). The ceramic fabric in Kostelec showed the most homogeneous structure (relatively) of all the assemblages discussed.

The Žďár nad Sázavou assemblage is dominated by sandy fabric A. This fabric is apparently of local origin and deliberately tempered, with a relatively lower proportion of temper within the observed assemblages.

The origin of the sandy ceramics from Staré Město indicates two variable groups within the basic fabric, originating either directly from Tertiary clay or from clay redeposited together with Quaternary deposits. It was possible to distinguish two basic fabrics. Fabric A was of a silty-clayey character and fabric B was more of a clayey character. Fabric A dominated in the ceramics from the more recent kiln III/98, while in the older kiln 11, judging at least by the proportion in the set of samples taken, fabric B predominated. It seems that fabric B, in particular, was in part tempered deliberately. Macroscopically, two classes were distinguished based on the opinion that the ceramics from the older kiln 11 and related finds from waste pits, probably from contemporary pottery production at a different location on the same site, are coarser than the ceramics from the later kiln III/98. Moreover, the ceramics from the waste pits, which are morphologically and technologically similar to the ceramics from the kiln, more frequently showed pronounced oxidised surfaces. Although petrographically these are two groups, they are essentially indistinguishable from a macroscopic point of view. This is similar to the case of the roughly contemporaneous ceramics from nearby Veselí nad Moravou. Even comparable firing temperatures were found on both sites (Sedláčková 2015, 191; Petřík,



Graph 42. Principal component analysis of the elemental composition of sites within Jihlava and Kostelec near Jihlava: A, C – affinity of the Kostelec fabric with Křížová Street fabric A, partial similarity with daub from Křížová Street, and a comparable composition with fabric A2 from the U Skály Street (A – PC1 × PC2; C – PC1 × PC3); B, D – affinity of graphitic fabrics across sites, particularly between fabric B from Křížová Street and fabric B1 from the U Skály Street (B – PC1 × PC2; D – PC1 × PC3). Author K. Slavíček.

Slavíček, Sedláčková 2015, 103–104). The assumption that the raw material of the late phase of the domestic pottery tradition was prepared differently than the otherwise more advanced high medieval ceramics with different morphology and typology thus proved to be false. Given that Tertiary clays in the vicinity of Staré Město come to the surface, they could easily be used alternately with redeposited clays; in this context, it will be necessary to analyse at least the available sources of the first of the aforementioned types. When considering the diversity of the used sources, it is necessary to take into account the relatively large time gap between the two kilns, which amounts to approximately half a century.

Variant of group A was also found in the assemblage of samples from the ceramic hoard from Staré Město (site 62) from the mid-14th or early 15th centuries. Here, we can very reasonably assume that the deposited ceramics come from several batches but from one workshop, the kilns of which, however, have yet to be found or were destroyed by construction work. The distinct predominance of fabric A was already recorded in the ceramics from kiln III/98. The structure of the ceramic fabric from the hoard may indicate a stabilization of the raw material source.

Ceramics with an inclusion of graphite or graphitic rocks represent a specific component of the studied assemblages. The proportion of graphite to organic carbon in the basic matrix was not monitored. In Jihlava, this mainly involved separate graphite grains, which were sometimes contained in fragments of gneiss (Graph 42: B, D). Garnet grains are provenance-specific for graphite ceramics from Jihlava and were not found in sandy fabrics. Their connection to graphite is evidenced by the garnet contained in a fragment of graphitic gneiss. One of the likely possibilities is that the extraction of graphite took place from the aforementioned graphitized tectonic clays. The potters therefore were probably using two different sources for these two specific types of ceramics (sandy and graphitic). It is obvious from the considerable presence of graphite ceramics in one of the whole vessels, and the proportion of 'graphite' ceramics in the assemblage from the kiln in U Skály Street, that the raw material with graphite in question was being prepared intentionally separately from the predominant sandy clay. Similarly, the minority of products with graphite documented in the kiln in Žďár nad Sázavou also seem to represent a component with intentionally prepared raw material. Graphite occurred here together with graphitic metaquartzites. Possible deposits closer than 8 km from Žďár nad Sázavou have not yet been discovered. Fragments of graphite ceramics from Křížová Street as well as in the filling of kiln 11 in Staré Město most likely represent an intrusion. The raw material for graphitic pottery from Staré Město should be assumed to have come from distant areas, namely in the area of the Svratka or Thaya Dome, or in the Desenská Dome of the Silesian Domain. In the settlement material of the Uherské Hradiště region, or possibly the nearby Veselí nad Moravou region from the 13th century, graphite ceramics occur marginally, mostly in the form of storage vessels (Procházka 1984, 436, 438; Sedláčková 2015, 191).

Ceramics with intentionally added mica were represented marginally in the examined assemblages. This includes fabric C from Křížová Street in Jihlava and from Mstěnice, and SM4 from kiln 11 in Staré Město. Altogether, the fabric was represented by six samples. The kiln in Jihlava is very likely an intrusion. No larger fragments of micaceous ceramics were represented in the assemblage. However, they did not differ much in terms of fabric from graphite ceramics. The ceramic fabric contains a similar proportion of the main rock-forming minerals – quartz, alkali feldspar and plagioclase – as in graphite fabric B; it also contains garnets. Local production can be assumed. Mica, in this case both biotite and muscovite, could have been obtained directly in Jihlava and in the nearby area from weathered granite or migmatite. Mstěnice micaceous ceramics differ quite significantly from other local fabrics due in part to the high content of muscovite, which, together with biotite, was used as a temper. Their clay must have been of a different origin. In terms of composition, it could correspond to weathered gneiss, for example, which is found in the bedrock near the village. A more distant source may have been found in the weathered schists near Čučice (13 km northeast) or near Rudlice (15 km south). Fragments of micaceous ceramics were found in both kilns at the site. Macroscopically, it was possible to distinguish these within the assemblage. Their representation was in single-digit percentages. However, they were not represented in whole vessels, so they are more likely to be a more recent intrusion. In general, the material content of the local kilns can be said to be distinctly heterogeneous. How, then, could one batch come from heterogeneous clays? The potter could have obtained clay from seemingly random sources directly in the village and its immediate hinterland, for example during construction work. The collected clay was then not homogenized during storage and processing, or it was homogenized, but imperfectly.

One micaceous fabric (SM4) sample from Staré Město, which represents a later intrusion, constitutes a somewhat different case compared to the other kiln assemblages. The geological bedrock in the vicinity of the site does not contain mica in quantities sufficient to serve as temper, and the nearest potential sources are located roughly 90 km away (in the Lukov and Bílý Potok units of the Moravicum, or in the Jeseníky Mountains). If the vessel from which this sherd originated was produced locally, the mica must have been brought to the site. Evidence for this practice is provided by the pot inv. No. 12396 (sample 40),

which was preserved intact in the 'Na Dvorku' kiln. This vessel belongs to fabric A, further supporting its local production. Sheets of muscovite were deliberately applied to its surface, possibly as a decorative or functional coating. A plausible explanation for the presence of mica is its secondary acquisition from mica schist grinding stones: during their repeated use, fine flakes of mica would have been abraded and detached from the stone surface, collected, and subsequently used by potters. However, around 2% of all vessels and sherds in the assemblage show mica flakes on their surfaces, which is a relatively high proportion; this raises the question of whether all of this mica could indeed have originated solely from such grinding stones. The only other plausible explanations would be the intentional crushing of an old grinding stone to obtain mica, or the direct import of mica as a raw material.

7.2.3 What significance does the composition of a particular ceramic fabric have for the course of the subsequent stages of the production process (shaping, firing) and how did the potter influence this?

The question of how archaeometric findings reflect the preparation of potter's paste is difficult to solve without knowing the variability of the clays used, i.e. of the deposits in specific procurement sites. In addition, if the samples represent multiple batches, the ceramic body resulting from a deposit with a certain degree of heterogeneity of the temper or composition of the basic matrix may to a certain degree give the impression of being from multiple fabrics (this mainly involves the ratio of grain size fractions, heterogeneity within the lithology of clusters, and the associated variability of the overall chemical composition). Possible differences between clay deposits should be admitted; moreover, the material may not have always been perfectly mixed, and thus we should allow for differences between individual batches. The situation is more complicated when we work with samples predominantly or almost exclusively from one batch in which we observe significant differences, as is apparently the case with the kiln in Jihlava – U Skály Street. As for the sandy fabric A, where the differences are found only in the granularity of the non-plastic component, we can speculate about differences caused within the processing of the clay, which is supported by the fact that among the analysed whole vessels, most likely made simultaneously, only fabrics A1 and A2 are represented from the sandy facies in a 2 : 1 ratio. For example, insufficient homogenization can be supposed – i.e. the coarser-grained part remained – in fabrics A2, and A3, thus the potter stopped further tempering. These two fabrics are, moreover, represented in the assemblage in a significant minority, while the structure of fabric A3 clearly indicates the mixing of two types of clays. However, the same does not apply to the graphite fabric, the raw material of which was of a different origin and was processed in a different way. Even the graphite fabric was not uniform, and two types of graphite paste were identified – one type was used to make a pot and an ewer, and another type to make a storage vessel. The storage vessel fragment is an intrusion in the batch assemblage; however, it indicates a development or different approaches in the preparation of the paste in one workshop (we assume that it is possible to attribute local origin to this storage vessel). In the case of the last batch of this kiln, we must acknowledge the possibility that it was made from two different raw materials stored in different deposits.

Three different fabrics within one batch of the kiln in Jihlava – Křížová Street (sandy, graphite and micaceous) support the hypothesis of the use of multiple clay deposits within one workshop. The potter was aware of the different properties of various clays and worked with them, as is evidenced by the technologically exceptional, exceedingly thin-walled pot made of graphite paste from the kiln in Jihlava – U Skály Street. Thus, we can consider the possibility that there were 3 differently mixed clays corresponding to groups A (sandy), C (with mica) and B (graphite).

In terms of material, the kiln batch in Kostelec was homogeneous both according to macroscopic observations and the results of analyses. No multiple sources of clays, tempers, or variability in production technology were found. This apparently probed the routine work of a single potter. Due to the homogeneity of the non-tempered sandy ceramics with naturally occurring inclusions, this evidently involved a single source.

In the case of Mstěnice, there was undoubtedly a special raw material stockpile serving as the base for ceramic fabric C with a distinct mica inclusion (numerous biotite is common at the site, but this fabric stands out for its high muscovite content). Despite the apparent macroscopic homogeneity of the paste of the majority of sandy-micaceous ceramics containing biotite as a natural inclusion in the clay, it was possible to distinguish

two main fabric groups and several subgroups within them. The sample set in both kilns was dominated by fabric A, with kiln 2 exclusively containing subgroup A1, while kiln 1 had a balanced representation of subgroups A1 and A2, which differed only in grain size; however, the difference in the roundness of the grains of the non-plastic component demonstrates a different origin (eluvium × alluvium). If this were a single batch, it would suggest two different clay sources. However, the samples were not taken from whole vessels, and therefore they may be remnants of different batches. The origin of the other subgroups, each of which is represented by a single sample, remains a question. These either indicate several different clay sources, or the heterogeneity of the sources used. If these are later intrusions, then this would indicate changes in sources over time. It is necessary to consider that the time scale may not be very long, i.e. that we are dealing with only several years or possibly 1–2 decades.

The older kiln from Staré Město showed quite a significant heterogeneity in the represented sandy ceramics, with subgroups of probably intentionally tempered silty fabric B prevailing. The ceramics came from the kiln's stoking pit. Whole vessels were not analysed, and only a few deformed large fragments of the same pot belong to subgroup B3. The samples may represent multiple batches, while the potter, possibly operating one of the first ceramic kilns on the site, tested multiple sources, as in the case of Mstěnice. The concurrence of subgroups A1 and A2 in one of the kilns may indicate that the potter was simultaneously testing clays from two sources – from eluvia and alluvia. This corresponds to the initial stage of production, which was characterized by the search for the most suitable sources.

The ceramics of the later Staré Město kiln III/98 belong predominantly to fabric A (8 samples), including the only whole vessel that was analysed; four samples were represented by the more clayey, tempered fabric B. The abundance of small fragments clearly supports the thesis that a large portion of the material of the lowest size category comes from multiple batches. The last batch was probably made from the raw material of fabric A. The general petrographic characteristics and the concentration of the chemical elements probably suggest natural variability within one source, i.e. geological genesis of the used sediment. Geographically, this may or may not involve a single site. Nevertheless, the use of one dominant fabric may indicate some stabilization in clay procurement as a part of pottery technology development around 1300.

It is evident that even where it was possible to distinguish multiple petrographic subgroups of sandy or sandy-micaceous ceramics, one often has a more or less dominant position – A1 in the Jihlava – U Skály Street assemblage, A at the kiln in Křížová Street, A1 at kiln 2 in Mstěnice, A1 in Žďár nad Sázavou, A at kiln III/98 in Staré Město, and finally fabric A in St. Pölten. This does not apply as unequivocally to kiln 11 in Staré Město, where three subgroups of fabric B are quite significantly represented, with a considerable share of fabric A. In Mstěnice, subgroups A1 and A2 are equally represented in both kilns and differ in one important feature, thus allowing us to consider the possibility of different origins of the raw material. For the reasons already mentioned, we are once again faced with a dilemma concerning whether there were multiple batches or multiple material sources.

The next question deals with the significance of the samples of predominantly individually represented subgroups within sandy or sandy-micaceous ceramics in relation to the preparation of raw materials by the potter: these are mainly subgroups A2 and A3 in the U Skály kiln, B1–B3 in Mstěnice and A2 in Žďár nad Sázavou. None of the subgroups of fabric B within Staré Město were represented marginally, except for B1 in kiln III/98. It is possible that in this case, the assemblage does not represent the very last batch of the kiln. In the case of kiln 11 from the same site (as well as in other cases), analyses of whole or reconstructed vessels could shed more light on the problem.

Further findings might be yielded by detailed research into possible sources in the vicinity of individual sites and by elaborating on existing analyses by means of a targeted selection of additional samples.

The question of the properties of ceramic pastes and intentional influence on them was also examined through experimental archaeology. Attention was focused on both the phases of the production process, shaping, drying and firing, and on the requirements for the properties of the final product. The experiments focused on ceramic production in the Bohemian-Moravian Highlands and were based on a comprehensive analysis of archaeological material.

In the period under study, pottery was still relatively tolerant in terms of the selection of raw materials, and they were thus not a limiting factor for production; over time and with the improvement of technologies, the demands on ceramic fabric and its quality began to increase. Based on the properties of the analysed ceramics and the experiments that were carried out, clayey soils of various qualities from sources close to the pottery workshop can be

considered to have been raw material sources for potters in the 13th century. For example, the lowest-quality clays used in the Bohemian-Moravian Highlands evidently correspond to the material used in modern brick-making; these fabrics contain a relatively large amount of sand or other non-plastic inclusions. In the period under consideration, however, it can be assumed that the requirements placed on the quality of raw materials were not as high and specific as in later periods, yet certain interventions by potters in the natural composition of the ceramic fabric or the avoidance of a certain type of source, e.g. loess loam, can be observed.

The analyses revealed two basic types of clay modifications – tempering and mixing of several types of clays. Tempering was evidenced in some sandy fabrics from Jihlava – U Skály Street (A1), in Žďár nad Sázavou (A1), in Staré Město (B1–B3), and in St. Pölten (B). In Mstěnice, tempering was recorded only in a few samples (B1, B4). The intentional addition of graphite can be assumed in all graphite fabrics, although in the case of Jihlava ceramics, it is possible that the graphite was a natural part of the clay. The intentional addition of mica flakes can be assumed in fabrics C from Jihlava's Křížová Street, C1 and C2 from Mstěnice, and SM4 from Staré Město (see the more detailed description of tempering in Chapter 4). The mixing of two types of clays was documented only in one sample from Jihlava – U Skály Street (fabric A3).

Sand, often quartz, with a variable amount of feldspars and rock fragments and a variable content of mica flakes, was a natural part of these fabrics. Therefore, we can claim that the intentional tempering of clays took place only rather sporadically, as this always involves only a minority of samples from most locations (Mstěnice, Staré Město, St. Pölten). In the kiln from Jihlava's Křížová Street, tempered fabric C (micaceous) and probably also tempered sandy fabric A1 were found. Most of the fragments from the Žďár nad Sázavou – 'Staré Město' kiln were probably intentionally tempered as well.

Another inclusion found in the fabric of vessels from kilns was graphite. It could have been added intentionally, but in the case of the kilns in Jihlava and Žďár nad Sázavou, clay enriched with graphite either in the form of silt (or smaller) sized particles could have occurred as part of the plastic component of the clay, or as graphite flakes or graphite containing rock fragments. We know of finds of lump graphite from Jihlava – U Skály Street, which could have been further processed as an additive to the ceramic fabric. Here, both options can be considered.

7.3 Application of experiments

The results above were gradually reflected in the experimental production of ceramics, where various sources of clay were used, as well as loess and natural kaolin sources, and for comparison with industrially processed potter's clay. The preparation of clays followed ethnological procedures, such as summering, wintering, selecting coarse inclusions or repeated kneading (from numerous sources in literature, e.g. Plicková 1959, 35–36; Pražák 1961, 29–58). The higher the demands on the fabric during production, the more attention needs to be paid to these processes. However, these procedures are essentially untraceable on the ceramic fabric in retrospect.

The quality of these fabrics was compared not only subjectively by their behaviour in the production of vessels, but also by analysing the content of kaolinite and clay minerals, which was intended to allow for a comparison of the plasticity of different fabrics (see Chapter 7.1). Here, too, the fact that the quality of clay can fluctuate within a single deposit was demonstrated. One can assume that the medieval potter was usually able to find a suitable material within the deposit, as is also clear from the abundant amount of ethnoarchaeological parallels (Landsfeld 1950, 122–125; Arnold, Neff, Bishop 1991).

Clays that match the properties of ceramic production of the period in question in the Bohemian-Moravian Highlands are more suitable for the production of vessels using wheel coiling techniques than wheel throwing. The primary reason for this is probably that a relatively small amount of plastic clay can be dampened more quickly. Vessel throwing using one piece of fabric significantly involves water from the very start of the production process, and the fabric can become damp even before the desired shape is achieved. Wheel coiling, on the other hand, uses water only in the final stage of rapid rotation, thus allowing for the production of larger vessels or vessels with thinner walls from the same clay. Another reason may be the presence of coarse grains if the clay is not levigated; this can hurt the potter's hands and damage the wall by wearing down the fine material when water is used. The coarse grains are left on the surface, and they move and damage the walls of the vessels during rotation. Włodzimierz Hołubowicz considered tempered clay to be more suitable for wheel coiling than for throwing based on observations of traditional pottery techniques in Belarus, as it better withstood the pressure of the fingers on the clay coils (Hołubowicz 1950, 150). Similarly, V. Roux and M. Rogier consider strongly

tempered clay to be a disadvantage for the wheel throwing technique (Rogier 2015, 79; Roux, Corbetta 1989). The relationship between clay plasticity and the method of attachment and speed of rotation has also been assumed by M. Richter (1982, 95, 98).

Both natural ceramic fabrics and those with various modifications (e.g. levigated) and also inclusions (e.g. graphite, mica) were tested. Sand inclusion was not significantly applied, as it was found naturally in the natural fabrics that were used.

A high proportion of sandy addition resulted in the clay cracking less during drying and was more resistant to temperature jumps during firing (on this issue, see e.g. Towner 1988, 347–356; Zaccaron et al. 2024, 339–348). This fact was also confirmed during experimental firings, which showed that the regional clays used from the Bohemian-Moravian Highlands are suitable for rapid firings, where the temperature can rise by hundreds of degrees within minutes (see Chapters 6.4, 6.5). Numerous studies have already been written about the properties of graphite in ceramics and the reasons for its use in pottery (summarised by e.g. Fusek, Spišiak 2005, 288–292; Scharrer-Liška 2007, 149–151; Kaltenberger 2009, 174; Gregerová et al. 2010, 99–100, 127–128, 131–138; Rzeźnik, Stoksik 2004, 332–335; Macků 2023, 177–202). Its properties were advantageous for all phases of the operational chain. The ability to improve the properties of the fabric for shaping and absorbing excess moisture during fabric preparation appears to be a key property within the experiments conducted here (similarly to various organic temper, see Skibo, Schiffer, Reid 1989, 136; for organic inclusions see Roux 2019, 39). The fact that the addition of graphite could cause better cohesion in the ceramic fabric is mentioned in the study of La Tène ceramics by M. Hlava (2008, 213). The graphite addition was intended to reduce the shrinkage of fabric during drying and the first phases of firing (Macků 2023, 173). However, graphite vessels from the U Skály kiln do not confirm the theory that the more thick-walled the vessel, the higher the graphite addition, since its presence should have been more desirable for thick-walled vessels precisely because of shrinkage. Storage vessels probably represent an exception, as this ability of the coarse graphite addition was likely to have been utilized in their production (cf. Macků 2023, 174). During the actual forming of the clay coils, the addition of graphite increases the ability to build a higher vessel piece without continuous drying and improves the slipperiness of the walls during forming (on slipperiness, see e.g. Rzeźnik, Stoksik 2004, 336). Given the lower quality and plasticity of fabrics used, e.g. in the area of the Bohemian-Moravian Highlands, it cannot be assumed that the graphite addition would have been necessary to minimize the cracking of vessels during drying along the clay coils (cf. Macků 2023, 175). Graphite ceramics require a specific type of firing. Graphite induces a reducing environment in the fabric up to certain temperatures and prevents oxidation; however, when it combusts, the permeability of the walls of the vessels increases (Gregerová et al. 2010, 120–121). For kiln firing, graphite was no longer an ideal inclusion, primarily in regard to the numerous oxidation phases in the initial stages of firing, when the combustion of organic and graphite components occurs, as shown by the results of the experiments carried out here (see Chapter 6.5.5; e.g. Rzeźnik, Stoksik 2004, 321–342). Graphite was intended to reduce permeability when the vessels were being used (Hlava 2008, 213). Another property of ceramics using organic tempers and probably also graphite may be better thermal conductivity and the more efficient heating of ceramics during use (Budka, D'Ercole 2022, 1–17; Hlava 2008, 214).

A certain specificity of graphite ceramics can be observed in the batch of the kiln from Jihlava – U Skály Street. The analysis of complete vessels indicates that pots made of sandy fabric were produced in larger quantities, often in series, whereas graphite-tempered pots typically occur as solitary pieces. At the same time, all three marked bottoms in the assemblage (from one production board) belonged to graphite vessels, and according to the faint imprint, the board could have already been considerably worn. However, the production technology does not differ between sandy and graphite ceramics, and it is also impossible to find a characteristic sign of shaping that would distinguish one from the other.

7.4 Formation of vessels in the 13th century and first half of the 14th century: The involvement of rotational kinetic energy in the production of ceramics from clay coils

Whole vessels from pottery kilns represent ideal material for technological analysis. On the one hand, they provide a comprehensive view of the traces left on individual parts of vessels, and on the other hand, they are vessels that were never used, and therefore

the production traces, especially from the outer part of the bottom, have not been erased. However, some of the features could have disappeared due to the overfiring of fabric as the structure or surface of the vessel broke; nevertheless, batches from pottery kilns can be considered ideal for studying the shaping technology of specific periods.

Just as in the research of the composition of ceramic fabric, the analysis of shaping cannot be done without an interdisciplinary approach, which is based on a detailed macroscopic description of traces on vessels, their verification using ethnological parallels, and experiments. The analysis is also supplemented by methods of 3D documentation and spatial analysis of vessel shape.

The basic questions within this section of the operational chain are as follows:

1. What was the technology of vessel formation in the 13th century and the first half of the 14th century based on the analysis of ceramic assemblages from kilns?
2. Is it possible to trace differences in technological procedures in different pottery workshops based on the study of traces on ceramics using macroscopic description and 3D scanning?
3. What equipment could have been used for the production of vessels from the examined kilns? Based on the archaeometric study of traces on ceramics, can we formulate a statement regarding the form of the shaping equipment used for the production of ceramics via specific procedures?

7.4.1 What was the technology of vessel formation in the 13th century and first half of the 14th century based on the analysis of ceramic assemblages from kilns?

In general, the basic features of the technology of vessel formation from prepared raw pottery material are quite well known. Construction is carried out either by manual modelling from a single piece of clay, or from slabs, by combining variations of these techniques, or by rotating clay coils at different speeds and, finally, via quick rotation while shaping from one piece of clay. In addition, shaping and surface treatments including decoration took place either on a fixed or rotating base which, in its most perfected form, was part of the potter's wheel (for a summary, see e.g. Rada 1995; 2007; Chavarria 1999; Cuomo di Caprio 2017, 116–155; Roux 2019, 54–92).

Research into the ceramics of the high medieval period in the Czech lands has long been based on the fundamental division of ceramics into two stages: wheel coiling and wheel throwing. For this, basic determining characteristics, namely the traces of dusting or trimming at the bottoms and possible visibility of clay coils on the inner walls of vessels (Nekuda, Reichertová 1968, 36–38) were used. In the case of coiling, a variant of ceramic production from clay coils using rotational kinetic energy was later defined, which M. Richter, based on the analysis of ceramics from Hradišťko near Davle, labelled 'advanced/perfect' coiling, taking inspiration from the ethnological research of traditional production in eastern and eoutheastern Europe published mainly by W. Hołubowicz (1950; 1957; 1965; Richter 1982, 97–99). Later, the term wheel coiling appeared for this technology (e.g. Procházka, Peška 2007, 173, 223). Miroslav Richter's work, however, long remained unique, especially in the depth of his analysis of the technology of shaping vessels. A more structured view began to appear only after the influence of foreign research, which utilized ethnological observations and later also experiments.

The research of pottery forming techniques has a long tradition in Poland, where the aforementioned W. Hołubowicz, based on the study of folk pottery from Belarus and Albania, called the method of building vessels using clay coils the *ślizgowo-taśmowa* technique, which can be loosely translated as the clay coil moving technique. At the same time, he emphasized that this technology is associated with the rotation of the board on which the vessel was formed and distinguished between two main types with regard to the speed of the rotational movement. This formed the basis for the theory of pottery formation in Poland in the following decades (Hołubowicz 1950, 140–141; 1965, 17–30; Kruppé 1961, 122–162; Buko 1990, 105–106). Following W. Hołubowicz, P. Rzeźnik distinguished the technique of slow coiling known as *krokowo-ślizgowa*, and rapid coiling, i.e. the *ślizgowo-taśmowa* technique. Moreover, for high medieval ceramics, he emphasized the technological features associated with the technique of strong or full coiling, especially the undulation of the inner side of the vessels' walls (Rzeźnik 1995, 44–60; 1998, especially 132, 136). The research of A. Bobrinskij, who distinguished seven stages of shaping by studying Eastern European traditional pottery, cannot be overlooked. In this research, the 6th stage probably corresponds to the use of fast rotation in completing the shaping of the coiled vessel body (Bobrinskij 1978, especially 27). More recently, he has dealt in greater detail with traces of work on the slow, whole or partially coiled

Latvian ceramics of the 11th–13th centuries, which corresponds technologically to Czech early medieval production (Gunnarssone et al. 2021). German research distinguished wheel coiled (*nachgedreht*) and thrown pottery (*gedreht*), with the latter being traditionally associated with the shaping of vessels from a single piece of clay using rapid rotation. However, as early as the 1960s, for example, U. Lobbedey noted the distinct rotational ridges on the vessels with clear traces of construction from clay coils and used the term *schnellaufend nachgedrehte Keramik*, i.e. rapid-coiled ceramics (Lobbedey 1968, 26). Generally speaking, however, little attention has been paid to shaping technology in German-language literature. The recent work of M. Rogier, as an experimenter himself, has analysed traces of work in detail and, subsequently, the terms *gedreht* a *nachgedreht*. He did not rule out traces of wheel shaping even on ceramics shaped in ways other than via clay coils, and therefore created the concept of *Wulst-Dreh-Technik* for ceramic production from clay coils without strictly defining the variations or types of this technology (Rogier 2015, 22–41). A significant contribution to current research is found in the study by V. Roux, which focused on the ceramics of older periods but is also applicable to medieval material. Valentine Roux applied a comprehensive approach to the technology of production by applying the methodology associated with the concept of *chaine opératoire*, while involving physical principles and concepts in her research of forming techniques. The key factor in her classification within the technology of vessel construction from clay coils became the degree of the application of kinetic energy in subsequent or simultaneous shaping. She divided this into four stages (Roux 2009, 197–198; 2019, especially 54–92; Roux, Courty 1998, 748–749). In Czech scholarly literature, production technology long lacked the degree of attention that was given to the cited work of M. Richter. This situation changed only in the mid-21st century, when newer, especially Anglo-Saxon works and especially part of V. Roux's work dedicated to the shaping of vessels was reflected in a useful summary by L. Běhounková (2018). At the same time, K. Těsnohlídková began to systematically study the entire production chain in an interdisciplinary manner (e.g. Doležalová 2015; Těsnohlídková et al. 2017; Čapek et al. 2018; Těsnohlídková 2021; Těsnohlídková, Slavíček 2021). This has primarily led to a deeper understanding of the possibilities of shaping technology via clay coils and a significant deepening of the study of the traces of pottery work.

The ceramics from the stoking pit of kiln 11 from Staré Město stand out in terms of the studied assemblages. The vessel bodies built from clay coils were probably made on a hand-thrown base, with kinetic energy only being applied in the neck and rim area, where horizontal papillary rings are visible (method 3 according to A. Bobrinskij, or possibly 2 according to V. Roux, Courty 1998, 752–753; 2019, 84, 188; cf. Richter 1982, 97–98; Čapek et al. 2018, 98–10; Běhounková 2018, 18–20). The uneven walls without any traces of shaping during turning are typical; sometimes imperfect attempts at smoothing the joints of the clay coils are evident at the bottom (see Chapter 4.6). Exceptionally, more pronounced irregular traces of imperfect surface levelling in a roughly horizontal direction were recorded above the base. The ceramic section of two samples used for archaeometric analysis showed a striking orientation of grains and pores copying the original clay coil. The bottoms are smooth or show impressions of fine dusting. Uneven, relatively thick walls (minimally 6–7 mm) are typical. This therefore involves a technology that was known centuries before the activity of the kiln in question, and its manifestations differ more or less only in detail (in detail, see Rzeźnik 1995, 39–60; 1998). The technique was obviously applied, for example, in the traditional component of the ceramic assemblage from Hradišťko-Sekanka, in the assemblage from the ceramic kiln from Tisová – 'Staré Mýto', and elsewhere (Richter 1982, 97–98; 1994, 147; Čapek et al. 2018, 98–105). Similar to the aforementioned sites, this technique survived in the settlement context of Staré Město near Uherské Hradiště for some time alongside more advanced production, roughly corresponding to the batch of kiln III/98 (Procházka 1984, 436–439; Procházka et al. 2024, 143).

The evidence of the forming technology on ceramic vessels from other examined kilns has shared characteristic features, which prove that in all cases these are vessels produced using clay coils with the involvement of rotational kinetic energy, which is referred to as the wheel coiling method. These are bases with dusting on their surface and around their circumference with traces of attachment to / removal (via pulling off, trimming) from the base. The boundary between the dusted centre and the rim is such that it sometimes creates the effect of a seemingly inserted base. Above the base, in a number of cases, there is a remnant of a first, thicker clay coil in the form of a rounded wall reinforcement. Marks on the bases occur in some kilns, although rather

sporadically; this is found in Jihlava – U Skály and Křížová streets, in Mstěnice, and in Staré Město – 'Na Kostelíku'. There is always one motif in each site. This probably demonstrates the presence of one marked base in each of these workshops. In the kiln in Jihlava – U Skály Street, the markings occur on graphite vessels.

Another set of characteristic features is found primarily on the inner walls of the vessel bodies. These can be further divided into localized (occurring in a specific area) and widespread (present across the entire surface) traces. Some of these features document the presence of clay coils in the walls of the vessels, while others indicate the involvement of rapid rotation. Widespread evidence of clay coils in the form of their incomplete incorporation into the walls is manifested by unevenness of the wall or dents at their joints. Analyses of entire vessels at all sites show that evidence of clay coils occurs most frequently above the bottom, in the lower third of the vessel, further under the neck (between the neck and the maximum bulge) and then, in flask-shaped forms, between the maximum bulge and the neck, as previously noted by, e.g. M. Richter (1982, 98).

Traces of the use of rapid rotation are mostly widespread. These include grooves left by the papillary lines of the fingers or traces of a tool used to smooth the wall during the application of rapid rotation. These traces are most visible on the inner sides of the necks. In the bodies of the vessels, the intensity of rotation is documented by the undulation of the walls, be it in grooves that are even more strongly related to the presence of clay coils in the walls or ridges that originate from the application of rotational kinetic energy. Undulation may vary in regularity or shape in connection to the frequency of rotation and its inconsistency. These marks are more pronounced in the lower parts of the vessels and sometimes in the area below the neck. However, we can also encounter walls that are essentially smooth without undulation, which probably resulted from the effect of long uninterrupted rotation. These traces are more frequent on vessels from the second half of the 14th century.

In addition to the chosen technology and experience or intention of the potter, the appearance of the traces is also related to the ceramic fabric used, as shown by the experiments carried out regarding shaping. In the case of natural brick-making clays from the Bohemian-Moravian Highlands, the traces of shaping manifested themselves in a form slightly different from the one in the case of natural or industrially processed kaolin fabrics. Similarly, we observe that the marks on ceramics from individual kilns also differ slightly from each other, especially in the prominence of the undulation from the inner side of the vessels' walls. The same applies to the marks on the vessels from the ceramic hoard from Staré Město (feature 62). Most different are the ceramics from St. Pölten, where the ceramics were made from more plastic kaolin clays, which probably influenced the appearance of these marks.

The shaping technique and its traces were documented on experimentally produced vessels, where vessels were made from different types of natural clays (see Chapter 6.1.4) based on ethnologically documented production methods and using clay coils by means of wheel coiling. The macroscopic traces on the inner walls of the vessels and on the bottoms correspond to archaeological ceramics. The results of the experiments also demonstrate that wall thickness (and probably the uniformity thereof) is not likely to be a factor that could distinguish between ceramics made via clay coils and ceramics thrown from a single piece of material. In this regard, wheel coiling technology can achieve parameters that are almost identical to throwing with minimums of around 3–4 mm (cf. Gunnarssone et al. 2021). These facts are probably more related to the quality of the ceramic fabric, e.g. in our experiments with local low-quality clays from the Bohemian-Moravian Highlands, we continually failed to achieve a more significant degree of thin-walledness, which, however, some vessels from the batches of kilns in the region visibly demonstrate. Even in the production of vessels from a single piece, throwing while using coarser clays may create a significant undulation of the inner wall (Rogier 2015, 35–38, 46), which was often considered in the past as evidence of coils. The reason for the presence of the undulations could also be practical, i.e. if they were intended to prevent the shape from collapsing after its completion. These so-called ridges usually have rounder transitions than the grooves caused by clay coils. They are also usually denser, finer and more regular. Sometimes rotational ridges may be left intentionally; at other times, they are intentionally smoothed out and traces of them are absent. Smoothing out traces is easier with fine clays at high rotation speeds.

In recent years, discussions pointing to the possibility of producing dusted vessels from a single piece of fabric via throwing (Bernhardt 2011, 67–75; Běhounková 2018) have become increasingly common. In the assemblages we examined, this technique was not documented.

The only vessels that may differ in their technology in terms of kilns are bell-shaped and conical lids. On some, especially from the kilns in Jihlava – U Skály Street, traces of fabric pulling during slow rotation are visible, and therefore they may have been made from one piece of fabric and then finished.

7.4.2 Is it possible to trace differences in technological procedures in different pottery workshops based on the study of traces on ceramics using macroscopic description and 3D scanning?

Mostly thanks to vessels that have been preserved entirely intact, the study of kiln batches allowed us to observe the specificities of individual workshops in terms of forming technology and thus partial differences in technology across sites. The level of the advancement of these techniques may be related to the forming equipment used, but primarily to the social environment, the degree of the craft's professionalization, or the dating of the workshop (e.g. Roux, Courty 1998, 750).

The production process for the wheel coiling technique may vary, primarily according to the part of it that is involved in rotational kinetic energy. The classification scheme for the variations of the wheel coiling technique in this work was inspired by V. Roux's classification and based on the specificities of medieval ceramics, ethnological parallels, and experiments. Her typology distinguishes in which phase of production rotational kinetic energy is applied; in method 1 it is only used to smooth the walls; in method 2 to thin them; method 3 already uses rotational kinetic energy to join the clay coils; and method 4 already uses this energy during the process of their winding (Roux, Courty 1998, 748–750; Roux 2009, 197–198).

The analysis of individual assemblages in comparison with the results of experiments allowed us to distinguish five variants of wheel coiling (hereinafter WC; Tab. 46, Fig. 190). Within the groups used by V. Roux, we encounter the application of all four stages here. The use of the first three stages is linked to the bodies of vessels, whereas the 4th stage, in which rotational kinetic energy is already used when the clay coils are being wound, was probably applied in closing the neck and during rim formation, when the clay coils were laid down one by one and then smoothed with the involvement of rotation. Some assemblages may contain vessels corresponding to one lower or, conversely, one higher stage, which is most visible in the kiln from Jihlava – U Skály Street. However, the majority of production always belongs to one group. All four variants share common features on the bottoms, i.e. dusting across the bottom or around the circumference after attachment or, conversely, after cutting off or removal from the table of the rotational device, since all of these variations require the bottom to be firmly attached to the production equipment. Furthermore, there are also shared features on the neck and rim, which are always formed with the involvement of rotational kinetic energy.

For the purpose of specifying the technological procedure of wheel coiling, several macroscopic features, their form, position on the vessel, or frequency of occurrence are of fundamental importance. Features occurring on the surface include grooves and ridges, which often occur on most of the area of the inner body of the vessel. A uniform, smooth surface may occur in part or occasionally throughout the whole vessel, and its presence is influenced by the potter's intention. The presence of grooves or ridges is not entirely intentional and is a result of fluctuations in the pressure of the fingers on the wall of the vessel that is being formed during rotation; this is especially evident in stiffer, tempered material. Grooves are visible in irregular decreases in wall thickness – linear grooves between coils, which appear as an unevenness in wall thickness, are relatively sharply delineated and occur cyclically according to the thickness of the clay coils. In contrast, the grooves alternating with raised ridges are formed by the pressure of the fingers during rotation. The transition between them is rounded and, like grooves, they can vary in terms of how pronounced they are. Both features can also blend together. Other significant features include local traces of the clay coils in the form of vacuoles (small cavities that formed when the joints between the clay coils were filled in – these are clearly delineated, usually deep, and occur cyclically at certain intervals), lines (joints between the clay coils in the form of thin incisions or pressure lines in places where coils were not completely stuck to one another), and dents (indentations made by the fingers at the joints of the clay coils). Fast rotation in local features is evidenced primarily by grooves left by the fingers or a tool, or incisions made by shifting temper grains (in detail see Těsnohlídková 2022a, 94–99).

The assemblage from kiln 11 from Staré Město – 'Na Kostelíku' still bears features of predominantly classical coiling and was classified as a certain preliminary phase of the wheel coiling technique – WC 0.

Wheel coiling technique and its kiln batch representation	Characteristics of the procedure for forming the body of a vessel	Inner wall of the vessel body (characteristic features)	Minimum requirements for forming equipment
WC 0 **Staré Město – 'Na Kostelíku'**	The vessel body was built using coils without the involvement of rotational kinetic energy (RKE); only basic rotation was employed. RKE was used only to a minimal extent for smoothing the walls, and more noticeably for smoothing the neck and rim.	Numerous local coil traces. Grooves/depressions (often uneven and not across the entire surface). Traces of wall thinning by pressing, mainly from the base to the maximum bulge.	Turntable with the ability of basic rotation.
WC 1 **Žďár nad Sázavou – 'Staré Město'**	The vessel body was built from coils. RKE was used to smooth the walls, predominantly from the exterior, and to remove coil traces on the interior surface. RKE was also employed for coarse centering of the shape by applying pressure to the exterior walls, allowing it to be further used in forming the neck and rim.	Local coil traces. Grooves/depressions (often uneven and not across the entire surface), partially smoothed, mainly in the upper half, and may appear as rings. Traces of wall thinning by pressing, mainly from the base to the maximum bulge.	Turntable with the ability of short rotation.
WC 2 **Mstěnice** **Staré Město – 'Na Dvorku'**	The body is built from coils. RKE is used to thin the walls, mainly in the upper part of the vessel body, to smooth them from the outside, and to erase coil marks on the inside. A higher degree of RKE involvement is applied already during the body formation to help roughly center the shape, enabling its use during the forming of the neck and rim.	Local evidence of coils in the lower part of the vessel. Grooves/depressions across the entire body, sometimes fading upwards (occasionally uneven). Moderate grooves or ridges may appear on the shoulders.	Turntable with the ability of advanced rotation or light kick wheel.
WC 3 **Jihlava – U Skály Street** **Jihlava – Křížová Street**	The vessel body was built from coils. RKE was used to thin the walls across the entire body, to smooth the exterior surface, and to remove coil traces. In the upper parts of the vessel, the coils may be fully integrated, and partial redistribution of clay within the wall may occur. At this stage, the use of RKE is already sufficiently effective for the vessel body to be properly centered.	Local evidence of coils in the lower part of the vessel – infrequent. Grooves/depressions or ridges – from the base to the maximum bulge if the wall is undulated. On the shoulders, wall undulations may sometimes diminish, or they may appear as moderate grooves or ridges. The wall may be even or have traces of papillary finger lines or a wooden tool and be relatively thin, similar to thrown pottery – infrequent (related to the clay used).	Turntable with ability of advanced rotation or light kick wheel.
WC 4 **Kostelec near Jihlava** **Staré Město – ceramic hoard** **St. Pölten**	The vessel body was built from coils.RKE is applied to such an extent that clay is redistributed within the walls; after complete or nearly complete integration of the coils, the vessel's shape can be modified using RKE (e.g., producing a more pronounced bulge). The vessel is perfectly centered, comparable to a wheel-thrown pot.	Ridges – pronounced or only slight undulations across the entire body, sometimes fading into a smooth wall upwards. Moderate grooves may appear in the lower part. Local traces of coils above the base are rare. The wall may be even and smooth or have traces of papillary finger lines or a wooden tool and can be relatively thin (related to the clay used). Compressive twisting of the clay – rather infrequent and dependent on the type of clay (more common with fine clay).	A flywheel-powered (block crossbar) kick wheel with a heavy top plate capable of regular and prolonged rotation, but the use of an older type of construction with improved rotational properties also comes into consideration.

All the techniques share the necessity of firmly attaching the base, at least along its perimeter.

The coils are not 'laid' on top of one another; instead, their clay is pressed into the upper part of the inner wall. On the outer side of the wall, the trace of coil attachment may not even be visible

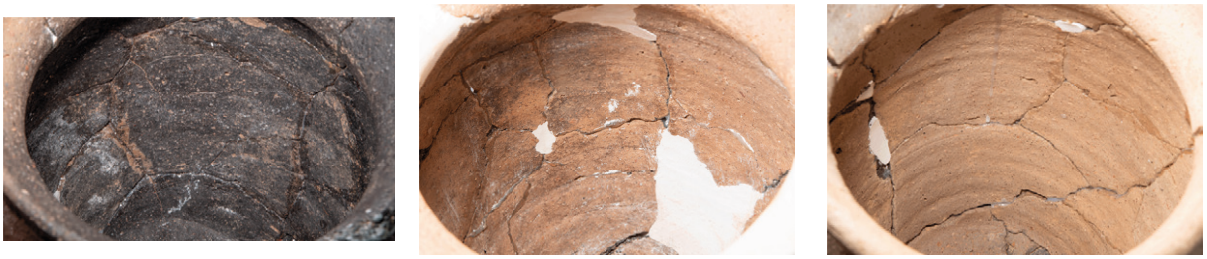
All variants share technique of forming the upper part of the vessel – the neck and rim. These parts are shaped using rotational kinetic energy, with individual coils possibly being gradually worked in. Characteristic traces occuring here are traces after tools or fingers. Significant is usual wall regularity. A shared feature is the forming technique used in the upper part of the vessel – the neck and rim. These parts are shaped using rotational kinetic energy, with individual coils potentially being integrated progressively. Characteristic traces occur here: tool- or finger-made grooves, and the wall in these parts of the vessel is usually regular and even, often relatively thin-walled and thinner than the vessel body. The wall is usually regular and even, often relatively thin-walled – more so than the body of the vessel.

Tab. 46. Variants of the wheel coiling technique identified in the studied assemblages from pottery kilns – basic characteristics, macroscopic traces, and the assumed suitable forming devices.

WC 0



WC 1



WC 2



WC 3



WC 4



Fig. 190. Inner vessel walls with characteristic traces of the individual variants of the wheel coiling technique. Photo by K. Těsnohlídková, R. Procházka.

It is characterized by a vessel body built from clay coils joined while using only slow rotation or none at all. The walls are thus uneven and bear no sign of rotation. Occasionally in their lower section, imperfect levelling of the surface in the horizontal direction was recorded.

The assemblage from the kiln in Žďár nad Sázavou in 'Staré Město' was designated as the lowest variations – WC 1. These vessels are characterized by the low involvement of rapid rotation on the bodies of vessels; traces of rotation are sometimes completely absent in the lower areas of the vessels. Rotational kinetic energy was used primarily to smooth the walls and traces of clay coils and to centre the shape approximately by pressing on its walls in order to allow for the more effective use of rotation in forming the neck and rim of the vessels. Sometimes the walls of the vessel body were thinned by squeezing during slow rotation.

The WC 2 technique was identified in material from two sites, namely from the kilns in Mstěnice and Staré Město –'Na Dvorku'. Traces of clay coils are still quite visible in the lower parts of the bodies of vessels in this variant, but a stronger involvement of rotational kinetic energy is now visible here, which was more effectively used primarily in the upper parts of the bodies to thin the walls.

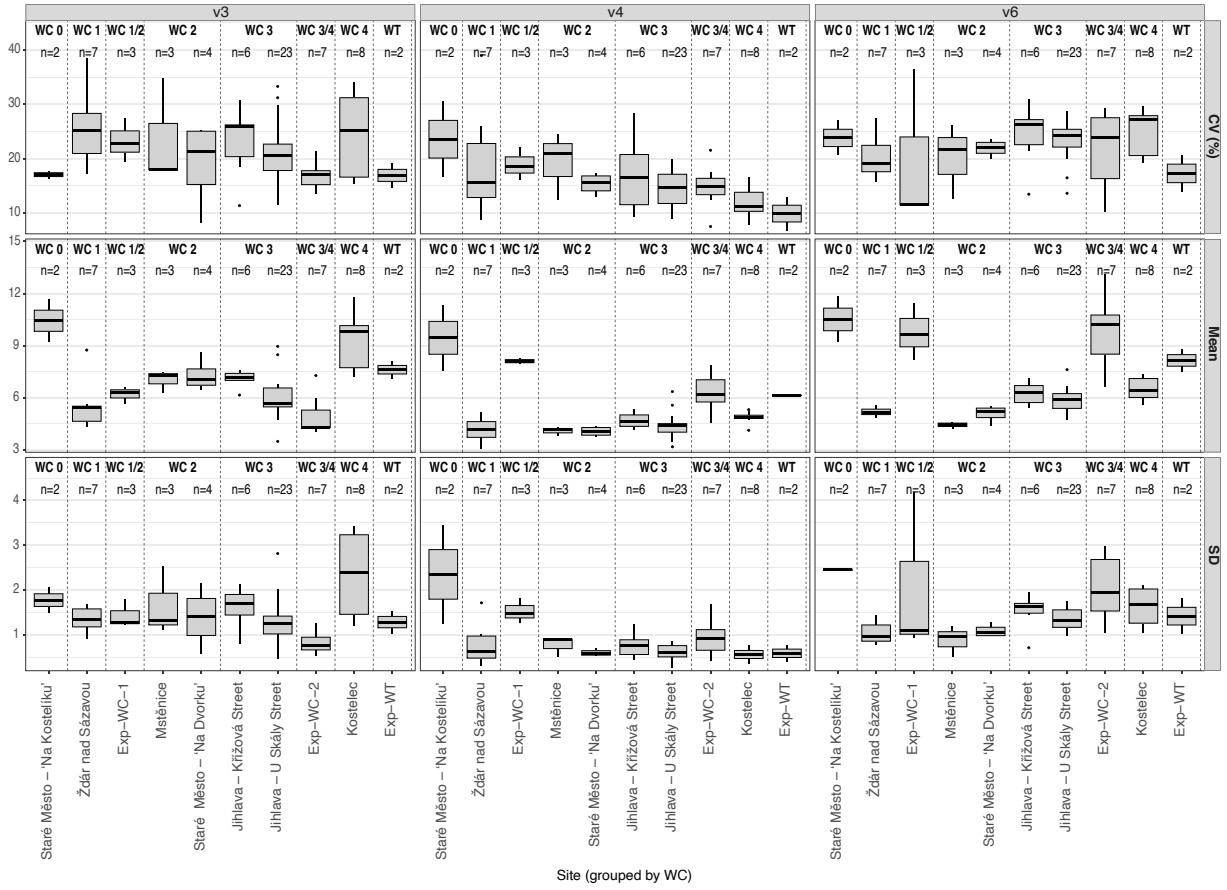
Despite certain differences in the occurrence of technological features, both kilns from Jihlava, i.e. U Skály and Křížová streets, were included in the WC 3 variant. In this variation of advanced wheel coiling, rotational kinetic energy is now involved throughout the entire body of the vessel. Starting from the lower part of the bottom, it was used to thin the walls and erase the traces of clay coils. Rotation is used so effectively that there may now be a partial shift of the fabric of individual clay coils in the walls of the vessels. However, we acknowledge that the traces left from rotation may not be completely uniform.

The most advanced techniques – WC 4 – were achieved by potters firing ceramics in kilns in Kostelec and St. Pölten. Traces of this are also found on vessels from the ceramics hoard from Staré Město. In terms of the kiln from Kostelec, we can note – based on the morphological properties of the vessels – that it is the most recent ceramic assemblage, probably dating to the second half of the 14th century. WC 4 now represents a technique that requires rotation properties that are akin to thrown goods. Rotational kinetic energy is used uniformly throughout the body, and a shift of the fabric of the individual clay coils takes place in the walls. The vessel can be perfectly centred. Traces of the clay coils occasionally remain preserved in the lower parts of the bodies or under the neck.

Complementary analytical approaches were used to study the technology of forming ceramic vessels, including 3D imaging methods for measuring wall thickness and axial symmetry, as well as microscopic analysis of particle orientation and pores in the ceramic body. Various scanning technologies for the creation of 3D models (e.g. laser scanning or photogrammetry) serve as effective tools for determining the original methods of ceramic vessel shaping (Mara, Sablatnig 2006; Revello Lami, Opgenhaffen, Kisjes 2016). The possibilities of identifying production techniques have also been examined via analysis of the scanned surface (Scaro 2022, Wilczek et al. 2022) or a combination of studying the topography of the surface and measuring the thickness of the walls while applying archaeological experimentation (Thér, Wilczek 2022). Within our research, 3D analysis showed some variability within individual sites. However, these results need to be compared with the entire examined assemblage, including experimentally produced vessels. Two variables were monitored within the 3D analysis – wall thickness (WT) and axial symmetry (Y) – in three horizontal sections of the vessel: from bottom to maximum bulge (v6), from maximum bulge to neck (v4), and from neck to the mouth of the rim (v3).

Wall thickness

The absolute value of wall thickness depends primarily on the overall size of the vessel, and therefore it does not in itself provide new insights into categorizing individual stages of shaping (WC). However, it is significant in terms of assessing how large vessels could be produced with a given technology. Indicators of standard deviation (SD, the statistical measure of absolute variability of data around the mean, listed in mm) and coefficient of variation (CV, a normalized measure of variability expressed as the ratio of standard deviation to mean, listed in %) provide higher informative value. The lower part of the vessel shows that as the shaping technique becomes more advanced (higher level of WC), the percentage values of CV increase, i.e. the variability of wall thickness increases (Graph 43). Experimental vessels made by combining WC 1/2 show a significantly higher average thickness and at the same time a high variance of values, similar to vessels made by combining WC 3/4. Wheel-thrown

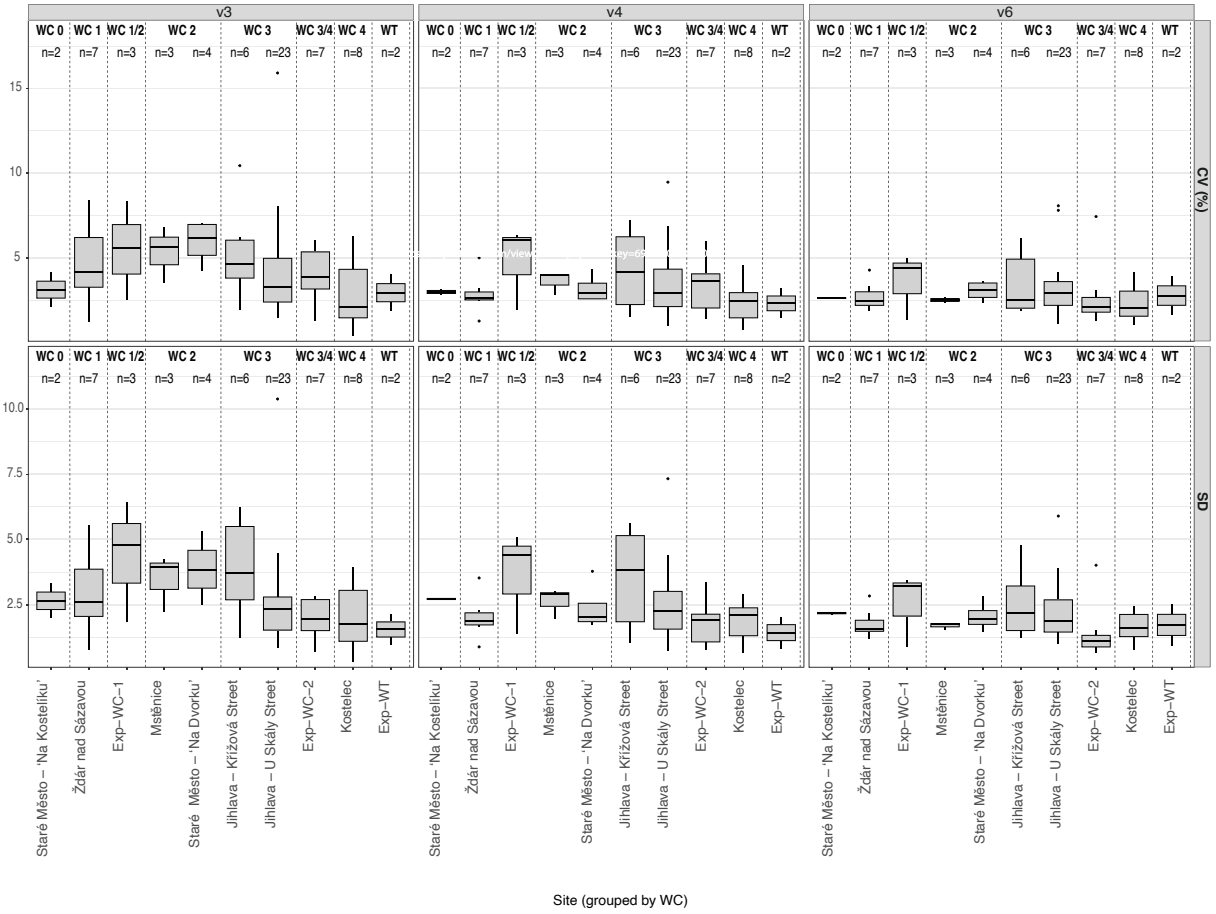


Graph 43. Variability of wall thickness (WT) across sites and wheel-coiling stages (WC). WC 0–4 represent successive stages in the development of the wheel-coiling technique. Rows show the mean WT, the coefficient of variation (CV%) and standard deviation (SD) for individual sites (including experimental vessels) and vessel parts (v6 – bottom to maximum bulge; v4 – maximum bulge to neck; v3 – neck to rim). Author K. Slavíček.

vessels, on the other hand, achieve a significantly lower CV. In terms of the examined medieval vessels, the spread of values is consistent, which suggests that potters, regardless of the combination of the shaping techniques that were used, put care into creating a relatively uniform wall thickness even in the lower parts. The higher variance of experimental pieces can be attributed primarily to the producer's lack of experience. An interesting trend is evident in the middle part of the vessels between the maximum bulge and the neck. CV values increase from WC 1 to WC 2, then begin to decrease. From WC 3 onwards, the individual coils in the upper parts of the vessel are usually fully incorporated. At this technological stage, partial shifting of paste within the wall can occur. Rotational energy is used to such an extent that the walls thin out in the upper parts of the vessel. In this vessel part, the results of experimental and archaeological vessels coincide. In the upper part, i.e. between the neck and rim, no significant trends can be observed, with the exception of a decrease in SD from WC 3. However, these values are listed in millimetres and are thus influenced by the overall size of the vessel. Moreover, the type of rim itself also influences the result here. Therefore, the most interesting finding is the significantly high variance of wall thickness in the rims of vessels from Kostelec.

Axial symmetry

Several interesting trends can be observed in the development of axial symmetry as the degree of wheel coiling increases (Graph 44). In the lower part of the vessel (v6), the values are low for all sites; only a slightly increased variance was observed in the Jihlava kilns (WC 3 level). In the area between the maximum bulge and the neck, vessels with WC 1 and WC 2 levels show low values and low variance (both CV and SD). On the other hand, higher values accompanied by high variance appear in WC 3. However, this trend gradually decreases as levels advance. This can be explained by the higher degree of rotational engagement in



Graph 44. Variability of distance from the rotational axis (Y) across sites and wheel-coiling stages (WC). WC 0–4 represent successive stages in the development of the wheel-coiling technique. Rows show the coefficient of variation (CV%) and standard deviation (SD) of Y values for individual sites (including experimental vessels) and vessel parts (v6 – bottom to maximum bulge; v4 – maximum bulge to neck; v3 – neck to rim). Author K. Slavíček.

this part of the vessel, which was not fast enough; in combination with the plasticity of the clay, it led to increased axial asymmetry. Moreover, the higher asymmetry of the experimental pieces is a result of the experience and motor skills of their manufacturer (Thér, Toms 2021). In the upper part of the vessels, between the neck and rim, there is a generally increasing trend in axial symmetry with an increasing degree of WC, which corresponds to a higher degree of the use of rotation for shaping.

Particle orientation

The analysis of particle and pore orientation on experimentally produced vessels shows that it is possible to record certain diagnostic features. The most striking difference between wheel coiling and wheel throwing is the presence of a third preferred direction in cross-sections that are perpendicular to the part above the bottom and in tangential cross-sections at the maximum bulge, which was manifested in the wheel coiling technique. This demonstrates that different methods of engaging rotational energy are reflected in specific patterns of ceramic fabric arrangement. This conclusion corresponds to the findings that the orientation of inclusions and pores is one of the most reliable signs of the transfer of physical forces during the formation of a vessel (Hanykýř, Maryška, Brůček 2002, 52; Thér 2015; 2020; Thér, Toms 2021). At the same time, this confirms that the differences are most easily detected in the lower and middle parts of the vessel profile, as previously shown by experimental series focused on the variability of wheel-thrown vessels (Thér, Toms 2016).

The next step in research should be to expand the experiments to include the production of vessels according to the individual stages of the wheel coiling technique and a subsequent analysis of particle and pore orientation. Our results confirmed the applicability of thin sections; however, verification

is needed in terms of whether this procedure can reliably distinguish individual phases of wheel coiling or whether it will be necessary to use other methods, for example μCT. If the hypothesis regarding the manifestations of the individual stages of wheel coiling on the orientation of components of ceramic fabric is confirmed, it will be possible to apply this approach to archaeological material as well.

7.4.3 What equipment could have been used for the production of vessels from the examined kilns? Can we, based on the archaeometric study of traces on ceramics, formulate a statement regarding the form of the shaping equipment used for the production of ceramics via specific procedures?

The final point of the analysis of vessel forming technique should be to determine the equipment with which this pottery was produced. Whether this is possible is questionable. We do not have a direct connection from the medieval period between forming equipment and vessels that were produced, and therefore we can only work with iconographic depictions, ethnological parallels and, last but not least, experimentation.

The greatest amount of information concerning the shape of potter's wheels or turntables in the Middle Ages is provided by iconography. The oldest depictions of potters can be dated to the 13th century and come from the Western European environment. They involve turntables or spoked-type kick wheels. In the Central European environment, the depiction of a turntable on the western triforium of the cathedral in Gurk in Carinthia from the 13th century is of considerable significance, as is as the depiction of a light crossbar wheel in the *Corcodanitiae caritatis* manuscript from around 1355, the author of which was the abbot of the Lower Austrian monastery Lilienfeld, as well as the depiction of a wheel of the same type operated by a female potter on a playing card made as part of a set for King Ladislaus the Posthumous around 1455. From the Czech lands, it is worth highlighting the depiction of a similar device on a tile from Lichnice Castle from the second half of the 15th century. A block wheel with a robust top board, significantly increasing the inertia of the device, appears on the ceramic signboard belonging to Prague potters and stove makers from the second half of the 16th century. One of the early depictions of the so-called kick wheel, now without crossbars and with a robust bottom table, is a depiction in the work of Italian majolica specialist C. Picolpasso from 1556–1559. However, as early as in the codex of B. Behem from Wrocław, probably from 1506, we find a picture of a potter presumably still with a crossbar wheel, but with a robust bottom table. Whether this is a stylization or indeed the last phase of the development of the crossbar wheel, which was applied only in some places, remains a question (Picolpasso /I/, 1879, tav. 6, fig. 21–25; Husa, Petráň, Šubrtová 1967, 99–101; Kaltenberger 2009a, 310–322; Rogier 2015, 13–22; Čapek et al. 2018, 44–47; Macků 2018, 266–270; Těsnohlídková 2021, 21; Čapek, Těsnohlídková, Slavíček 2022, 44–50).

A large amount of information can also be drawn from ethnological sources; those most akin to the Czech environment are from Eastern, Southeastern, and Southern Europe. It is here that the parallels point to the fact that seemingly similar devices can achieve different qualities of rotation based on the construction details that were used. (Hołubowicz 1950; 1965; Scheufler 1968; Bobrinskij 1978; Buko 1990, 109; Drabina 1998, 53; Kaltenberger 2009a, 189–199, 310–322; Djordjević 2011). V. Roux also draws information from these sources and distinguishes turntables (so-called tournettes) and potter's wheels precisely according to their rotation abilities. He sets the limit at 80 rpm – below this speed, he applies the term *tournette* (Roux 2009, 198).

Based on the analysis of the forming technique, we are able to determine the efficiency of rotation needed for this technique better than we can determine the exact appearance of the forming device. Then, while taking ethnological parallels and experiments into account, the most probable forming device can be chosen. However, it is always necessary to take into account that the exact design solution could have been different, or that less efficient production on a more perfected type of device cannot be ruled out.

Early medieval ceramics from the 11th–12th centuries in the Czech environment were allegedly produced on various turntables, primarily by using clay coils or by drawing out the walls or the paddle-and-anvil technique (Čapek et al. 2018, 33–48). During the 13th century, however, ceramics produced with various wheel coiling techniques appeared, now with higher demands on the rotational abilities of the production equipment. It now required the involvement of a turntable or kick wheel, which can maintain consistent rotation for at least a short time, allowing the potter to use rotational kinetic energy in parts of the formation process and also involve both hands simultaneously.

The advent of these devices represents a major change in medieval pottery and is often associated with the high medieval transformation of society in the Czech lands. The culmination of this process was allegedly the adaptation of a light form of a fly-wheel powered/crossbar potter's wheel powered by foot. The advent of the fast-rotating potter's wheel is traditionally dated in the Czech environment to the period of the 13th and 14th centuries. Wheel-thrown pottery from a single piece of clay (i.e. wheel throwing) is thought to have appeared more frequently in the 15th century, first in the urban environment, and became prevalent in the second half of the 15th century (Čapek, Těsnohlídková, Slavíček 2022, 44–50; Rogier 2015, 60–69; Kaltenberger 2009a, 189–199).

The advent of the block fly-wheel powered/crossbar wheel with a robust table top did not necessarily or automatically mark the transition to thrown production. The adaptation of such a device and the advent of throwing technology likely proceeded gradually, since in some areas it probably also required a change in resources or a more significant modification of the fabric that was used. These areas probably included the Bohemian-Moravian Highlands. Ethnographic parallels from less urbanized and rather peripheral areas point to possible reasons for the long retention of coiling-roll production techniques, or the parallel occurrence of this technique together with throwing in one region. The reason was not lack of knowledge, insufficient ability, or the unwillingness of the original potters to adapt to a newer technology. The retention of technology may be related to the properties of the available clay, which was unsuitable for throwing, and the demand for vessels made of a specific material, which may have more advantageous properties, e.g. for cooking in a fire. Another reason may be the preservation of tradition (Djordjević 2011, 47–48; Rogier 2015, 72–78). Incidentally, the block wheel appears only in the 16th century, while the transition to throwing technology, for example in the Czech lands, began a century earlier (Scheufler 1972, 68).

The vessels found in the processed pottery kilns from the 13th and 14th centuries were made using the wheel coiling technique, which involved several different procedures, specifically in relation to the purpose for which the rapid rotation was used, whether it was only for smoothing the walls and erasing the marks from the clay coils, or for thinning the walls to the point of repositioning the fabric of the individual clay coils within the walls, which could reduce the risk of the walls cracking along the clay coils during drying or in the early stages of firing. The analysis carried out within this book allows for the determination of likely devices for individual techniques (Tab. 46, Fig. 190).

The WC 0 technique, represented in this book by the kilns in Staré Město – 'Na Kostelíku', does not yet involve any rotational kinetic energy or only a minimum thereof, and rather utilizes only basic rotation and turning of the plate by hand; thus, an ordinary turntable was sufficient for production. The WC 1 technique, predominant in the vessels in Žďár nad Sázavou – 'Staré Město', which also has very low demands on rotation, probably used various types of turntables with the ability of short rotation for the production of vessels, or the application of this rotation was too demanding for the potter, and therefore it was applied more only in the upper parts of the vessels, primarily in the production of the neck and rim. The WC 2 technique, represented by vessels from kilns in Mstěnice and Staré Město – 'Na Dvorku', now uses rotational kinetic energy more for working on the walls of vessels, so a device that allowed for more efficient rotation was necessary. This may have involved variations of turntables or light kick wheels.

Even with the WC 3 technique, which is predominant on vessels from both kilns in Jihlava (in U Skály and Křížová streets) and now uses rotation more for the lower parts of vessels, it is evident from the shape of the undulation walls that rotation was often not completely uniform. This suggests the still limited ability of rotational kinetic energy compared to what a fly-wheel powered (block crossbar) kick wheel with a heavy plate offers. For this technique, the most likely devices are thus turntables with the ability of advanced rotation or a light kick wheel.

The WC 4 technique observed on vessels from kilns in Kostelec, St. Pölten, and on vessels from the ceramic hoard from Staré Město is technologically and probably also chronologically the most recent, and its requirements are already close to the production of wheel-thrown pottery. The production of such pottery could now have taken place on a fly-wheel powered (block crossbar) kick wheel with a heavy top plate capable of regular and longer rotation, but the use of an older type of construction with improved rotational capabilities cannot be ruled out.

7.5 Ceramic kilns – their emergence and use in terms of construction and ceramic properties

The emergence of pottery kilns represented a fundamental technological change in the firing of ceramics in the High Middle Ages. Pottery kilns are also registered in earlier periods, but the number of finds dateable to the 13th century is significantly higher (Procházka 2015, 215–224; Čapek, Preusz 2019, 313–355). In the same period, finds of pottery kilns began to concentrate in areas north of the Danube and east of the Rhine (Weiser 2003; Vágner 2002; 2007; Kaltenberger 2009a, 250–261). The emergence of kilns was associated with the establishment of pottery as a specialized professional craft during the 13th and 14th centuries. Until then, the firing of ceramics did not likely require advanced pyrotechnological devices. Simpler devices that were used are not archaeologically detectable. Pottery kilns should also be associated with another change that is observable in ceramics, specifically the emergence of fired goods of a higher quality. In areas with a tradition of reducing firing ceramics, including the Bohemian-Moravian Highlands, this involves the technology of smoking ceramics.

Kiln finds and especially kiln designs have received considerable attention in the Czech lands. The first summary of the issue was published in the 1960s (Nekuda 1963). Additional updated reviews in the 1990s and especially in the last decade attest to a renewed interest in the subject (Zatloukal 1998; 2000a; Procházka 2015; Čapek, Preusz 2019; Čapek, Těsnohlídková, Slavíček 2022, 60–70). František Kalesný (1993) has also summarized findings from Slovakia.

Comprehensive summaries usually including inventories of sites have been published for a number of areas in Western, Central and Southeastern Europe. These works often focus primarily on the typology of kiln constructions. Less attention is paid to pottery finds, and they are often used only as a means of dating. In terms of the German-speaking environment, the most significant work has been carried out by A. Heege (2007); the monographs by B. Weiser (2003), A. Kaltenberger (2009a, 95–96), and Scharrer-Liška (2000; 2015) can also be mentioned. Similar works are known from England (Musty 1974; McCarthy, Brooks 1988, 40–54). In addition to the systematic study by F. Thullier (2015), France has also produced a number of summaries, albeit only regional (e.g. Châtelet 2006; Mouny 2013). Poland (Kwapieniowa, Walowy 1969, 205–289), Southeastern and Eastern Europe have also produced comprehensive, although older, works (Vágner 2007, 309–341; 2005, 83–101; Duma 1980, 53–84; Bobrinskij 1991, 69–134).

In the context of the issue of kilns and ceramic firing, the following three questions are discussed:

Question 1: What was the technology and strategy of firing in the 13th and 14th centuries? What information does the pottery found in the kilns carry, what analogies does experimental archaeology provide, and how can the analysis of ceramic material from the kilns be utilized?

Question 2: Is it possible to reconstruct the former appearance of kilns? Can they be typologically classified on the basis of their relics? How can the experimental reconstruction of firing devices help address these questions

Question 3: How should finds of complete vessels in kilns be interpreted? The problem of primary deposition versus production waste.

7.5.1 What was the technology and strategy of firing in the 13th and 14th centuries? What information does the pottery found in the kilns carry, what analogies does experimental archaeology provide, and how can the analysis of ceramic material from the kilns be utilized?

The 13th-century pottery settlement of the Bohemian-Moravian Highlands and Staré Město shows a clear predominance of one type of firing. Macroscopically, this type of firing manifests as full-reduction fired fabric with black to dark grey colouration, which may be due to the content of graphite or organic carbon. The surface of the fragments is often light in colour, ranging from beige to orange or bright red. Pronounced oxidation only on the surface also appears often, sometimes at random or on one part of the vessel. In other cases, this layer of oxidation is more pronounced, and only a black core is left in the fired fabric, which is caused by an insufficient amount of O_2 for the combustion of the organic fabric (Maritan et al. 2006; Laita, Bauluz 2018). Part of the pottery can be described as having a mixed atmosphere. Fully oxidised pottery is represented here only in rare cases. Firing producing a pronounced oxidised surface occurring in the final phase of firing pottery at some sites significantly predominates over full reduction, e.g. in Žďár nad Sázavou – 'Staré Město'. The analysis of local pottery has clearly demonstrated this to be a feature that occurred during firing (Těsnohlídková 2021, 228–232; 2022a, 72–74). The surface of the pottery

from the later kiln III/98 from Staré Město near Uherské Hradiště appears to be predominantly but not exclusively light or medium grey, but the oxidation atmosphere is often visible on the fractures and thin sections (Tab. 45). The frequent reduction, weak oxidation, and oxidation marks suggest the imperfect closure of a kiln in which conditions for reduction were maintained only in a part of the batch. No major changes occurred in the late 14th century, as indicated by the pottery from hoard 62, where whole vessels with predominant oxidation effects were also found.

These features best correspond to the results of experiments with rapid, one-time firing without the addition of fuel. These were carried out in open fireplaces, pits, or in simple kilns with a temporary covering. Only these procedures provided pottery with black cores, preserved graphite within the paste, and pronounced oxidised surfaces. The ceramic fabric that was used was rich in organic additions or graphite, which supports these results. However, even during the strongest smoking, carbon never fully penetrated into the sherd during the experimental firing. It remained in a thin surface layer.

The firing was clearly done with a rapid duration and could only be supplemented by a short phase of fuel addition. In terms of the technology of the time, this appears to have been an effective strategy requiring only a minimal investment of time and energy. Its advantage was the low consumption of fuel, which could be found in any kind of wood waste; its disadvantage were frequent temperature shocks. Nonetheless, local ceramic raw materials tolerated these well: so-called brick-making clays with a low content of clay minerals did not sinter and were suitable for faster firings with lower maximum temperatures. On the contrary, when firing in a kiln with temperatures approaching 1000°C, these clays showed signs of overfiring. A similar type of rapid firing is also known from other areas – G. Scharrer-Liška assumes it was used for the graphite ceramics of the Early Middle Ages; M. Rogier documented it in ceramics from Baden-Württemberg (Scharrer-Liška 2007, 25–26; Rogier 2015, 78–81).

The adaptation of pottery kilns represents a fundamental change that had both technological and social impacts (cf. Thér 2009, 43–47; Roux, Brill, Karasik 2018). Firing ceramics in closed pyrotechnological devices, i.e. in kilns, carries specific characteristics that are reflected in the appearance and properties of the products. Kilns gave potters the opportunity – at least to a certain degree – to influence the rate of temperature increase, maximum temperature, and the duration of its peak (Thér 2014; Thér, Květina, Neumannová 2019). Whether and how individual manufacturers utilized this potential is, however, a different question. Closed kilns allowed for a slower temperature increase than open firings – the firing could last from one to twelve hours, or even longer. The duration that maximum temperature could be maintained was also significantly longer in kilns: while in open firing the time interval lasted only a few minutes, in kilns the potter could regulate and maintain it according to his specific needs (cf. Gliozzo 2020).

The energy efficiency of kilns was significantly higher than that of open fireplaces, yet they required better quality fuel and the more time-consuming, active involvement of the potter. A pottery kiln loses 30–40% of its heat or fuel calorific value via radiation through its walls. An open firing only utilizes about 10% of the fuel's thermal energy. The disadvantage of kilns could also lie in the need to use better quality fuel, whereas with open, rapid firings, it was possible to use any combustible waste, such as wood chips, sawdust, straw, or even dried grass. From modern ethnology, we know of an example where the need to use wood instead of straw was one of the factors for the rejection of pottery kilns in favour of dynamic open firing (Henderson 2000, 141–142; Pool 2000, 72; Roux, Brill, Karasik 2018).

A pottery kiln requires a higher investment of time and energy in work organization, material preparation, and subsequent maintenance. Ethnographic parallels, however, show that it was precisely the higher demands on operation and the risk of technological complications that led to the rejection of kilns in some places (Roux, Brill, Karasik 2018). Another factor could have been the number of vessels that could be obtained in a single firing. The kiln may have been rejected because the batch was limited by the kiln's dimensions (Roux, Brill, Karasik 2018). On the other hand, kilns had a larger capacity in comparison with simple bonfire-like (clamp) firing devices, which are assumed to have been present in the Czech lands before the advent of kilns (Varadzin 2010, 23). In Africa, for example, we have evidence of large-scale open firing devices, but the size of such devices in the Czech lands is unknown (Herbich, Dietler 1991, 125–128). However, we have evidence from a Slavic settlement area in Eastern Germany of large shallow pits (several meters long), which are thought to have been bonfire-like (clamp) firing devices. Furthermore, there is also evidence

here of pit kilns with a dome diameter of 1.5 m, the operation of which was likely difficult to control (Biermann, Pust 2008–2009). The use of kilns is often tied to production using primarily fine ceramic fabrics, which require a gradual increase in temperature or types of goods that require long durations of a maintained heat and rather high temperatures.

The spatial and social context also played an important role. The expanding urban development preferred permanent, safer operations with closed fires. In addition, covered kilns reduced dependence on the weather and allowed for year-round production. Anthropological studies have long pointed out that the adoption of new firing facilities is more likely a response to changing social needs (professionalization of the craft, growth in demand) than purely an effort to 'improve' technical performance (Thér 2009, 51). This may have involved the need to meet the sharply increasing demand for pottery goods, primarily in rapidly developing cities.

The first generation of potters who fired ceramics in pottery kilns in the Czech-Moravian Highlands after the mid-13th century was not yet fully utilizing these kilns' functional potential (similarly, see Varadzin 2010, 29; Pool 2000, 72–73). The firings in these first kilns were still relatively rapid and uncontrolled. However, they were not suitable for graphite ceramics or ceramics with a more pronounced inclusion of organic temper; a more consistently applied procedure with longer oxidation phases at higher temperatures caused the combustion of these inclusions and could increase the permeability of the vessels. The advent of kilns is thus related to the decline of graphite ceramics, although it was possible to temporarily fire it in simpler single-chamber kilns without stoking channels, where the firebox was in the same space as the batch, creating a distinct reducing environment – and it is precisely in kilns of this type that graphite vessels are found (Jihlava – U Skály Street; Žďár nad Sázavou – 'Staré Město'). An early medieval, most likely single-chamber vertical kiln with a circular ground plan solely for the production of graphite ceramics is known from Auhof, part of the town of Perg, in Upper Austria (Scharrer 2000, 70–71).

During the 14th century, ceramics with smoked surfaces began to be produced in the Czech-Moravian Highlands, and by the first half of the 15th century, they had already become predominant. They are already found in the material from Kostelec. The technology of these ceramics best illustrates the formation of pottery as a professional craft. These ceramics were already definitely being fired in kilns with the full utilization of their potential. The process of firing these ceramics was systematic and controlled by the potter, placing higher demands on the time and energy invested and on the preparation of fuel. Compared to our experimental firings with smoked ceramics, this process was probably faster, but the resulting maximum temperatures were similar, which was made possible by the properties of local clays. The experiments also demonstrated that the local ceramic fabric was quite tolerant to the firing process, and thus kiln technology was often not utilized to its full potential. On the contrary, high temperatures or longer durations did not suit these fabrics. However, this evolution cannot be generalized for the entire monitored area: no significant change in the firing method was observed between 1300 and 1400 in Staré Město near Uherské Hradiště. Although traces of smoking do appear in the ceramics, smoking was not as perfect as in Kostelec. This difference seems to reflect the intention, skill level, or modus operandi of the local potters rather than being a consequence of limitations imposed by the properties of the clay used. Our experimental firings have shown that the success of surface smoking is closely linked to the arrangement of vessels within the kiln – the pots must not overlap excessively, and sufficient gaps must be left to allow the flame to pass through during the firing and later for the smoke to circulate after the kiln is sealed. At the same time, the vessels should not be spaced too far apart, as mutual heat accumulation is essential. The temperature of the vessels at the moment of kiln closure determines the efficiency of carbon penetration. The kiln construction together with vessel arrangement effects the kiln's draft properties, and thus the kiln's ability to accumulate heat evenly. Another crucial factor is the amount of glowing embers remaining before the final stoking phase, i.e. the last addition of fuel. The type of fuel also plays a significant role – resinous wood proves considerably more effective for achieving a dark, evenly smoked surface.

Firing required the physical presence of the potter from the beginning up until the final loading of fuel into the kiln and its closure, after which surface smoking occurred. The finer and higher-quality paste used for wheel-thrown pottery required a gradual increase in temperature, and the longer soaking time at higher temperatures also suited it more. The final carbon saturation of the surface then led to the creation of less permeable, finer and more durable goods, which were also easier to maintain.

In terms of the analysed samples from the kilns, their ability to provide answers to questions concerning the technology of ceramic production in the 13th and 14th centuries is limited. It should be taken into account that the analysed samples of whole vessels belong to failed firings, as seen, for example, in the material from the kilns in Jihlava – U Skály and Křížová streets, or in Kostelec. For this reason, the technical capabilities of the kilns cannot be reliably inferred solely from the remains of their final batches. A more suitable starting point would be research into settlement pottery that is assumed with certainty to have undergone successful firing. At the same time, the result is determined not only by the pyrotechnological device itself, but also by the raw material used; the potter had to adapt the firing to the properties of the clay and temper, especially in regard to their resistance to sudden temperature fluctuations and maximum temperatures.

Nevertheless, by analysing the samples, it is possible to estimate the capabilities of individual kilns, based on those that have been exposed to the highest temperatures, although these are rather exceptional cases (Tab. 45). They include, for example, a pot from the U Skály kiln (sample 15, fabric A2), which bears traces of firing at temperatures around 1000°C, or two samples from Mstěnice (7 and 13, from kilns 1 and 2, both fabric A1), fired at up to approximately 950°C. Also significant are four pieces from Staré Město, two of which – sample 18 from kiln 11 in 'Na Kostelíku' (fabric B3) and sample 19 from kiln III/98 in 'Na Dvorku' site (fabric A) – reached temperatures around 1100°C. In the first piece, this is evident in the fabric's deformation and melting. A kiln discovered in 1909 in St. Pölten could have reached similar values; this, however, did not cause problems, as the local kaolin clay could withstand higher temperatures (up to 1100°C; see Chapter 6). Maximum recorded temperatures correspond to the results of our experiments with these types of equipment and the data published in the literature (Thér 2014).

The firing of ceramics in the 13th and 14th centuries in the Bohemian-Moravian Highlands and to a large extent in Staré Město shows a predominance of rapid reduction processes, in which not only the surface but also the core of the fabric turned black or dark to medium grey. The maximum temperatures were not high enough and not held for long enough to allow for the combustion of the organic/graphite component to take place during the oxidation phases. The reducing environment was probably also supported by direct contact of the fuel with the ceramics. An uneven or complete oxidation layer could often be found on the surface of the vessels, which documents the final oxidation phase of the firing, i.e. that the firing was not sealed as it cooled or that a sufficient reducing environment did not develop in the closed kiln. These signs correspond to experiments with one-time firings in open fireplaces or simple kilns.

Adaptations to pottery kilns, which we associate with the emergence of professionalized pottery, were a major innovation and allowed for temperature regulation and longer holds at peak temperatures. Initially, however, their potential was not fully utilized. This may have occurred unintentionally due to insufficient knowledge of the correct technology, but also intentionally, primarily in regard to traditional fired ceramic fabric or the additions it contained. The standard firing process in a pottery kiln was now no longer suitable, e.g. for ceramics with an inclusion of graphite or a significant organic component, which would largely burn away during the process and could lead to increased vessel permeability. The advent of pottery kilns may have also required a change in the composition of the ceramic fabric, whether it was a change in its source or the technique used to modify it. Despite these initial obstacles, the new firing technology gradually prevailed as more advanced methods of forming vessels also required a change in ceramic fabric. This is evidenced by the proliferation of smoked ceramics in the studied areas during the 14th century and its complete dominance in the 15th century, when pottery technology came to be standardized. Regional differences, such as the absence of a significant change in this period in Staré Město near Uherské Hradiště, probably reflect the lingering conservative practices of local potters and likely also the demand for a different type of product.

The process of firing smoked ceramics in kilns was essentially the same as with the firing of oxidation goods characteristic of other regions and only differed in the very final phase, whereas oxidation ceramics are created during the cooling process in an environment with access to oxygen, i.e. when the kiln is not sealed at the end or is only 'partially sealed'. Smoked ceramics require the kiln to be sealed airtight after the last addition of fuel is placed in it. Why some regions continued to make smoked products for centuries while others produced mainly oxidation goods remains a question. The answer may lie in the adherence to tradition, i.e. conservatism among potters or consumers, but also in practical

reasons, e.g. the quality of the final product. The surface treatment of ceramics by smoking reduced permeability, and it is possible that this was more necessary for some clays. This may also be due to a combination of both factors. Smoking ceramics as a technological process was an innovation, but in essence, it is just a continuation of the tradition of 'black ceramics'. Goods with an inclusion of graphite or a strong organic component were fired in such a way that the graphite or organic addition in the fabric was maintained, as the combustion of these materials increased the permeability of the ceramics. As technology transformed, so did the process of clay treatment, shaping, and firing; however, the regional raw material base remained the same – smoking thus essentially became a new way to put carbon into ceramics, thereby reducing its permeability. Smoked ceramics thus arose or were accepted as part of the gradual process of applying new technologies (new types of potter's wheels and kilns) to an older tradition.

In addition to the firing process and the fuel chosen for its final phase, the final colour of smoked ceramics reflected the type of ceramic fabric used. Experimental firings of smoked ceramics show that regional differences in the colour and gloss of smoked ceramics can be influenced the most by the different properties of raw material sources (Těsnohlídková, Slavíček 2021).

7.5.2 The appearance of kilns based on preserved relics, their typology, and the experimental reconstruction of firing devices

Archaeological finds of kilns usually provide information about parts of kilns buried underground, i.e. the heating chamber and the lower part of the chamber. In terms of kilns from later periods, finds may also include above-ground parts if these were built using stone or bricks. In regard to simple clay structures, the above-ground parts can only be reconstructed in exceptional cases when fragments of a collapsed dome are preserved, usually in the form of daub bearing the imprints of wicker rods. The presence of chimneys (or chimney openings), probable dome size, and the placement of these features can only be inferred from ethnological parallels and the results of experimental reconstructions. Only exceptionally do finds contain evidence of a dividing element between the fuel and the batch, such as fragments of a perforated clay grate; in the kilns from the sites we have examined, the presence of this element is unlikely.

The issue of the typology of medieval and modern kilns has received considerable attention abroad in recent years (see Vágner 2002; 2007; Weiser 2003; Heege 2007; Kaltenberger 2009a, 251–253; Cuomo di Caprio 2017, 324–374). In the Czech environment, the first typology was created by V. Nekuda (1963), but his approach was primarily based on the morphology of archaeological relics. More recent works by R. Procházka and L. Čapek have shifted the research towards technical-functional aspects and the principles of firing itself. Their typology therefore reflects not only the appearance of the archaeologically preserved kiln, but also the technological possibilities and the ways in which ceramics were fired (Procházka 2015, 217–221; Čapek et al. 2018, 69–77; Čapek, Preusz 2019, 314–315).

When classifying firing devices, one can proceed in two ways. The first and most commonly used is based on the design of the interior space. Kilns are distinguished as single-chamber and double-chamber, depending on whether the ceramics come into direct contact with the fuel. With the second method, the direction of the flame draft – horizontal, vertical, or diagonal – is decisive (Weiser 2003, 19–30; Heege 2007, 15–16). Double-chamber kilns can be further categorized according to how the fuel and batch are separated and type of grate design. There are kilns with an earthen grate with slotted vent holes as well as variants with a radially arranged grate. The grate can be placed on a central column or on a clay spoon; it can be permanent or temporary, and also assembled from either slabs or bricks. Instead of a permanent grate, clay bricks or old pots (known in Czech ethnology as 'kabáty' – coats) may also have been fired before the first firing, but we do not know this for sure. Vessels could span the stoking channel by leaning against each other when placed on the central pedestal and around the inner periphery (Snášil 1970, 332; Weiser 2003, 15). Vessels could also be used in the construction of kilns, and in our case they formed part of the central spoon of one of the kilns in St. Pölten. However, from the second half of the 14th century, kilns with vessels in arched constructions and daubed on both sides also appear in the Czech environment. This technology can be found as far back as Roman times, with the last of such kilns still operating in Austria at the beginning of the 20th century (for a summary, see Káčerik 2010, 455–464; Heege 2007, 4–5). Bohemian and Moravian typology is based on the classification created for the German-speaking regions (Heege 2007, 15–19;

Kaltenberger 2009a, 251–253; Gregerová et al. 2010, 28–29; Procházka 2015, 217–221; Čapek, Preusz 2019, 321–322).

Thus, the current typology reflects some functional aspects of the kilns, but it does not capture all the factors that have a major impact on their operation – e.g. the size and construction of the dome and the location and shape of the chimney. It is in this direction that experimental archaeology can play a crucial role. It should be emphasized that it is not possible to determine the firing strategy or the type of pottery for which the kiln was originally intended based solely upon the archaeological relic. Specialized kilns designed for certain types of firing and certain types of pottery are better known from ethnology and from the Early Modern period (e.g. kilns for glazed or smoked pottery, or stoneware). In the Slovácko region, as late as the 19th and early 20th centuries, the construction of kilns differed depending on whether they were used for firing smoked or glazed pottery (Plicková 1959; Snášil 1970, 329).

In the second half of the 13th century, kilns with a central pedestal became more prevalent, especially in Moravia. These constructions can be vertical, but more often they are horizontal, and they continued to be used until the end of the Middle Ages. In addition to these pedestals, single-chamber vertical kilns without a central pedestal continued to be used. So far, two-part vertical devices with a grate appear only exceptionally (Procházka 2015, 217). Among kiln finds in the Czech lands, simple single-chamber kilns with a vertical flame draft and single-chamber horizontal kilns with an undivided base prevail. Only occasionally do kilns appear that can be classified as single-chamber and diagonal, with a slanted bottom or a bottom divided by a pedestal. No clay grate was preserved in any of the Czech finds, and therefore we still have no direct evidence of the existence of two-chamber kilns. On the contrary, the use of pots as part of the construction is more typical for the Czech environment (Čapek, Preusz 2019, 349). In Moravia, vertical two-chamber kilns are also documented, e.g. from Ivančice or Znojmo – Sokolská Street (Procházka 215, 218, 222). Horizontal two-chamber kilns became more widespread in the Czech lands only in connection with the production of Faenza ceramics in the 16th century (so-called Kassel type; Pajer 1983, 108–111). In neighbouring Germany, their advent was primarily related to the beginning of stoneware production (Heege 2007, 17, Abb. 15, 82–95).

A specific variant is represented by bonfire-like (clamp) kilns, which were used mainly for firing smoked ceramics until the 20th century. These above-ground structures had one or multiple stoking channels, a loading opening, which was walled up after the batch was loaded, and a chimney (Snášil 1970; Zatloukal 2000a, 62). Archaeologically, they are documented, for example, in Mohelnice and Loštice. At least some kilns from Domažlice – Horní Předměstí also belong to this type (Goš 1980, 96; 2007; Procházka 1983, 6–7).

All archaeologically studied potter's kilns in the Bohemian-Moravian Highlands can be dated to the second half of the 13th–14th centuries. Typologically, these represent two examples of simple single-chambered kilns with probably a vertical or diagonal flame draft from sites in Žďár nad Sázavou – 'Staré Město' and Jihlava – U Skály Street. Kiln 11 from Staré Město near Uherské Hradiště, which has a somewhat unusual trapezoidal floor plan for the firing chamber, can probably be classified in a similar manner. More complex constructions are represented by the kiln from Jihlava – Křížová Street, Mstěnice, and the more recent kiln III/98 from Staré Město, where horizontal single-chambered kilns with a central pedestal were discovered. The same type can be assumed for the kiln in Kostelec (see Chapter 4). Here, a diagonal direction of the flame can be assumed, which is supported by the slightly rising base in site III/98.

In the German lands, elongated kilns with a central pedestal have been found sporadically since the 11th century. However, in the area of the Danube region, where impulses for the development of South Moravian ceramics originated, these types of kilns are only documented from the late 13th century (e.g. Heege 2007, 35–36, 69–75; see Chapter 5 in this book).

The possibilities of firing in both types of archaeologically documented pottery kilns were experimentally reconstructed, and their above-ground parts, which are not preserved in archaeological contexts, were also addressed. There was undoubtedly a permanent dome covering the kilns with a central pedestal (Jihlava – Křížová Street, Kostelec, Mstěnice, Staré Město). The presence of the dome is evidenced by finds of plaster with impressions of wicker rods, which suggest a wickerwork construction daubed with clay, which burned away during the first firing. The variability of the dome's height could have affected the overall volume of the kiln, while the location of the chimney opening and the loading

method had a significant impact on the uniformity of the flame draft (see Chapter 6.4.7).

A more complex issue is found in single-chamber kilns without an auxiliary construction for the creation of stoking channels (Žďár nad Sázavou – 'Staré Město', Jihlava – U Skály Street). Two variants of reconstruction were tested here. The first was based on the assumption of a permanent dome similar to kilns with a central pedestal: space was left in the front for heating, and the batch was placed in the chamber, where gradual firing took place. In the final phase, the kiln could be sealed, thus resulting in the production of smoked goods. However, this procedure was not highly suitable for full-reduction or graphite ceramics.

The second variant was based on the principle of dynamic bonfire (clamp) firing. The batch and fuel were alternatingly placed in the kiln pit and covered with a temporary dome of wicker rods daubed with clay, while the chimney opening remained open in the rear section. Ignition took place through a narrow stoking channel, which allowed for the gradual ignition of the fuel; the entire firing lasted approximately three hours. Once the fuel was fully ignited, the holes in the kiln were sealed, resulting in full-reduction ceramics with preserved graphite in the fired fabric. If final closure was not carried out, the result would be ceramics with dark cores and pronounced oxidised surfaces, similar to bonfire (clamp) firings in pits (see experiments). For these types of kilns, two variants – either with a permanent dome or a temporary one – can be considered.

7.5.3 Interpretation of finds of whole vessels in kilns – a question of batches and production waste

Whole ceramic vessels found in kilns cannot be automatically interpreted as the final batch or as the remnants thereof after terminated operation, which occurred due to an unsuccessful firing, dome collapse, or the abandonment of the workplace. Each assemblage must be assessed individually via a detailed analysis of the ceramics contained in the kiln, in which the spatial arrangement of these ceramics within the relic and the composition of the assemblage itself is crucial. Regardless of whether this deals with an actual batch or waste deposited at a later time, it always involves ceramics that are directly connected to the given production site and thus made within one pottery workshop. The most convincing argument for the interpretation of the assemblage as an actual batch, or part of it, is the preservation of vessels in their primary position – that is, as they were stacked in the kiln during firing. Here, the possible use of 'kabáty' (kiln furniture) should also be considered – i.e. vessels, mostly large pots, that are fired repeatedly. These could have served as an auxiliary grate or to cover thermally exposed places at the front of the kiln. Vessels may have been produced intentionally for this purpose, or pots from previous firings containing certain defects may have been used. The uniform morphology of the pots, the presence of some characteristic feature, as well as the use of identical ceramic fabric, may further indicate the short-term nature of the production of such vessels (Slavíček et al. 2023, 429–430; Čapek, Preusz 2019, 344–346).

There is no doubt that the pottery kiln from Jihlava – U Skály Street involves the final batch of an unsuccessful firing. Ceramics made up 80–90% of the site's fill. Only a limited amount of daub was preserved, which corresponds to the type of firing that did not reach the very high temperatures and long periods of maintained heat that are necessary for a high-quality firing. Moreover, experiments have shown that the dome above the kilns was not necessarily a permanent feature. The bottom of the kiln contained an uninterrupted layer of charcoal, and the kiln's fill consisted of red-fired clay. The kiln was missing a back part (about 10% of the volume) due to a building intervention, yet after thorough conservation of the ceramics, it provided 50 wholly intact vessels and another 27 fragmentary pieces. Ten vessels were preserved completely intact. There was relatively little fragmentary material, which was mostly made up of the bulges belonging to fragmentary vessels. Part of the pottery showed traces of overfiring or even fabric crumbling. Part of the filling also included ceramic fragments that clearly did not belong to the batch – a fragment of a storage vessel and probably parts of two stirrup-handled ewers. Both sandy and graphite pottery were represented in the kiln. Goods of both types were fired simultaneously. Systematic placement of vessels in the kiln was difficult to trace, yet it can be stated that whole or cracked but still intact vessels were most often found in the peripheral areas of the relic. They were probably subjected to less pressure in these places after the site was filled in, because they were protected by overhanging walls of the kiln. Additional whole vessels were found near the stoking channel, with one jug directly wedged inside of it. This was definitely not the vessel's primary position, as it probably entered into the hole during the collapse of the batch.

In potter's kiln 927 in Jihlava – Křížová Street, it is also highly likely that part of the batch has been preserved. The ceramics were significantly damaged by heat, and the clay fill contained both daub and fuel residues. Vessels at the bottom of the kiln stood upside down, which corresponds to their primary position after firing. In addition, five bowls were found at the very bottom, which could have been used to bridge the stoking channels. A total of 108 vessels were identified, most of which have survived only in a fragmentary state. A certain number of these vessels are also likely to be a waste from the vicinity of the kiln. Only a smaller number of vessels could be reconstructed or recorded in their entirety. The reconstruction of the assemblage was complicated by significant damage from heat, which, in addition to shape deformations, also caused considerable crumbling of the ceramic fabric.

Due to the state of the field documentation, it was difficult to determine in the potter's kiln from Kostelec which other ceramic finds from the research in the vicinity of the kiln come directly from the kiln's remains apart from the 27 originally preserved vessels. Moreover, only a part of the kiln was examined. On several preserved pots, distinct vertical fissures are visible on the walls due to thermal shock. Overall, however, the ceramic fabric is less overfired than in the vessels from the Jihlava kilns, and the firing was relatively homogeneous, with a dark core and a light or medium grey surface. It is possible that the defects in the vessels occurred in the front part of the kiln, where the temperature increased abruptly. The firing was, however, apparently completed, and the defects were only revealed after opening. For this reason, the interpretation of the assemblage remains ambiguous. A partially failed batch may have been involved, but the possibility that ceramics that were already poorly fired were subsequently placed in a kiln that was no longer functional at the site cannot be ruled out either. The fact that some vessels are visible in an upside-down position in period photographs, i.e. in a position corresponding to their arrangement during firing, supports the interpretation that these are the remains of the original batch. The author of the research also recorded cases in which smaller vessels were placed inside larger ones (Meduna 1954; Zimola 2021, 106, obr. 10–12). This would, however, be contrary to the procedure that had to be applied when attempting to achieve smoked goods. During the smoking procedure, it was desirable for the vessels in the kiln only to lean against each other and for their prominent parts, which were to be evenly smoked, not to overlap.

Two pottery kilns situated directly next to each other were found in Mstěnice. Kiln 1 had a stoking pit, in which kiln 2 was probably built after the first kiln was destroyed. Moreover, relatively large pieces of ceramic vessels were found in the stoking pit of the second kiln. However, the number of preserved whole vessels in both kilns clearly does not represent complete batches. It is perhaps more likely that these were damaged vessels that were left on the site. The cause of the abandonment of kiln 1 remains a question, i.e. whether the kiln simply ceased to fulfil its purpose, or whether it collapsed during a firing and the found pieces represent the remainder of the batch. The details of the arrangement of vessels during firing is unknown; the author of the research only states that whole forms were placed upside down, but documentation is insufficient. According to the most detailed list (Nekuda 1963, 66–68), the older kiln 1 contained seven whole or reconstructed vessels (6 pots, 1 bowl) and another 19 larger parts. Kiln 2 was thought to have five whole pots and 15 larger reconstructed parts. A considerable amount of ceramic fragments from earlier batches undoubtedly entered into the kiln's filling. The whole vessels may have been 'kabáty' (i.e. kiln furniture) that were possibly used repeatedly in firings in certain parts of the kiln.

A total of 629 ceramic fragments come from the kiln in Žďár nad Sázavou – 'Staré Město'. From these, 16 pots were reconstructed: four were preserved only to a degree of 30–40%, but with an intact profile; the remaining twelve were glued together in the range of 60–95%. Practically all pots were reconstructed from fragments, and none were preserved intact. Part of the fill consisted of small, significantly smoothed ceramic fabrics, which most likely entered into the kiln relic secondarily from the surrounding areas. According to photo documentation from the course of research, whole or fragmentary pots were concentrated mainly above the bottom of the kiln, mostly in the middle area of the relic. Firing producing pronounced oxidised surfaces predominates in the preserved pieces and occurs with similar frequency in other ceramics from the settlement. Thus, we are not dealing in this case with overfired pottery. It is possible that these were damaged vessels – i.e. they were either mechanically damaged after firing or had certain shape defects (e.g. finger indentation in the wall) – which were left in place and only inserted into the kiln when it was abandoned. Their possible use in the front part of the kiln as a buffer zone between the heating chamber and the batch can also not be ruled out.

The rest of kiln III/98 from Staré Město near Uherské Hradiště up to a maximum height of 20 cm was almost completely filled with fired clay debris, probably from the walls, as well as with pottery that was mostly in a fragmentary state. In total, nine whole and reconstructed pots and seven large torsos, one bowl, as well as two whole hollow lids were preserved. The lower layer of vessels, partly in their original position, was documented by the head researcher exceptionally well in terms of both drawing and photography, yet some important information still escaped attention (Galuška 2003, especially 596–601; cf. Procházka et al. 2024, 128–133). Nine pots and torsos stood on a very low pedestal (max. 8 cm) in two rows, and seven originally in an inverted position. Another pot, along with the other torsos, lay on its side next to the pedestal, with another broken one in an inverted position. The high concentration of large vessel fragments, especially around the pedestal, is evident in the photographs. This, for example, involved 30 large fragments of the upper parts of the pots. An unfavourable factor for the reconstruction of the kiln's firing process and its contents was the removal of the vast majority of the entire device's contents after its abandonment. Material from the kiln's stoking pit was not separated from the contents of the firing chamber. Outside the kiln itself, for example, the pottery could have been more fragmented and included a greater degree of surrounding waste. Unfortunately, a large portion of the pottery could not be reconstructed. With such a concentration, it is advisable to collect pottery in small, spatially defined sectors and document the position especially of whole vessels and larger parts in an attempt to obtain the most complete picture of the last batch. The position of some vessels on their sides suggests that others around them were taken out after firing. It is not clear why vessels on the pedestal were most commonly preserved, as this did not involve 'failed' pottery as in the case of Kostelec. In addition, the possibility that these were so-called 'kabáty' (kiln furniture), i.e. the lower layer of vessels that had only a technical purpose during firing, still fails to provide a complete explanation. Moreover, the function of the central pedestal itself is not clear in regard to its height. In any case, a significant part of the batch was present in the kiln immediately after its abandonment, but it is probably not possible to reconstruct the course of this abandonment precisely. Given the number of unclassifiable fragments, we must also allow for the possible presence of waste from the surrounding site.

Even a quick glance into published pottery kilns in the context of European countries presents us with a somewhat surprising picture, i.e. that the concentration of finds of parts of the batches in the studied assemblage of Moravian kilns is a rather exceptional phenomenon.

The most famous example of a part of the batch left behind is probably the kiln from Tisová – 'Staré Mýto' (Richter 1994), and this is also how the find in one of the 15th-century kilns from Beroun (Vyšohlíd 2015a, 166) and perhaps also in Kroměříž, with vessels placed upside down (Simonides 1892, 86), is interpreted. The two kilns from St. Pölten contained at least parts of the batches, but the documentation, especially that of the older finding from 1909, is wholly inadequate (Scharrer-Liška 2007, 73–74; Scharrer-Liška, Scherrer 2010, 86–104; see chapter 5 in this book). Isolated examples from the German lands include the kiln from Duisburg from the late 9th and early 10th centuries, where the collapsed dome covered up ceramics that were considered to have been a failed firing. The find of 24 whole vessels in the kiln from Langerwehe from the end of the 15th or the beginning of the 16th centuries is interpreted in a similar manner. Finally, we can mention the find from Witznitz, where two intact pots stood at the bottom of the firing device from the 12th century while other vessels were crushed by the pressure of the collapsed dome (Weiser 2003, 64–65, 100, 180–181). A part of the batch may have been left behind in the case of kiln 1 in Hlohovec in western Slovakia, which is dated to the 14th century. Unfortunately, there is no record of the position of the 18 pots that were either preserved intact or later reconstructed and accompanied by an incomplete jug with a lid and a bowl and also large fragments of other similar vessels. The drawing of the whole vessels in a cross-section of the kiln seems rather schematic. Also, in the second kiln, which was heavily disturbed, there were four whole vessels next to fragments, some of which were large (Polla, Rejholec 1961). Dozens of near-stoneware (*faststeinzeug*) vessels lying on their sides were found at the bottom of kiln 2 in Fredelsloh from around 1300 and are interpreted as the products of a failed firing (Lönne 2007, 371, Abb. 8). The ceramics from kiln fills are most often interpreted as secondary waste backfill, or its presence is only noted, possibly with the mention of defective products (e.g. Vágner 2002, 331–332; Ruttkay 1988, 128; Dawson, Kent 2021, 5; Cuvillier, Mouny 2018, 246). The kiln in Tábor was probably filled mainly with waste from production,

although the backfill contained one whole vessel (Krajíc 1982, 271). The same applies to the 2nd kiln from Kapucínské náměstí (Capuchin Square) in Brno (Nekuda 1963, 72–73) or the kiln from the house of the Lords of Lipá in Ivančice (Uhrová 1973, 57) and in Horažďovice in Příkopy Street. However, the kiln found in Horažďovice in 1941 on Husovo náměstí (Hus Square) could have contained part of a batch in regard to the assemblage of intact vessels (Tetour 2002, 164–173). In some cases, the pottery comes almost exclusively from the kiln's stoking pit, while the kiln itself is almost completely lacking pottery, as was the case with feature 11 in Staré Město near Uherské Hradiště or in Jihlava in the case of kiln 925 (Seiler, Kopecky-Hermanns 2012, 423).

7.6. Morphology – shape composition in one kiln, application of morphometrics, standardization of production in one workshop, and the regional and supra-regional context

7.6.1 Bohemian-Moravian Highlands

In this paper, we focus on pottery in the regions where the studied potter's kilns were located. All of them were located in the South Moravian region with – broadly speaking – a number of common features. The development of ceramic production here in the 13th century was significantly influenced, albeit to varying degrees, by the production of neighbouring Lower Austria. In the following centuries, the differences between the two large regions increased, but Lower Austria's contribution was long evident in South Moravian ceramics.

The Czech-Moravian Highlands were mostly settled only in the 13th century, and the so-called 'young settlement area' includes the Jihlava and Žďár nad Sázavou regions, while the Třebíč region, where the deserted village of Mstěnice is located, is a region at the northern edge of territory settled in prehistoric times. Mstěnice itself developed continuously from the Early Middle Ages (8th–9th centuries) until the 15th century, transforming in the 13th century into a high medieval village, the buildings of which underwent further transformation in the 14th century (Nekuda 1985; 1992; 2000; Nekuda, Nekuda 1997; cf. Procházka 2002). The final phase of domestic pottery from tradition, however, was most prominently documented in Třebíč, where it is primarily represented by handleless pots with an inclusion of graphite and decorated with horizontal bands of imprints from a roulette (potter's tool), which predominates in terms of imprinted decoration (up to 60% of decorated fragments). The decoration and profiling of variable and mostly low-everted rims (V, VN and VZ type) situate Třebíč ceramics within the Brno region (Poláček 1990; Vokáč 2001, 140–143; Procházka, Peška 2007, 172, 220; Čapek et al. 2022, 138–139). Similar pottery with some differences in shape was also found in Moravské Budějovice further to the southwest (Poláček 1989). High medieval ceramics were apparently formed in close relation to the Brno region, as shown by assemblages not only from Třebíč, but especially from the pottery kilns in Mstěnice. In the settlement layers of Třebíč, we find mixed assemblages consisting of a mixture of traditional ceramics and high medieval ceramics, with the proportion of the former decreasing and with it the occurrence of graphite in the ceramic fabric. Around 1300, the proportion of graphite ceramics reaches amounts to less than one third. The layers from the plot of the house at Karlovo náměstí 25 (Charles Square) provided fragmentary ceramics showing a transition from traditional production often decorated with a roulette, with a wide range of rims everted upward, to high medieval ceramics. In addition to the straight-edged rims (S type) that were widespread in the South Moravian area, high medieval pots also have specific shapes of rims that are everted upwards, or even collars. Throughout the 13th century, storage vessels with typical club-shaped edges and external incised decoration were used (Obšusta 2000; Vokáč 2001, 140–142). In contrast to the narrower Brno region, there is a very low percentage of ceramics tempered with mica. The potter operating the kiln in Mstěnice exclusively produced relatively technologically high-quality high medieval ceramics without the addition of graphite. These were primarily handleless pots with egg-shaped and barrel-shaped forms, which by vast majority contained variants of a straight-edged rim (S type) with a small number of rims everted slightly upward (VN type). The older kiln contained part of a pot-like bowl and fragments of conical and bell-shaped lids. The later kiln, including the stoking pit, also contained funnels, i.e. bowl-shaped vessels with an open bottom and fragments of flat lids for jugs and ewers with stirrup handles). The assemblages can be dated to the second half of the 13th century or possibly to the early 14th century (Nekuda 1963; 2000; Nekuda, Reichertová 1968). The close relationship to modern Brno ceramics – which

is also characterized by a low proportion of low everted rims and, on the other hand, by a significantly higher proportion of ceramic classes with deliberately added mica – muscovite (Procházka, Peška 2007) – is striking. An unusual variation of straight-edged rims has a precise analogy in the assemblage from kiln III/98 in Staré Město near Uherské Hradiště, which is also stylistically similar to the Mstěnice assemblage (Procházka et al. 2024).

The extensive published fund of more recent ceramics from individual homesteads in Mstěnice was not sufficiently stratified to allow for a more detailed categorization. A considerable part of the fund is dated to the final decades of the settlement's existence in the 15th century, when pottery production on the site is no longer documented. The shape spectrum in the 14th century grows to include tripod pipkins, ladles and goblets, and lamps). Variable shapes of jugs and bowls became very widespread, while flat lids disappear. Glazed production is rare for a village setting and is related to pipkins. With the continuing predominance of straight-edged (S type) and folded rims (P type), now mostly with pronounced grooved undersides, a smaller number of the pots are finished with collared *okruží* type rims (O type), sometimes with a dented rim. The firing, or more precisely the final phase of firing, was predominantly reduction firing (especially Nekuda 1985).

The Jihlava region, which lies much deeper in the higher area of the Bohemian-Moravian Highlands, differs from the Třebíč region in many respects in terms of ceramics production, although the initial phase of production of high medieval ceramics in the second half of the 13th century suggests roots in the old settlement area of southwestern Moravia (e.g. Poláček 1989; 1992; Těsnohlídková 2021, 282–297; summarized by Těsnohlídková, Zimola 2021; Čapek et al. 2022, 138–147). Some elements, e.g. the offsetting of the pot neck from the bulge with an edge and some rim variations allow us to consider the possibility of a connection with traditional South Bohemian production (e.g. Čapek et al. 2013, 526, 527, obr. 1; Richter, Krajíc 2001, 157–158). We no longer find complete assemblages of distinctly traditional production here. The pottery from the settlement layers and fills from the time horizon accompanied by coins of King Přemysl Otakar II represents a mix of traditional and progressive elements – we can observe a smooth technological, formal and typological transformation. When assessing the nature of ceramic production in the Jihlava region in the second half of the 13th century and beginning of the 14th century, we can on the one hand rely on the large fund obtained from the research of the mining area of Staré Hory and from Masarykovo náměstí (Masaryk Square), and on the other hand on assemblages from kilns in Křížová Street and in U Skály Street. An important comparative assemblage was provided by the mining settlement Černov Cvilínek in the Pelhřimov region, suggesting a broad area with shared approaches to shaping products, although undoubtedly divided into several smaller production and distribution circuits (on localities, see below; for a summary, see Čapek et al. 2022, 138–144).

An exceptionally valuable assemblage of whole vessels was provided by the U Skály kiln (Kochan et al. 2021); in addition to the predominant pots, we can also mention conical lids, jugs, flask-shaped ewers, a small bottle, a cup with a handle, and also fragments of ewers with stirrup handles. The spectrum of vessels is thus significantly more diverse than assemblages from other examined kilns from the Czech-Moravian Highlands and elsewhere. Part of the vessels, especially pots, were made of fabric with an inclusion of graphite. Kiln 927 from Křížová Street, which is roughly contemporaneous, contained pots (4 wholly intact), largely in fragments and mostly bell-shaped, less conical lids, shallow bowls or lamps, stirrup-handle ewers, and a goblet. Fragments of storage vessels can be considered to be an intrusion. In the stoking pit, which is again temporally close to kiln 925, fragments of a jug, shallow bowls, ewers with stirrup handles and also flat lids were found in addition to pots. This was high medieval pottery, produced by wheel coiling, which possessed few residual features of traditional pottery (occasionally, e.g. the offsetting of the neck from the bulge, decoration using diagonal scratches). The distinctiveness of local production is manifested by the presence of some unusual or specific shapes (flask-shaped pitchers, jug/pitcher without a neck, hollow lids), some of which were inspired by German-speaking countries. Conical lids with concave walls were produced exclusively in the U Skály kiln in two variants, one of which, with the rim bent downward, has analogies in the South German environment (see below). Surprisingly, flat lids were not produced much in the examined workshops; these also originate from the South German environment and, in our case, the Austrian environment (Procházka 2022, 280). The same applies to ewers with stirrup handles and a jug without a neck, which also occurred in the assemblage from the older kiln in St. Pölten – see Chapter 5

(Krenn 1992, Taf. 3: B3, Taf. 8: H1). Classic jugs with a high straight rim, which are surprisingly common in the assemblage from the U Skály kiln, have analogies in Lower Austria, where, however, by the late 13th – early 14th centuries, they were already being replaced by vessels with an open mouth, as we can also see in the assemblages from St. Pölten (cf. collectively Huber, Kühtreiber, Scharrer 2003; Steininger 1985, 26–27; Felgenhauer-Schmiedt 1977; Scharrer-Liška, Scherrer 2010, especially 9–10, 100–107; see Chapter 5). The rims of pots are remarkably varied, with a strong representation of a wide range of mostly low everted rims, while straight-edged rims, which we might associate with the Austrian environment, form a minority. In terms of decoration, bundles of grooves above the maximum bulge are dominant. In some cases, we can note a transition to a 'whirl' pattern, i.e. continuous, spirally-winding grooving. Further research is required for the unique shape of a goblet with a funnel-shaped mouth from Křížová Street, for which we still have no analogies in contemporary ceramics. In Moravia, the proliferation of goblets can be commonly assumed from the second half of the 14th century, but earlier in some Czech regions (Čapek et al. 2022, 91, 105–106, 132–133, 159). There is a lack of support for the absolute dating of ceramics from kilns, and in all cases, we can consider the possibility of the late second half of the 13th century to the early 14th century.

The character of the settlement material, with which finds from kilns can be compared, differs from the previous material in some of its features. It is more fragmentary and originates from multiple unidentified workshops, as evidenced by various marks with the motif of a cross or a wheel with spokes. It also has a broader timespan (Hrubý et al. 2006, 205–2016; Zimola 2004; 2014). In the numerous assemblages from Staré Hory, ceramics with a proportion of graphite occur relatively frequently and are considered to be more archaic. However, they were evidently produced and used simultaneously with other ceramic groups. Some vessel types known from kilns are still missing or have not yet been determined. We also record other variants of hollow lids. Some already suggest the path towards a classic bell-shaped profile, but this profile is still only moderate. They have analogies more commonly in the domestic environment of various Moravian regions and represent the initial phase of development of this shape before the general spread of classic bell-shaped lids (e.g. Sedláčková 2015, 202–205; Goš, Novák, Karel 1985, 215; summarised by Procházka 2022). One variant of a conical lid has precise analogies in the potter's kiln from U Skály Street (Hrubý et al. 2006, 212, obr. 30: 10). Similar vessel types can be found in the Bavarian-Swabian Wittelsbach Castle, where they are dated to the 12th century, and their survival into the following century is likely (Koch 2017, 19, Taf. 112: 3, 6, 8). Fragments of rimmed hollow lids from kiln 927 in Křížová Street do not allow for an exact determination of their shape; however, at least two with the rim bent downwards correspond approximately to the 'Bavarian' lids from the U Skály kiln. In this case, these conical shapes dominate, which distinguishes this assemblage from similarly dated assemblages in the Jihlava region. Among the vessel types from the Staré Hory site, the upper part of a specifically shaped bottle with incised ornamentation is worth noting. Deep conical bowls with inverted rims, which are missing in the kilns, occur here, as do ladles. At the Cvilínek site near Černov in the Pelhřimov region, which otherwise has quite similar pottery, bowls with straight walls and a narrow bottom of unclear function were distinguished (Hrubý et al. 2012, 385–393). In the assemblages, vessels with features of an older period still appear, with a pronounced neck offset from the bulge and an apparently high-set maximum diameter, and elements of traditional decoration – punctures, scratches, twirls, and occasionally even impressions of a roulette. It is possible that low-everted rims are genetically related to typologically similar elements of late traditional production as evidenced in the adjacent part of the old settlement area and represented, for example, by finds from Moravské Budějovice and further to the southwest from the Telč region. We can also consider the possibility of an influence from South Bohemian production, in which we often find offset shoulders and some types of pot rims, e.g. trimmed in a cone shape (Bláha 1975, 11–12; 1997, 228–229; Poláček 1989). In general, it can be said that Jihlava ceramics from the mid-13th to early 14th centuries – although revealing numerous innovations likely prompted by those coming from German-speaking countries, especially the Lower Austrian Danube region – exhibit strong autonomous features in the typology and shapes of vessels compared to other parts of Southern Moravia. With some exceptions, it is not possible in this context to sharply separate the ceramics of 'domestic tradition' from 'colonization ceramics', as traditional and innovative elements intertwine within the ceramic assemblages.

Jihlava pottery production from the 14th and early 15th centuries is not sufficiently known, and existing publications for the most part lack an analytical element. Our evidence is limited to only partially published ceramic assemblages recovered from medieval cesspits on urban properties (Novotný 1982; Karel, Dušek 2013). The ceramic production from nearby Kostelec shows certain similarities to that of Jihlava (Zimola 2021; see the Chapter 4).

In Jihlava, reduction fired or smoked production, with parts possessing striking surface polishing, were applied in this period in addition to the beginning of glazed ceramics. We can encounter graphite coating on the outer surface of vessels. The handleless pot remained the main type of vessel, but we also encounter pots with handles. Ewers with stirrup handles were completely replaced by more practical jugs. The beaker with a handle and circular, triangle or five-lobed mouth represents a novel vessel type (Karel, Dušek 2013, 157, obr. 8: 2, 161, tab. III: 7). Furthermore, we encounter conical bowls sometimes with a spout, goblets and advanced bell-shaped lids in addition to conical lids. Flat lids do not occur in the second half of the 14th century in contrast to the Austrian lands. In this case, the influence from the more northern parts of Moravia and Bohemia prevailed, and the shapes of the lids became homogenized in both Czech lands.

The shapes of the pots often appear rather clumsy due to the wide bases and often barrel-shaped bodies, which are accompanied by egg-shaped and exceptionally even situla-shaped forms. The offsetting of the neck with an edge is still maintained, although this concerns only a minority of vessels; this phenomenon is also observed in contemporaneous Austrian vessels, as we can see e.g. on the assemblages from St. Pölten in this book (see Chapter 5). The rims are mostly thickened, turned in or oval, and collars are also mentioned. Decoration is reduced, and a number of pots completely lack it. Only some pots are furnished with a developed spiralling groove in the upper part; narrow incisions or wider spaced grooves are applied, and a wavy line between grooves is also used. Some specimens were adorned in the area under the neck with an interesting combined decoration consisting of a three-dimensional protrusion and three incised lines, which probably represent a stem with leaves and a flower in very stylized form. On the bulges of vessels, primarily pots, we encounter incised crutch-shaped crosses or marks in the shape of three converging grooves. The rims of jugs are most often everted upwards and slightly slanted inwards, and the fracture above the neck can be accentuated with a raised ridge. The strap handle of jugs is usually decorated with notches.

This context also broadly encompasses the assemblage from the kiln in Kostelec. Given the fact that it comes from one workshop, it appears to be more homogeneous and also has certain specificities in comparison with contemporaneous Jihlava production. According to the preserved whole vessels of barrel-shaped form, the assemblage primarily consists of low-set pots that are slightly convex. In addition, jugs, a bowl with a spout at the rim, fragments of jugs, bell-shaped lids and storage vessels were represented.

Among the almost exclusively reinforced pot rims, everted and funnel-shaped ones (VV type), which in Jihlava most likely do not occur in such numbers, prevail. Straight-edged and folded rims (S and P type) were also used. The bodies of the vessels are usually undecorated, but in a few cases, the shoulders of the pots were decorated with grooving or incisions (in rare cases one groove, more commonly around five grooves) similar to those in Mstěnice; in Kostelec, this often already involved a full whirl of wide grooves. The simple upright undecorated rims of the jugs are delineated at the bottom by a decorative strip, and grooving occasionally appears on the outer side. The handles lack scratches, and the decoration consists only of a dimple at their root. Fragments of graphite storage vessels with rims with Austrian analogies probably made their way into the kiln as an intrusion or involve pottery from surrounding disturbed layers (Scharrer-Liška 2007, 41–42). The rim of the conical bowl is distinctly horizontally everted. The pottery in terms of shape and technology essentially conforms to the production of the advanced 14th century.

The Žďár nad Sázavou region is located in the northeast part of the Bohemian-Moravian Highlands, thus in the vicinity of both the areas of eastern Bohemia and northern Moravia. It can be assumed that contacts with production from these areas also influenced the appearance of Žďár nad Sázavou pottery. The assemblage that is available is primarily from the 'Staré Město' site, i.e. the market village of the nearby Cistercian monastery, which is dated to the second half or third quarter of the 13th century (Richter 1974; Zatloukal 1999). After preliminary evaluation (Zatloukal 2000b), parts of the assemblage, including the potter's kiln, were processed in detail (Slavíček et al. 2023).

Sixteen whole pots were found in the kiln itself, as well as fragments of bell-shaped lids, possibly a fragment of a flat lid, and several reconstructed jugs. The large assemblage from the entire settlement offers significantly more diverse insight into local ceramic production. The spectrum of vessels is complemented by storage vessels with club-shaped 'Moravian-type' rims, ewers with stirrup handle, bottles, and hollow lids. Less than half of the pot rims are variants of mostly low-everted rims; roughly half have simple-edged rims along with rims undercut from below. Compared to the part of the assemblage evaluated by K. Těsnohlídková as part of her dissertation, we note slight differences in the representation of rim types (Těsnohlídková 2021; 2022a). In the entire assemblage, everted rims have a slight predominance over simple-edged and straight-edged ones. In general, a similarly high variability and a strongly individual approach can be noted, as with ceramics from a similar time horizon in Jihlava. A minority of pots in all the assemblages have a neck that is offset from the bulge by an edge. Regular horizontal grooving, a precursor to the continuous wavy whirl, predominates in pot decoration. Occasionally, slanted scratches and impressions of a potter's tool were present.

Another larger assemblage of whole and reconstructed vessels, mainly ewers, comes from a well on the Žďár nad Sázavou – 'Staré Město' site and is undoubtedly connected with its use (Těsnohlídková 2022a, 87). In the European context, this is not a completely unique find; analogies can be found in Brno's Františkánská Street (Procházka 2000, 55), in Hradišťko-Sekanka (Richter 1982, 53, 76, 80, 86–88, fig 56, 63–69), or in the Bavarian-Swabian Wittelsbach Castle (Koch 2017 (1), 17, 184–189, Taf. 48–66). Hollow lids represent exclusively older forms of bell-shaped lids, mostly with a wide bottom and a wide, neckless handle forming a continuous part of the lid body, but we have occasionally encountered fragments that allow us to suggest more advanced forms (Zatloukal 1999, Těsnohlídková 2021, 248; 2022a, 84–85, 86: obr. 1), such as those known from Rýmařov or Hradišťko-Sekanka in the most advanced component of the ceramic assemblages there (Goš, Novák, Karel 1985; Richter 1982, 81, 86; Procházka 2022).

Less than half of the ceramics contain graphite, sandy goods predominate, and a significant addition of mica occurs in approximately 4% of the fragments.

The subsequent development of ceramics from the late 13th and early 14th centuries is not known on this site. Assemblages from more distant castles in the Bystřice nad Pernštejnem and Kunštát area can provide general information. The ceramics of the late 14th century, which are best known in the assemblage from Pyšolec Castle, suggest that this area in the eastern part of the Bohemian-Moravian Highlands has a character that is akin to the production in the Boskovice Furrow and Drahany Highland in terms of ceramic morphology. A characteristic feature is the significant representation of high, mostly decorated collars on the rims of pots (Korbičková et al. 2024, 180–184).

7.6.2 Eastern Moravia

As part of the Lower Morava River Region, the area of Uherské Hradiště is a long-established region similar to the Třebíč region. This former royal town, with its satellites – i.e. Staré Město and Kunovice – still represents the natural centre of the region.

The findings that have been published so far, especially the studied pottery kiln from Staré Město near Uherské Hradiště, allow us to form a rough idea of the development of local ceramics from the 13th to the beginning of the 15th centuries. Following earlier individual studies (Snášil 1982; Procházka 1984, 436–438), several studies of both an analytical and comprehensive nature have appeared in recent years (especially Bartíková, Bartík 2019; Čapek et al. 2022, 147–154; Procházka et al. 2024, 135–158). These include the significant study from the nearby castle in Veselí nad Moravou (Sedláčková 2015).

The transition from stage RS III.3 ceramics (second half of the 11th century to 12th centuries) to the final phase of the ceramic development of domestic tradition in the first half of the 13th century has not been fully explored in the studied region. Assemblages from the abandoned village of Záblacany near Polešovice, which have been presented so far only in a master's thesis (Kováčik 1998), suggest the emergence of certain new elements as early as the 12th century, especially including incised ornamentation on the outer surface of pots with upward-everted and initially inward-slanting rims (Procházka 1984, 436; cf. Balcárková, Dresler, Macháček 2017, 606, tab. XLIX). The pot with perpendicular-everted rim remained the dominant shape, but increasingly often had a rim bent outwards and trimmed at the top and was almost always decorated with incisions (incision-grooves, wavy lines, multiple waves) on the outer surface. Similar decoration with a predominance of grooves around the vessel, sometimes combined with diagonal scratches or a wavy line under the neck,

occurs on the bodies of these vessels. In terms of shape, these vessels build upon their 12th-century predecessors. Due to the rather imperfect forming technology, they often have an irregular, barrel-shaped form, or less frequently an egg-shaped form, with slight convexity (bulbosity) in the upper part. The situla-like shapes of the previous period with a decorative band at the bottom of the rim disappear. At the same time, storage vessels continue to develop essentially in the shape of large pots, and are made of fabric with an inclusion of graphite; they have similar decoration, and their rims acquired the characteristic 13th-century club shape that spread through nearly all of Moravia. The first hollow lids, conical lids or early variants of bell-shaped lids begin to appear, apparently with a certain delay. This horizon also includes the assemblage from kiln 11 from Staré Město near Uherské Hradiště (Procházka et al. 2024, 135–139). In the broader context, the traditional production of the region under study shows analogies throughout Bohemia and Moravia in terms of technology, shape range and decoration (Klápště 1998; Čapek et al. 2022). Eastern Moravian ceramics have numerous shared features with production especially in central, northern and northeastern Moravia (e.g. Goš, Novák, Karel 1985). The Brno region bordering to the west differs in many respects (Procházka, Peška 2007, especially 220–221). The southern border is unclear, but at least Veselí nad Moravou can be included in the Uherské Hradiště region (located 14 km southwest from this town; Sedláčková 2015). Late manifestations of ceramics of the domestic tradition with features shared with Uherské Hradiště were recently obtained in valuable archaeological situations in Uherský Brod, 16 km to the east (Šimík 2020, 129–131). Common features can be found in the traditional pottery of neighbouring western Slovakia, from where the small detail found on some pots of the region in question probably originates, i.e. namely the rounded transition from rim to neck, which is much more widespread in Slovakia (Sedláčková 2015, 195; Ruttkay 1996, 277. Abb. 8: 7; Hanuliak 2018, 130–131, obr. 7, e.g. D3–5). The proportion of ceramics with an inclusion of graphite is negligible in the Uherské Hradiště region, except for storage vessels and slightly smaller storage pots. The possibility of imports can be considered here, as suggested by the analysis of the vessel fragment from the kiln in Staré Město and the unambiguous export of graphite ceramics with typically Moravian shape features to western Slovakia (Hanuliak 2018, 135–136 with further references). The traditional pottery described was undoubtedly produced in the region in question and its surroundings throughout the second half of the 13th century, as suggested by findings from the chartered towns of Uherský Brod and Uherské Hradiště, which were founded after the half of the 13th century, and also from the contemporaneous time horizon of the castle in Veselí nad Moravou (Procházka 1984, 436–437; Sedláčková 2015, 210–211). Assemblages from the contemporary settlement context also include pottery that differed markedly in both technology and form – pottery that represented the future. In terms of the southern, larger part of Moravia, the source of this production was the South German region, specifically Lower Austria (Felgenhauer-Schmiedt 1977; Huber, Kühtreiber, Scharrer 2003). In addition to more advanced technology, we observe a large expansion in the spectrum of vessel types and, in regard to the still-dominant type of vessel, i.e. the handleless pot primarily intended for cooking, also a number of shape innovations. These lie in the overall profile of the vessels, the relatively chronologically sensitive rims, and the decoration. It is intriguing to note how long graphite storage vessels persist – commonly until the first half of the 14th century and in some places until the 15th century (Goš, Karel 1979; Unger 1984, 292–294; Procházka, Peška 2007, 221–229; Scharrer-Liška 2003). They were created using the coiling technique and were not fired in kilns of the type described above, but in bonfire-like (clamp) devices (Macků 2021). Among the new types of vessels partially belonging to newly emerging table ware, ewers can be mentioned, mostly with stirrup handles, as well as jugs, lids, and bowls (Sedláčková 2015, 199–210; Procházka et al. 2024, 139–142). Although they make up a minority, the rims in the Uherské Hradiště region – unlike Lower Austrian pottery – still significantly involve pot rims that are everted upwards; initially, they are rather low variations with a shape that was somewhat different in profile from similar rims on traditional pottery. Features related to South Moravian pottery, including the well-known Brno region, can be observed, as demonstrated in the kiln production from Mstěnice presented here, including a specific variation of a straight-edged pot rim. The occurrence and further development of upward-everted rims, which evolve into collars, is shared by Uherské Hradiště pottery with the more northerly Moravian regions (e.g. Kohoutek 2003; for a summary, see Čapek et al. 2022, 147–149).

The second half of the 14th and early 15th centuries, which encompasses the ceramic hoard

from the 'Na Kostelíku' site and the assemblages from waste pits from the 'Na Dvorku' site in Staré Město, is marked by further developments in pottery production, as was the case in the previous period. In the field of technology, the already established principles are perfected. The typology of vessels expands to include cups with handles, goblets, and ladles; pipkins occur more frequently. We also note new types of jugs, while ewers decrease in frequency. The basic spectrum of vessels is shared with the original source area of Lower Austria, where we can also find similar formal features and trends. For instance, we can mention the pronounced grooving of straight-edged and folded types of pot rims compared to older predecessors. On the other hand, autonomous expressions grow stronger, generally in South Moravia, but also regionally. Specific types of jugs emerge, especially the particular goblet-like shape, the spread of which has yet to be sufficiently studied. The mouths of some pots are shaped into high, mostly externally decorated collars, and in addition to the rebirth of wavy lines, the toothed wheel decoration also becomes increasingly popular (Procházka et al. 2024, 143–148). It shares common features with the production from the ceramic kiln in Uherský Brod – Komenského Street, but also displays differences. These can be seen, for example, in the number of collar shape variants or the shapes of goblets (Bartíková, Bartík 2019, 13, obr. 5). High, slender collars similar to those from Staré Město also sporadically occur in Veselí (Dejmal, Ostrý 2014, obr. 9, 16–20). Staré Město production is similar to the ceramics from the more northerly region of Zlín in its significant number of collar-shaped rims, as shown by the preserved material from local castles, which is unfortunately only fragmentary (Kohoutek 2003). Conversely, to the south, the number of collars tends to decrease; however, the lack of published assemblages of a high informational value hinders an objective comparison (Vařeka et al. 2010, 254–256, obr. 9).

The morphology of Lower Austrian pottery is addressed in part in Chapter 5. The undeniable relationship to South Moravian production in terms of types and shapes of vessels has been dealt with by a number of authors (Unger 1970; 1984; Procházka 1995; 1996; Procházka, Peška 2007; Sedláčková 2020; Čapek et al. 2022, especially 128–144). Although developments in South Moravian and Lower Austrian ceramics moved along their own mutually distinct trajectories since the late 13th and early 14th centuries, their common roots throughout the entire Middle Ages cannot be denied. Examples of significant differences that can be highlighted include the strikingly homogeneous profile of the rims of Lower Austrian pots and the unmistakably specific rims of storage vessels or jugs. In Lower Austria, we note the occurrence of some special vessel types, especially kettles with zoomorphic spouts, which were imitated by Brno potters (Sedláčková, Hložek 2021).

7.6.3 On the morphometrics of vessels from ceramic kilns

The comparison of the index values W (the height of the maximum body bulge within the vessel height), D (the degree of the body's convexity), and H (bulbosity), carried out on pots from nine assemblages across seven sites (Jihlava – U Skály and Křížová streets, kiln 927, Mstěnice, Staré Město, Kostelec, Žďár nad Sázavou and St. Pölten – kilns excavated in 1909 and 1991), was intended to show the degree of standardisation in the shape of the upper part of the vessel profile / contour curve of pots (tab. 47, 48). The informational value of the submitted data is certainly limited by the number of measured vessels, by their typologically non-uniform state of preservation, etc. One assemblage can be dated to around the middle or possibly second half of the 13th centuries; six assemblages can be dated to the interval of the second half of the 13th – first half of the 14th centuries; and two assemblages belong to the second half of the 14th century, with a possible overlap into the following century. Nonetheless, the 116 measured specimens did provide a certain picture. All assemblages had relatively close mean and median values of the W index, indicating the position of the maximum diameter of the body at the upper limit of the 'low' grade; a minority of vessels belong to the middle grade, and in Jihlava – U Skály Street, and in Žďár nad Sázavou, we encounter specimens positioned at the lower limit of the 'high' grade on exception. Only the pots from Staré Město (site III/98) with the lowest mean value of the W index fall into the 'medium' category; only two pots slightly exceed this limit into the 'low' grade. It should be borne in mind that the ratio of overall vessel height to the distance between rim level and the largest diameter does not adequately capture the location of the maximum bulge. If we were to take into account the shape of the curve between the bottom and the neck bend and relate the height to the distance between the plane diameter of the neck with the largest diameter, the W1 index values would shift to the 'medium' grade corresponding to ovoid pots, which they also appear to be optically.

Site	Number of measured vessels	W – Index range	H – Index range	D – Index range	V – Index range
Jihlava – U Skály Street	33	0.30-0.54	0.83–1.29	0.5–1.33	1.56–2.12
Jihlava – Křížová Street	7	0.37–0.45	0.95–1.17	0.41–1.02	1.61–1.83
Kostelec near Jihlava	8	0.39–0.47	1.01–1.13	0.49–0.71	1.58–1.88
Mstěnice	11	0.38–0.49	0.95–1.26	0.63–1.18	1.4–1.92
Žďár nad Sázavou – 'Staré Město'	10	0.30–0.46	1.03–1.35	0.41–0.8	1.54–2.04
	8	0.38–0.42	0.88–1.17	0.8–1.11	1.8–2.4
St. Pölten	23	0.38–0.51	1.04–1.78	0.17–0.6	1.48–2.06

Tab. 47. Range of values of indices W, H, D and Z for pots from pottery kilns.

Site	Number of measured vessels	Mean W	Med. W	Mean H	Med.H	Mean D	Med.D	Mean V	Med. V
Jihlava – U Skály Street	33	0.44	0.43	1.11	1.12	0.82	0.78	1.76	1.74
Jihlava – Křížová Street	7	0.42	0.44	1.04	1.01	0.83	0.95	1.76	1.81
Kostelec near Jihlava	8	0.44	0.45	1.06	1.06	0.62	0.63	1.7	1.675
Mstěnice	11	0.45	0.45	1.09	1.09	0.82	0.8	1.69	1.68
Žďár nad Sázavou – 'Staré Město'	10	0.41	0.41	1.18	1.17	0.63	0.67	1.7	1.79
	8	0.39	0.39	1.07	1.08	0.94	0.9	2.04	2
St. Pölten	23	0.44	0.43	1.25	1.16	0.42	0.39	1.72	1.72

Tab. 48. Mean values and medians of the W, H, D and Z indices for pots from pottery kilns.

We can also see small differences in the 'bulbosity' (H) category; these differences are larger when compared to the W index. The calculated mean and median values rank almost all assemblages mean to the 'high' grade, and only in St. Pölten (1991) does the mean value fall into the 'medium' grade, while the median is again more likely to be in the 'high' grade. Vessels from the older kiln at this site had a somewhat higher mean bulbosity, with two even in the 'very high' grade. A minority of pots with a very high degree of bulbosity also occurred in both assemblages from Jihlava, in Mstěnice and in Staré Město. In Jihlava – U Skály Street, Mstěnice and Žďár nad Sázavou, specimens with medium bulbosity are also represented, and in St. Pölten (1991), we find specimens with 'medium' and even 'low' grades (1). The largest range of values is found in Jihlava – U Skály Street, and in St. Pölten (1991), which may be due to the frequency and thus the greater representation of these assemblages. Index D, which focused on the degree of bulge, shows the relatively largest differences between the mean and median values between individual assemblages with a low degree of bulge; the relatively flattest bulge is thus characterized by assemblages from Žďár nad Sázavou, Kostelec and especially St. Pölten (1991). Values were found to be only slightly higher, but at the same level, in the assemblage from the kiln examined in 1909. Vessels from other assemblages have an mean bulge of medium, and in the cases of Jihlava – U Skály and Křížová streets and Mstěnice, the values are essentially the same.

The same applies to the relationship between the mean and median as in previous cases, and these are particularly close to one another in the case of the older assemblage from St. Pölten. The largest U Skály assemblage is again characterized by the largest interval of evenly distributed values. St. Pölten shows an even larger interval, but this is due to the extreme values of two indices of 1.5 and 1.78. The others are distributed without fluctuations on the scale of 1.04–1.25, which is similar to other assemblages. Index Z was used to examine a possible trend towards slimming and narrowing the lower parts of the vessels, which was observed in the assemblage from the well in Brno-Komárov, where it exceeds the value of 2 (calculation according to Kochan, Sedláčková, Vachůt 2015, obr. 5, 6). Only the assemblage from Staré Město reaches this value on mean, while the others are quite close in the middle range. The individual vessels with significant narrowing can be found in Jihlava – U Skály Street, in Mstěnice, and Žďár nad Sázavou. Based on the mean and median values, two groups can be distinguished with mean indices in the range of 1.6–1.72, medians of 1.68 and 1.72 (Mstěnice, Kostelec, both assemblages from St. Pölten), and with means of 1.76–1.79 and medians of 1.74–1.79 (both Jihlava assemblages; Žďár nad Sázavou). Of the two assemblages from St. Pölten, the older one

was characterized by a smaller average narrowing of the bottom of the pots.

Kiln 11 from Staré Město was included only with certain reservations. All indices could only be calculated in three vessels, and index D was the only index that could be calculated for all five pots. Only one index – index D – differed from most other assemblages, i.e. its low degree of vessel bulge (0.49–0.71) was closest to Žďár nad Sázavou, which was also the closest in terms of technology, then to the significantly later Kostelec. Even lower values are found in both assemblages from St. Pölten. Unfortunately, the incomplete vessel inv. No. 301250, which represents a group of pots with nearly cylindrical bodies, could not be fully assessed. The lower part of the vessel appears to have been only slightly constricted, with the Z index probably ranging between the very low values of 1.2 and 1.3. We recorded relatively low values for three objectively measurable vessels (around 1.6); based on illustrations, the comparable assemblage of vessels of the domestic tradition from Rýmařov allow us to conclude that there was a relatively frequent occurrence of vessels with an index around 1.5, which is sometimes accompanied by a flattening of the vessel body around the maximum diameter (Goš, Novák, Karel 1985, obr. 5–10). The low values reflect the limitations of the technology used and the varying degree of skill in specific cases.

It is evident that the values of all three monitored indices have a fairly wide range, but they always oscillate around a certain value within each index, which differs the most between individual assemblages for index D. However, there are no significant differences between individual assemblages. Ranges of mean and median values expressing the position of the largest bulge on the vertical axis are particularly close. Close values of the mean and median suggest that the scales of the indices are mostly evenly distributed within the intervals, which means that the products are defined by a stable range of monitored parameters. The findings show a certain degree of standardization of the shape of pot-shaped vessels over a fairly extensive area; the starting point was essentially the ancient and early medieval egg-shaped or barrel-shaped pot.

7.6.4 On the issue of ceramic relief marks

It is also necessary to deal in brief with the issue of relief marks on the bottoms of vessels in the examined assemblages. Their bas-relief matrices were located either on another wheel or on a removable base. They appeared in assemblages from four kilns dated to the second half of the 13th century or possibly the beginning of the 14th century, and came from Jihlava – U Skály and Křížová streets, Mstěnice, and Staré Město. In almost all cases, this involved a single mark. Only five identical marks had a direct relation to the kiln in question (the 6th is questionable), two of which were on whole reconstructed pots and another two on relatively large fragments. In this context, we can consider R. Snášil's interpretation that this is a miniscule letter h occurring in charters from the first half of the 13th century (Snášil 1982, 12, obr. III; Beránek 1982, 14). It is a rather unusual motif, which has not yet been found in other assemblages from Staré Město. The marks in Staré Město seem to be linked to ceramics of the domestic tradition, which is represented by ceramics from kiln 11 (technological group 0). Similar ceramics from other contexts, mostly with recessed features, include a wide range of other marks, which are unfortunately mostly in a fragmentary state. In the assemblage from the U Skály kiln, three bases with a simple cross motif were found exclusively on ceramics with an inclusion of graphite and one specimen with a similar motif from kiln 927 in Křížová Street (Zatloukal 1998, 41, obr. 9: 8). Finally, seven bases with identical marks of a cross in a circle evidently originate from kiln 1 in Mstěnice, two of which are found on reconstructed vessels and two on larger fragments. Unfortunately, most of them could not be verified. An alleged 8th mark is only assumed at the site of the hole in the bottom of the pot (Nekuda 1963, 66–67). In kiln 2, a similar but smaller mark appeared on a single vessel. Vessels from the Žďár nad Sázavou kiln did not contain marks, but they did occur in the common settlement material from this site. The examples recorded so far suggest that more complex motifs occurred on the handles of lids, while simple crosses are found more frequently on the bottoms of pots (Zatloukal 1999, 198; 2000b, obr. 5, 6, 38, 30; Těsnohlídková 2021(2), tab. I: 1–4, J: 7; 2022a, 71, 86, obr. 16: 1–4, 97).

Relief marks have been continuously found on ceramics in the Czech lands since the 9th century, and in the 13th century or first half of the 14th century, the epoch of their use ends. Compared to the older period, the motifs become more simplified; crosses, wheels and combinations of the two become dominant (summarised by Nekuda 1965; Varadzin 2005, 174 with incorrect dating concerning the end of the use of marks; Čapek et al. 2022, 89, 106, 115–116, 121). They reappear in some places in the 15th century (e.g. Belcredi 1990, 113–114; Himmelová, Procházka, Šmerda 1999, 56;

Sedláčková 2020(1), 34). The occurrence of a single dominant mark in one batch is not accidental, and it confirms the relationship between the marking of ceramics and a particular potter. It is also related to the development of specialization and market distribution, which is best demonstrated by means of identical marks (Varadzin 2005, on the discussion concerning the significance of marks, see 179–180; 2010, 39, 43–49). A single mark in five specimens is mentioned in connection with the 13th century kilns in Kostelec nad Orlicí (Richter 1967, 504–505); outside the Czech lands, we encounter both examples of one motif in a particular workshop and various motifs (e.g. see Richter 1982, 149–150). Here it is necessary to inquire into how these ceramic assemblages came into being. Marks with the same motif but divided into four types according to their design were published for the remains of the batch in Tisová – 'Staré Mýto', with individual types being related to three technological ceramic groups (Richter 1994, 146–154).

The percentage of marked products in the assemblage of bases was not calculated in the examined kilns. With the exception of Staré Město, it did not exceed single-digit percentages. For Staré Město, R. Snášil assumed a ratio of 1 : 5, but he did not take into account the other marks mentioned above (Snášil 1970, 10). In many sites, the number of marked vessels was considered to range in the tens of percent as early as the 13th century, but we only have reliable data from a few sites. At the same time, much depends on the calculation methodology (Varadzin 2005, 174). For example, the proportion of vessels with a mark in kiln 1 reaches about 50% only when we exclude most of the vessel sherds from the relevant assemblage and take into account only whole vessels and the lower parts of the vessels (Nekuda 1963, 66–68). In the case of Žďár nad Sázavou, three vessel bases were marked in the assemblage of 36 whole and reconstructed pots, which amounts to 8.3%.

The uniqueness of the motifs in individual kilns in our assemblage means that the potter used only one mark at a time. Further research in this area should also include marks in other contexts, at least in the sites where this is possible, with an emphasis on identical marks. Assemblages of marks suggest that, for example, both Žďár nad Sázavou and Staré Město were supplied by multiple pottery workshops. Deepening knowledge of distribution by potentially proving identical marks could be a topic of further research.

Incised marks, which are more common in southwest Moravia from the 14th century, present a somewhat different issue. In the assemblages from Jihlava – Křížová Street, and Mstěnice, we encountered the crutch-cross motif in the area under the neck of the vessels (Nekuda 1965, 119, obr. 6: 1) with an analogy, e.g. in Jihlava, where, however, other incised patterns are still numerous in contrast to nearby Kostelec (Novotný 1982, 144, Taf. 10: 3, 5; Taf. 12: 4; Karel, Dušek 2013, 144, obr. 7: 12). The occurrence of incised marks is largely regional and also requires further research.

8 Conclusion

This monograph presents the results of a comprehensive multidisciplinary analysis of ceramic kiln loadings from the period between approximately 1250 and 1400 in the Bohemian-Moravian Highlands, the Uherské Hradiště region, and St. Pölten in Lower Austria. A specific advantage of the examined assemblages is the fact that they clearly originate from a production context. The results of archaeological, scientific and experimental research have made it possible to provide an overview of the technological and typological development in the given period.

8.1 Pottery in a topographical and socio-economic context

Based on a sample of more than 30 Czech and Moravian sites with studied pottery kilns, it was possible to deepen the state of knowledge regarding the spatial and socio-economic context of the production specialisation in question by comparing it with written sources. An analysis of the spatial distribution of pottery workshops showed that in the High Middle Ages, pottery production in the Czech lands was predominantly an urban craft concentrated in settlements with a market function, while rural workshops tended to be short-lived and local in nature. A comparison with Western Europe revealed certain differences in this respect in terms of continuity, the distribution of production prices, and the social status of potters. While there was a long tradition of pottery villages in France and Germany integrated into the manorial economy alongside urban workshops, in Central Europe, including the Czech lands, pottery was dominated by settlements with markets with a relatively small distribution range. Certain signs of change began to appear in some places in the late Middle Ages, when the beginnings of centres with supra-regional reach emerged, the most prominent of which was Loštice. However, a larger distribution range is also indicated by the concentration of workshops in other, mostly small towns, such as Ivančice, Domažlice and Česká Lípa. The full development of pottery production centres did not occur until the modern era due to the advent of new technologies and types of products.

A survey of the socio-economic conditions of potters confirmed their middle to lower position on the scale of urban crafts; on the other hand, however, it indicated a certain social differentiation in places such as Brno or Znojmo, which manifested itself, for example, in residence within the town walls and an excess of financial resources invested in vineyards. Based on the possibility of monitoring the conditions of the craft in question over a longer period of time, the Brno example in particular showed considerable spatial mobility and demographic instability among families practicing the craft. This was related to the nature of the products, which in quality did not exceed the average in the Czech lands, and therefore also to their limited distribution. It is regrettable that there are no accounting records from Loštice in northern Moravia, which was the only significant export centre of local stoneware production at the time. What is a remarkable phenomenon that deserves further research is the presence of potters on city councils, which is documented from the 15th century. This is related both to the development of the guild system and to the personal position of some representatives of this craft.

8.2 Methodological aspects and interdisciplinary approach

The chosen research methodology, combining archaeological, petrographic, chemical and experimental procedures, confirmed the extraordinary potential of the interdisciplinary approach. The integration of macroscopic observations and microscopic and chemical analyses made it possible to create a detailed picture of the production process and to test hypotheses about the origin and preparation of ceramic raw materials. Of particular importance was the opportunity to compare archaeological data with the results of experimental archaeology, especially with firings carried out in replicas of medieval kilns. These experiments provided a reference framework for interpreting firing temperatures, raw material behaviour and characteristic technological features observed in historical samples.

The combination of petrographic description with chemical analysis and statistical data processing (e.g. PCA) was verified as an effective tool for identifying raw material sources, evaluating technological variability and tracking product distribution. At the same time, the fact that macroscopic evaluation must be validated by scientific analyses and that their interconnection is a prerequisite for comprehensive research was confirmed.

The results of the analyses conducted so far have shown the possibilities and limitations of working with finds from pottery kilns as a specific type of archaeological source. Material from these objects has great potential not only for understanding the production technology itself, but also for monitoring the dynamics of production over time and changes in the use of raw material sources.

8.3 The significance of the completed analyses in understanding medieval pottery

The results presented in this publication significantly deepen our current understanding of the technological and organisational aspects of medieval pottery in the Czech lands. They show that local potters worked with a relatively wide range of raw materials, the selection and processing of which demonstrate a high degree of practical experience and empirical knowledge of the material. From a broader cultural and historical perspective, there is a close link between the development of urban society and the professionalisation of the pottery craft. Although medieval pottery represented a rather poor segment in terms of urban crafts, it was essential for everyday life and certainly had a significant impact on the local economy.

From a broader geographical perspective, the work contributes to the understanding of regional differences and parallels between Central and Western Europe. Despite obvious differences in the organisation of production, it confirms that the basic technological principles of pottery in the High Middle Ages were largely shared and based on a common European cultural foundation.

The results showed that medieval potters in the areas under study mainly used local sources of clayey and silty clays, the selection of which was determined by the geological conditions of individual micro-regions. The raw materials that were used differed in structure and grain size and, in some cases, the deliberate tempering of clays with sand or mica was documented. The addition of graphite has been documented in two workshops (Jihlava, Žďár nad Sázavou). However, in the given period, this was already in decline, except for large storage vessels, which were not fired in the kilns in question. At the same time, it has been proven that the absolute homogeneity of the ceramic material cannot be assumed, even in terms of a single loading – differences may be the result of the natural heterogeneity of deposits, the imperfect homogenisation of clay, or the processing of multiple deposits with material from different sources within a single workshop.

Thanks to the analysis of technological traces on a number of whole vessels, it was possible to identify several stages of wheel coiling, which was the dominant technique of ceramic production in the studied period. These procedures are related to the quality of local clays, but also to forming devices, as the use of a rather wide range of turntables can be assumed in the period under review. These turntables allowed for the greater use of rotational kinetic energy, as did light kick wheels, which seem to have quickly become dominant. At the end of the period under review, we can also consider the advent of the cross-bar wheel with a heavy top table, on which the production of turning technology from a single piece of clay developed in the following period. The technical level of ceramic shaping using the described equipment was far from homogeneous. Several levels of sophistication have been identified, ranging from the workshop producing ceramics with distinctive traditional features in Staré Město – 'Na Kostelíku' or the workshop with only slight technological differences in Žďár nad Sázavou – 'Staré Město', to the most advanced producers in Kostelec near Jihlava and a potter who placed his products

in a sunken deposit in Staré Město. The sophistication of the rural craftsman from Kostelec may come as a surprise – here it is necessary to take into account the more recent origin of the assemblage, probably dating from the mid-14th century. At the same time, however, it is necessary to acknowledge the connection with urban craftsmanship in nearby Jihlava, which also presents a direction for further research.

The dominant features of the ceramics examined from the Bohemian-Moravian Highlands and Staré Město correspond to simple firing techniques with rapid duration in simple kilns. A more advanced firing technique can be observed on material from the kiln in Kostelec dating from the second half of the 14th century, in which the technique of surface smoking at the end of firing was already in use. The success of this technique depended on several factors, but mainly on sufficiently heating the loading, the use of suitable, ideally resinous wood, and the airtight closure of the kiln. However, numerous dark cores visible on fracture surfaces indicate a rapid firing process, which caused the organic component to remain 'sealed' in the ceramic material. When searching for the origin of a more perfected reduction effect, a connection with 14th-century pottery in Jihlava can be considered. The introduction of pottery kilns was a fundamental technological innovation enabling temperature regulation, longer temperature holds during firing, and final sealing, resulting in smoked vessel surfaces. However, the functional potential of the kilns – either out of ignorance or intentionally – was not fully exploited at first in terms of traditional ceramic materials containing graphite or organic additions, which lost their specific properties at higher temperatures. The gradual adaptation of ceramic material recipes to the new technology led to the standardisation of pottery production. The graphite and organic additives that dominated older ceramics were not suitable for firing in a kiln, where they would partially or completely combust, possibly resulting in the permeability of the vessel walls. The technology of smoking at the end of firing made it possible to saturate the surface of the vessels with organic carbon, thereby reducing the absorbency of the walls. In this regard, further research into ceramics will need to focus on comparing the physical properties of products from different workshops with varying degrees of smoking. However, the example of pottery from the Staré Město hoard shows that in many regions, manufacturers in this respect were satisfied with less perfected firing technology. Truly 'black' pottery was found in the Czech lands in the High Middle Ages only in certain places, for example in Brno (Gregerová 2007, 277, 282–283; Gregerová 2010 et al. 131, 136–137; Procházka, Peška 2007; Sedláčková 2020; Čapek et al. 2022, 129–137).

In terms of settlement development, it should be noted that most of the Bohemian-Moravian Highlands are a so-called 'young settlement area', which applies to the Jihlava and Žďár regions. On the other hand, the Uherské Hradiště region is an old settlement area. These facts also influenced the emergence of pottery of the High Middle Ages. While in the first case, after the mid-13th century, relatively uniform production with many new features and rather marginal relics of the older, early medieval period took shape; in the second case, pottery with characteristic features of the late phase of 'domestic' development continued to exist, while production using more advanced technologies coexisted for some time with more traditional production. Similar examples are known from several regions both in the Czech lands and beyond them (e.g. Richter 1982; 1994; Klápště 1998; Procházka, Peška 2007; Rzeźnik 1998).

The first major wave of innovation leading to the spread of wheel coiling and firing in specialised kilns was ultimately a compromise. The quality of available clays and their treatment process had to be gradually adapted to meet the higher demands of new technologies. At the same time, the use of suboptimal raw materials meant that new technologies may have been utilized less effectively than their properties allowed. Nevertheless, innovations were eventually fully adapted and the quality of the goods was significantly improved while maintaining some of the traditional features of dark-surface ceramics.

High medieval pottery craftsmanship could not be established under old legal conditions, in which the territory of castles was controlled by beneficed castle officials. Town law and emphyteusis in towns helped to create a new type of producer, whose economic mindset was much more strongly affected by the market than in the case of producers associated with manorial farms or peasants and craftsmen subordinated to the princely castle administration. This undoubtedly contributed to the more rapid adoption of technological innovations and related tools, such as the potter's wheel and specialised kilns. At the same time, earlier knowledge was naturally used in long-settled areas, especially in the search for raw materials. Craftsmen usually worked full-time in their workshops, producing exclusively in the framework of market exchange. The activities of relatively free producers significantly accelerated the pace of change in ceramic production.

8.4 Prospects for further research

The results obtained broach a number of new questions. Many of them concern the sources of raw materials and their use, which would help to anchor research of pottery sites in the surrounding landscape and track their interrelationships. In particular, it seems promising to combine petrographic and chemical analyses of raw materials from possible/selected sources and to verify them experimentally. A detailed study of the socio-economic aspects of production, including the relationship of potters with the authorities and the organisation of their workshops, even extending into the modern era, also has great potential. Another important area of research is the analysis of production in relation to the distribution and consumption of ceramic products, which would enable a more accurate reconstruction of trade and social networks within towns and regions.

The evaluated pottery kiln assemblages should become an important starting point for further research into the development of ceramic production in the regions concerned, both in the Bohemian-Moravian Highlands and in eastern Moravia. Assemblages consisting of dozens of complete vessels from the period under study will enable more effective work, even with the fragmentary material from settlement contexts, which represents the dominant part of the source base from research into medieval settlement areas.

From a methodological point of view, we consider the further development of an interdisciplinary approach to be essential. Continuing cooperation between archaeology, including experimental archaeology, geology and other disciplines is key to fully exploiting the potential of ceramological research and advancing our knowledge of the development of the pottery craft and craft specialisations in general.

9
Appendix

Appendix 1: Ceramic petrography

ID	Fabric	Quartz	Polycrystalline quartz	Alkali feldspar	Plagioclase	Muscovite	Biotite	Orthopyroxene	Amphibole	Garnet	Tourmaline	Sillimanite	Zircon	Chlorite	Sericite	Graphite	Fe oxy-hydroxides	Gneiss	Sillimanite gneiss	Gneiss with chlorite	Graphite gneiss with garnet	Graphite gneiss	Graphite metaquartzite	Metaquartzite	Mylonite	Granitoid	Plant tissue
1	A1	2	0.5	2	2	0.5	4			1		0.5		0.5			3	2								2	
2	A1	3	1	2	3	0.5	3		0.1	0.5		0.5		0.5			2									2	
3	B1	3	1	2	2	0.5				1				3	2	4		1						1		1	0.5
4	A1	2	1	2	2	0.5	3							1			2			2						2	
5	A1	2	2	2	2	0.5	2						0.1	1			2	2		1							
6	A1	2	1	1	1	1	2							1			3	1		1						2	
7	A1	3	0.5	2	2	0.5	3							2			4	1								3	
8	B2	1	1	1	1	0.5	0.5		0.5	2						4	2				2					1	
9	A1	2	0.5	2	2	0.5	2							1			4	2		1						2	
10	A2	3	1	2	2	0.5	2							0.5	2		2	2								1	
11	A1	2	2	2	2	0.5	2							0.5	1		4	1		2						1	
12	A1	2	2	2	3	0.1	4		0.1					2			3			1						3	
13	B1	2	2	2	2	1	1		0.5	1						3	3				1						
14	B1	3	1	2	2	0.5	1					0.5				4	2	2				3		2			
15	A2	2	1	2	2	0.1	2		0.5			0.5		2			1		1	3						1	
16	B1	2	2	1	1	0.5	1		0.5					2	3	4	1					1		2			0.1
17	A1	3	1	3	3	0.5	4						0.1	1			4	1		2						3	
18	A1	3	1	3	3	0.5	4							2			4		3	2						3	
19	A1	3	2	3	3	0.5	4	0.1	1					1			3									3	
20	A3	2	2	2	1	1	0.5		0.1						3		3									2	
21	A1	3	1	3	3	0.5	3										4									3	0.1
22	A2	3	1	3	3	0.5	3										2	2		3						3	
23	B1	2	1	1	1	0.5	1			1				3		3	0.5				2		1			1	
24	A1	4	2	2	3	0.5	4							1			3										
25	A1	2	1	1	1	0.5	3						0.1	2			3	2		2					0.5	2	0.1
26	Daub	4	2	2	1	1	3	0.5	0.5	0.1				2	3		2	4								2	

Appendix 1-A. Jihlava – U Skály Street. Semi-quantities of non-plastic inclusions (0.1 – trace; 0.5 – rare; 1 – occasional; 2 – common; 3 – frequent; 4 – abundant; 5 – dominant).

ID	Fabric	Quartz	Polycrystalline quartz	Alkali feldspar	Plagioclase	Muscovite	Biotite	Amphibole	Garnet	Sillimanite	Spinel	Titanite	Graphite	Graphite with garnet	Graphite with anyhdrite	Granitoid	Gneiss	Metaquartzite	Fe rich clay pellets	Sericitized alkali feldspars
2	D	3	2	2	2	1	2	0.5		0.1	0.5					3	1		2	
3	C	2	1	2		3	3		0.5								3		3	
4	C	2	2	0.5		4	3		2							1	4		3	
5	A	4	3	2	0.5	0.5	0.5			0.1						1			3	
6	A	3	3	2	0.5	0.1	0.5	0.5								0.5			4	
7	A	3	2	2	1	0.5	1			0.5						1	0.5		3	
8	A	4	3	2	1	0.5	0.5	0.1		0.5						0.5			3	
9	B	2	1	1		0.5	0.5		0.5			0.5	5			0.5			4	1
10	B	1	1	1		0.1	0.1		1				4			1		1	2	
11	B	2	2	1	0.1	0.1	0.5		1				4	1	1			1	3	
12	Pottery fragment	2	2	1	1	0.5	0.5									1	0.5			
12	Daub	3	2	2	2	0.5	1	0.1								2	1		2	3
13	Daub	3	2	2	2	0.5	2									3	0.5		1	3
1	Daub	3	2	2	1	1	2	0.5								3	2		1	2

Appendix 1-B. Jihlava – Křížová Street, kiln 927. Semi-quantities of non-plastic inclusions (0.1 – trace; 0.5 – rare; 1 – occasional; 2 – common; 3 – frequent; 4 – abundant; 5 – dominant).

ID	Quartz	Polycrystalline quartz	Alkali feldspar	Plagioclase	Muscovite	Biotite	Amphibole	Pyroxene	Garnet	Tourmaline	Sillimanite	Chlorite	Granitoid	Gneiss	Serpetinite	Metaquartzite	Fe oxyhydroxides	Clay pellets	Plant remains
1	4	0.5	1	2	0.5	2	0.5	0.1		0.1	0.5	0.5		3			0.5		0.5
2	3	1	1	1	1	1	0.1				0.1		0.5	3		0.5			1
3	2	0.5	1	1	1	4		0.1	0.1	0.1				3					2
4	3	0.5	1	1	1	3							1	3					
5	3	0.5	1	1	1	3							1	3					0.1
6	3	1	2	2	1	1	0.5	0.1			0.5		2	3	0.5				1
7	3	2	1	2	1	1	1				0.5		2	1				1	1
8	4	2	3	2	2	2	0.1				0.5		3	2		2		2	1
9	3	2	3	3	1	1	0.5		0.5	0.1	1		2	2			1	1	1
10	4	1	3	3	1	1	0.5						3	1	0.5		1	0.5	0.5
11	3	3	2	2	1	2							2	3		0.5			0.1
12	4	3	2	2	1	1	0.1						2	2		1			0.1
13	4	3	3	2	1	1	0.5				0.1		2	1	0.5	0.1	3	1	0.1
14	3	1	2	2	0.5	2	0.5				0.1		1	3			2		
15	3	2	2	1	1	3	0.1						2	2			1		0.5
16	3	2	2	2	1	4	0.5						2	3	0.5		1	1	1
17	4	2	2	2	1	2	0.1						2	2	2		2		0.1
18	3	2	2	2	0.5	1	0.5	0.1			1	0.5	1	2				1	0.1
19	4	2	2	1	1	2	0.5						1	2				1	1
20	3	2	2	2	1	1	0.5				0.5		2	2	1			1	2

Appendix 1-C. Kostelec near Jihlava. Semi-quantities of non-plastic inclusions (0.1 – trace; 0.5 – rare; 1 – occasional; 2 – common; 3 – frequent; 4 – abundant; 5 – dominant).

ID	Fabric	Quartz	Polycrystalline quartz	Alkali feldspar	Plagioclase	Muscovite	Biotite	Amphibole	Orthopyroxene	Clinopyroxene	Garnet	Olivine	Tourmaline	Micrite	Sparite	Glauconite	Talc	Serpetinite (serpentinized peridotite)	Migmatite	Metaquartzite	Gneiss	Chert	Amphibolite	Fe oxyhydroxides	Clay pellets	Iron rich clay pellets	Microfossils
1	B3	4	2	1	1	1	3				0.1		0.1			2			2		2						
2	Loess	3	0.1	0.5	0.5	2	3	2	0.1				0.1	4					0.5	1							
3	A1	1	1	1	0.5		3	2	1	2	2	1					1	4	1				0.5				
4	A2	1	1	1	1		3	1	1	0.1		1		2				4	1							2	
5	A2	1	2	1	0.5		3	2	1	2	2	2		1			1	5	0.5				0.5				
6	C1	2	2	2	2	3	3	1	1				0.5						2	1	2						
7	A1	1	2	1	1		3	3	0.5	1	2	3					1	4	0.5				0.5				
8	A2	2	1	1	0.1		4	1	2	1	2	3		3			2	5	1								
9	B1	3	3	1	1	2	1	0.1	0.1		2		0.5	1		2			3	1	3				4		0.1
10	A1	1	1	1	0.1		3	2	1	2	3	1		2			1	5	2	1							
11	A1	2	1	1	1		3	2	1	2	0.5	1						5	2	0.5			0.5				
12	A2	1	1	1	1		3	2	1	1		1		0.5			2	4	1							2	
13	A1	1	1	1	1		3	2	0.5	2	0.5	0.5						2									
14	C1	2	1	1	1	4	3		2		1						0.5	2	2	0.5	1						
15	A1	1	2	0.5	0.5		4	1	1	3	2	2					1	5	1				0.5				
16	B2	2	1	2	1		2	3	0.5	1	2	1						2	1	0.5							
17	A1	1	1	2	2		4	3	1	3	0.5			3	3		3	1	1		1						
18	A1	1	0.5	1	0.5		4	2	1	2	0.5	0.5					1	3	1								
19	C2	4	2	2	1	4	3	1	2				0.5	1					2		3	1					
20	A1	1	1	1	1		3	1	1	2		1		1				3	1	1							
21	B4	3	3	1	1	0.5	1	0.1								1			2	3	2			0.5			
22	A1	3	2	1	1		4	1	1	2		1			0.5		1	3	2	1							
23	D	3	3	1	2	1	1	0.5			0.1			1	0.5				0.5	1	3					2	2

Appendix 1-D. Mstěnice – both kilns. Semi-quantities of non-plastic inclusions (0.1 – trace; 0.5 – rare; 1 – occasional; 2 – common; 3 – frequent; 4 – abundant; 5 – dominant).

ID	Fabric	Quartz	Alkali feldspars	Plagioclase	Biotite	Muscovite	Graphite	Sillimanite	Amphibole	Garnet	Granitoid	Graphitic metaquartzite	Metaquartzite	Mica schist	Gneiss	Two mica schist	Plant tissue
1	A1	4	2	3	4	0.1					2		2		3		1
2	A1	3	1	2	3	0.1					2		2		2		
3	A1	3	1	2	3	0.1			1		2		1		3		1
4	A1	3	1	2	3	0.1			1		1		2		2		
5	A2	4	3	3	4	1			1	2	2		1		4		1
6	A1	3	1	1	3	1					1		1		3	2	1
7	A1	3	1	2	3	0.1					2		2		3		3
8	B	4	1	1	1	1	5		1			4	2		1		
9	A1	3	2	3	3	1					1		1		2		2
10	A1	3	2	2	3	1					2		2		2		
11	A1	3	3	3	3	1				0.1	2		1		3	1	1
12	A1	3	2	2	4	0.1					1		1		3		2
13	A1	3	2	2	4	1					1		1		3		
14	A1	3	2	3	3	1					2		1		3		
15	Brick – ref. sample	3	2	1	2	1		2			2		4		2		

Appendix 1-E. Žďár nad Sázavou – 'Staré Město'. Semi-quantities of non-plastic inclusions (0.1 – trace; 0.5 – rare; 1 – occasional; 2 – common; 3 – frequent; 4 – abundant; 5 – dominant).

ID	Fabric	Kiln/feature	Quartz	Alkali feldspars	Plagioclase	Muscovite	Biotite	Pyroxene	Amphibole	Tourmaline	Garnet	Serpentine	Chlorite	Glauconite	Graphite	
1	A	Feature 11	4	2	0.5	1	0.5	0.5	0.5					2		
2	A	Feature 11	4	2	0.5	1	0.5	0.5	0.5					2		
3	B2	Feature 11	3	2	0.5	0.5	0.1	0.1		0.1		0.1				
4	A	Feature 11	4	2	2	1	0.5	0.1	1					2		
5	SM4	Feature 11	1	1	2	5	3				0.5					
6	A	Feature 11	3	2	0.5	0.1	0.5	0.1	1	0.5	0.1			2		
7	B2	Feature 11	4	3	1	0.5	0.1	0.5	0.5					1		
8	B2	Feature 11	4	3	0.5	0.5	0.1	0.5	1					0.1		
9	B2	Feature 11	3	2	0.5	0.1	0.5	0.5	0.5					1		
10	A	Feature 11	3	2	1	1	0.1	0.1	0.5	0.1				1		
11	SM3	Feature 11	1	0.1	0.1	0.1	0.5		0.1					1	4	
12	SM3	Feature 11	2	0.1	0.1	1	0.5		1				1		5	
13	A	Feature 11	4	2	0.5	0.5	0.1		0.1					2		
14	B3	Feature 11	3	2	0.5	0.5	1		0.1		0.1			1		
15	B1	Feature 11	4	3	1	0.5	0.5	0.1	0.5					1		
16	B1	Feature 11	4	2	0.5	0.1	0.1	0.5	0.1					0.1		
17	B3	Feature 11	3	2	0.5	0.5	0.5		0.1					2		
18	B3	Feature 11	4	3	0.5	0.1	0.5		0.5							
19	A	Feature III/98	5	2	1	0.1	0.5		0.5							
20	A	Feature III/98	4	2	1	0.5	0.5	0.1	0.5					2		
21	B2	Feature III/98	4	2	1	0.5	0.5		1	0.1	0.1			2		
22	A	Feature III/98	4	2	1	1	1		0.1		0.5			1		
23	A	Feature III/98	4	3	1	0.1	0.5		1					1		
24	B2	Feature III/98	4	2	0.5	0.1	0.5		0.5	0.1	0.5			2		
25	A	Feature III/98	4	2	1	2	1		1					2		
26	A	Feature III/98	4	2	1	0.1	0.1		0.5					1		
27	A	Feature III/98	4	2	1	0.5	0.5	0.5	0.5					2		
28	A	Feature III/98	4	2	1	0.5	0.5		0.5		0.1			2		
29	A	Feature III/98	4	2	1	1	1	0.1	0.5					1		
30	A	Feature III/98	5	1	1	1	1		0.5					0.5		
31	A	Feature III/98	4	2	1	0.5	1	0.1	0.5					2		
32	A	Feature III/98	3	1	0.1	1	0.1	1	1	0.1				3		
33	B1	Feature III/98	4	3	1	0.1	0.1		0.5					2		
34	A	Feature III/98	4	2	2	1	1		1					2		
35	A	Feature III/98	4	1	0.5	1	1	0.1	0.5	0.1				1		
36	B2	Feature III/98	4	3	1	0.1	0.5	0.1	0.5					2		
37	A	Feature III/98	4	1	0.5	0.1	0.5	0.1	0.5					2		
38	A	Feature III/98	4	2	1	1	1	0.1	1	0.1	0.1			2		
39	A	Feature III/98	3	2	1	1	1		0.5	0.1	0.1			2		
40	A	Feature III/98	4	2	1	1	1	0.1	0.5					1		
41	A	Feature 62	3	2	1	0.1	0.5		1		0.1			2		
42	A	Feature 62	4	2	0.5	0.5	1		2					2		
43	A	Feature 62	3	2	0.5	0.1	1		1					2		
44	A	Feature 62	3	2	1	0.1	0.5		0.5		0.1			2		
45	A	Feature 62	3	2	1	1	1		1		0.1			2		
46	A	Feature 62	3	2	1	0.5	0.5		0.5					2		
47	A	Feature 62	3	2	2	0.1	0.5		0.1		0.1			2		
48	A	Feature 62	3	1	0.5	0.1	1		1	0.1				3		
49	A	Feature 62	3	1	1	0.1	0.5		1		0.1			2		
50	A	Feature 62	3	2	1	0.1	0.5		1					1		
51	A	Feature 62	3	2	1	0.1	0.5	0.1	0.5	0.1				2		
52	A	Feature 62	3	2	1	0.1	0.5		0.5					1		
53	A	Feature 62	3	2	1	0.1	0.5	0.5	0.5					2		

Appendix 1-F. Staré Město near Uherské Hradiště – kiln 11, III/98 and hoard f. 62. Semi-quantities of non-plastic inclusions (0.1 – trace; 0.5 – rare; 1 – occasional; 2 – common; 3 – frequent; 4 – abundant; 5 – dominant).

	Sillimanite	Sandstone	Siltstone	Mudstone	Chert	Granitoid	Chlorite schist	Phyllite	Mica schist	Gneiss	Sillimanite schist	Biotite schist	Graphite gneiss	Metaquartzite	Graphite metaquartzite	Andesite	Amphibolite	Plant tissue	Slag?
		2			0.5	1								3					
		1			0.5	1								3					
		2			1									4					
		1			0.5	0.5								3			0.5		
									3	3				1					
					0.5	2								3					
		1			0.5	1				1				3		1			
		1			1	0.5								3					
		1			1	1								3					
		2				2		1						2					
	0.5				0.5								0.5	1	1	0.5		0.5	
	0.5				0.5	0.5	2					2		2	1				
			0.5		0.5	2			0.5					3		0.5			
			0.5		0.1	1								3					
		2	0.5		1	3		0.5						3					
		1			0.5	0.5					0.5			3					
		1		0.5	0.5	2								3					
					0.5	2								3					
		0.5			0.5	1		0.1						3					
					0.1	2		0.1						3		0.5			
		1	0.5		0.5	1		0.1						3					
		1			1	0.5			0.1					3					
		0.5			0.5	0.1								3					
		0.5	0.5		0.1	0.5		0.1						2					
		0.1			0.5	0.1								2					
					1	0.1								3				0.1	
		0.1			0.1	2		0.1						3					
		0.5			0.1	0.5		0.1						2					
				0.5	1	1								2					
		0.5	0.5		1	0.5			0.5		0.5			2					
		0.5			0.5									2		1			
		0.5			0.1	0.1		0.5						2					
		2	1		1	1								4		0.5			
		0.5			0.5				0.1					2					
		1			0.1	0.1								1					
		1	0.5		0.1	1								2					
		0.5			0.5									3		0.5			
					0.5	0.5			0.1					3		0.1			
		1			1	1		0.5		1				2					
					1	1								2					
		1			0.5	1								3					
		2			0.5	0.5		0.5						2					
		0.5			1	2		2						2					3
					1	2		1						3					0.5
		1			0.5	1		1		1				3					0.5
		2			0.5	2								3					
		0.5			0.1	1		1						4					1
		2			0.5	1		0.5						3		0.5			
		2			1	0.5		0.5						3					1
		3			1	2		1						2		0.5			
		1	1		1	2								3		0.5			
		2			1	0.5		0.5						2					2
		3		1	1	0.5								2					1

ID	Fabric	Quartz	Polycrystalline quartz	Alkali feldspar	Plagioclase	Muscovite	Biotite	Sillimanite	Rutile	Kyanite	Zircon	Clay pellets/claystone	Sandstone	Calcite	Serpentinite	Sill-gneiss	Gneiss	Q-afs rock	Afs-plg rock	Fe pellets	Fe oxyhydroxides	Avian eggshell
1	A	4		1					2	2	0.1	4		2						0.5		
2	A	3	0.5	1	0.1				1	1		3		2				1		2		
3	A	4	0.5	1					2	2	0.5	4								1		
4	A	5	1	1					1	2		2		1						0.1		
5	A	5	1	0.5	0.1				1	2	0.1	2		0.5					0.1	0.5		
6	A	5	1	1	0.1				1	2	0.1	3		1				0.5		0.5		
7	A	4	0.5	0.5					1	2	0.1	4		3						0.5		
8	B	3	2	3	0.5	1	1	0.5							2			1		0.5	3	
9	B	3	2	3	0.5	1	0.5	0.5							4	0.5				0.5	3	
10	A	3	0.1	0.1					0.5	1		5		2						1		
11	A	5		1					1	2		3						0.5		0.5		
12	A	4	0.1	0.1					1	1	0.1	4		1						1		
13	A	4	0.5	1	0.1			0.5	1	2		3		1				1		0.1	1	1
14	A	3	1	0.5	0.1	1			1	2	0.1	4	3	0.5			0.5			2		

Appendix 1-G. St. Pölten. Semi-quantities of non-plastic inclusions (0.1 – trace; 0.5 – rare; 1 – occasional; 2 – common; 3 – frequent; 4 – abundant; 5 – dominant).

Appendix 2: Technological features observed with light microscopy

1/2

ID	Fabric	Microstructure	Microstructure – note	Heretogenous matrix	Sorting	Calcareous matrix	Grain size distribution	Aplastics (vol. %)	Aplastics size (µm)	Avg. aplastics size (µm)	Spacing	Aplastics shape	Shape 2	Mineral temper (vol. %)	Mineral temper size (µm)	Avg. mineral temper size (µm)	Spacing	Mineral temper shape
1	A1	Parallel		✓	Very poor		Bimodal	1	<25		Open	Angular to sub-rounded	Equant to elongated	15	~100–2100	~900	Double	Sub-angular
2	A1	Weakly parallel		✓	Poor		Bimodal	<5	<20		Open	Angular to sub-rounded	Equant to elongated	15	~100–1700	~400	Double	Angular to sub-angular
3	B1	Weakly parallel			Poor		Uni-modal	15	<1300	~350	Double	Angular to sub-angular	Elonaged to equant		<1500 (Graphitic rocks)	~400		
4	A1	Parallel		✓	Poor		Bimodal	1	<30		Open	Angular to sub-rounded	Equant to elongated	15	~100–2200	~450	Double	Angular to sub-angular
5	A1	Parallel		✓	Very poor		Bimodal	1	<25		Open	Angular to sub-rounded	Equant to elongated	10	~100–2150	~600	Open	Angular to sub-rounded
6	A1	Weakly parallel		✓	Poor		Bimodal	1	<30		Open	Angular to sub-rounded	Equant to elongated	15	~100–1800	~650	Double	Angular to sub-rounded
7	A1	Weakly parallel		✓	Very poor		Bimodal	1	<25		Open	Angular to sub-rounded	Equant to elongated	15	~100–2800	~550	Double	Angular to sub-angular
8	B2	Weakly parallel			Poor		Uni-modal	20	<1800	~400	Single	Sub-angular to sub-rounded	Elonaged to equant		30–3500 (Graphitic rocks)	~450		

	Mineral temper shape 2	Voids (vol. %)	Voids shape	Biotite pleochroism	Green amphibole pleochroism	Matrix optical activity	Matrix colour	Firing temperature (°c)	Outer surface	Outer layer	Core	Inner layer	Inner surface
	Equant to elongated	10	Planar, vughs	Strong-medium		Highly	Red, reddish brown, reddish yellow + yellow (in XPL)	<750		Oxidised	Oxidised	Oxidised	
	Elongated to equant	10	Vughs, planar	Strong	Green-gray	Highly	Layers of very dark brown, reddish yellow and brown	<700	Smoked	Weakly oxidised	Reduced	Weakly oxidised	Smoked
		5	Planar, vughs	Strong	Transparent to green	Highly (when not black)	Layer of light red, black in core, layer of brownish yellow	<800		Oxidised	Reduced	Oxidised	
	Elongated to equant	10	Planar, vughs	Strong		Highly	Red, reddish brown, reddish yellow + yellow (in XPL)	<700		Oxidised	Weakly oxidised	Oxidised	
	Elongated to equant	10	Planar, vughs	Strong-medium		Highly	Layers of red, reddish brown and red + reddish yellow (in XPL)	<750	Smoked	Oxidised	Reduced	Oxidised	Smoked
	Equant to elongated	10	Planar, vughs	Strong-medium		Highly	Red, reddish brown, reddish yellow + yellow (in XPL)	<750		Oxidised	Oxidised	Oxidised	
	Equant to elongated	5	Planar, vughs	Strong-medium		Highly	Red, reddish brown, reddish yellow + yellow (in XPL)	<750	Smoked	Oxidised	Weakly oxidised	Oxidised	
		10	Vughs, planar	Medium-weak	Transparent to green-gray	Highly	Brownish yellow, dark brown + yellow (in XPL)	<750		Oxidised	Reduced	Reduced	

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ID	Fabric	Microstructure	Microstructure – note	Heretogenous matrix	Sorting	Calcareous matrix	Grain size distribution	Aplastics (vol. %)	Aplastics size (µm)	Avg. aplastics size (µm)	Spacing	Aplastics shape	Shape 2	Mineral temper (vol. %)	Mineral temper size (µm)	Avg. mineral temper size (µm)	Spacing	Mineral temper shape
9	A1	Weakly parallel		✓	Poor		Bimodal	1	<25		Open	Angular to sub-rounded	Equant to elongated	10	~100–1200	~400	Open	Angular to sub-angular
10	A2	Weakly parallel			Poor		Uni-modal	15	<2200	~400	Double	Angular to sub-angular	Equant to elongated					
11	A1	Weakly parallel		✓	Very poor		Bimodal	1	<20		Open	Angular to sub-rounded	Equant to elongated	10	~100–1500	~700	Open	Angular to sub-rounded
12	A1	Weakly parallel			Very poor		Bimodal	5	<30		Open	Angular to sub-rounded	Equant to elongated	30	~100–2000	~500	Close	Sub-angular to sub-rounded
13	B1	Weakly parallel		✓	Poor		Bimodal	<5	<20		Open	Angular to sub-rounded	Elonaged to equant	15	~100–1700 (Graphitic rocks)	~450	Double	Angular to sub-angular
14	B1	Very weakly parallel			Poor		Uni-modal	20	<1200	~350	Single	Sub-angular to sub-rounded	Elonaged to equant		20–3000 (Graphitic rocks)	~300		
15	A2	Weakly parallel			Poor		Uni-modal	15	<1300	~400	Double	Sub-angular to sub-rounded	Equant to elongated					
16	B1	Very weakly parallel	Resi-dual coil		Very poor		Uni-modal	15	<1000	~350	Double	Sub-angular to sub-rounded	Elonaged to equant		50–2800 (Graphitic rocks)	~350		
17	A1	Weakly parallel		✓	Very poor		Bimodal	1	<50		Open	Angular to sub-rounded	Equant to elongated	20	~100–2500	~600	Single	Angular to sub-rounded
18	A1	Weakly parallel		✓	Very poor		Bimodal	1	<30		Open	Angular to sub-rounded	Equant to elongated	20	~100–3000	~700	Single	Angular to sub-rounded
19	A1	Weakly parallel			Very poor		Bimodal	10	<50		Open	Angular to sub-rounded	Equant to elongated	25	~100–2800	~1000	Close	Angular to sub-angular
20	A3	Weakly parallel	Clay mix-ing	✓	Poor		Uni-modal	15	<1800	~400	Double	Angular to sub-angular	Equant to elongated					
21	A1	Weakly parallel		✓	Very poor		Bimodal	1	<20		Open	Angular to sub-rounded	Equant to elongated	15	~100–3500	~700	Double	Angular to sub-rounded
22	A2	Very weakly parallel			Very poor		Uni-modal	25	<1600	~500	Close	Angular to sub-angular	Elonaged to equant					
23	B1	Weakly parallel			Poor		Uni-modal	15	<1200	~450	Double	Sub-angular to sub-rounded	Elonaged to equant		~10–220 (Graphitic rocks)	~500		
24	A1	Weakly parallel		✓	Very poor		Bimodal	5	<30		Open	Angular to sub-rounded	Equant to elongated	20	~100–1500	~650	Single	Angular to sub-angular
25	A1	Parallel		✓	Poor		Bimodal	1	<30		Open	Angular to sub-rounded	Equant to elongated	15	~100–1900	~600	Double	Angular to sub-rounded
26	Daub	Unpar-allel			Very poor		Uni-modal	40			Close	Sub-angular to sub-rounded	Elonaged to equant					

Appendix 2-A. Jihlava – U Skály Street. Description of structural and technological characteristics.

	Mineral temper shape 2	Voids (vol. %)	Voids shape	Biotite pleochroism	Green amphibole pleochroism	Matrix optical activity	Matrix colour	Firing temperature (°c)	Outer surface	Outer layer	Core	Inner layer	Inner surface
	Elongated to equant	5	Planar, vughs	Strong-medium		Highly	Red, reddish brown, reddish yellow + yellow (in XPL)	<750		Oxidised	Oxidised	Oxidised	
		5	Planar, vughs	Strong-medium		Highly	Yellow, brownish yellow	<750		Oxidised	Oxidised	Oxidised	
	Elongated to equant	5	Planar, vughs	Strong-medium		Highly	Yellow, brownish yellow	<750		Oxidised	Oxidised	Oxidised	
	Equant to elongated	15	Planar, vughs	Strong-medium		None in core, highly below surface	Red, reddish yellow, dark grey	<750		Reduced	Reduced	Oxidised	
	Elongated to equant	5	Vughs, planar	Medium-weak	Light yellow to green-gray	Highly	Red, reddish brown, reddish yellow + yellow (in XPL)	<800		Oxidised	Oxidised	Oxidised	
		<5	Planar, vughs	Weak		Slightly	Reddish brown, reddish yellow	<850		Oxidised	Oxidised	Oxidised	
		5	Vughs, planar	Weak-none		Slightly to none, vitrified	Grey, dark grey	950–1000		Reduced	Reduced	Reduced	
		<5	Vughs, planar	Weak		Slightly	Reddish brown, red	<850		Oxidised	Weakly reduced	Oxidised	
	Elongated to equant	10	Planar, vughs	Strong-medium		Highly	Red, reddish brown, reddish yellow, brown, dark brown + yellow (XPL)	<750		Reduced	Reduced	Oxidised	
	Equant to elongated	5	Planar, vughs	Strong		Highly	Red, reddish yellow + yellow (in XPL)	<700	Smoked	Oxidised	Oxidised	Oxidised	
	Equant to elongated	10	Planar, vughs	Strong	Transparent to light green	Highly	Yellow, pale brown + yellow (in XPL)	<700		Weakly oxidised	Weakly oxidised	Weakly oxidised	
		5	Vughs, planar	Strong-medium		Highly	Layers of red + reddish brown, yellowish brown, dark greyish brown	<750		Oxidised	Reduced	Oxidised	
	Equant to elongated	5	Planar, vughs	Strong		Highly	Red, reddish brown, reddish yellow + yellow (in XPL)	<700		Oxidised	Weakly reduced	Oxidised	
		5	Vughs, planar	Strong		Highly	Yellow, reddish yellow	<700	Smoked	Oxidised	Oxidised	Oxidised	
		5	Vughs, planar	Strong		Highly	Yellow, very pale brown + yellow (in XPL)	<700		Oxidised	Oxidised	Oxidised	
	Equant to elongated	5	Planar, vughs	Strong		Highly/none	Layers of very pale brown and dark greish brown (in core)	<700		Weakly reduced	Reduced	Weakly reduced	
	Equant to elongated	10	Planar, vughs	Strong		Highly	Red, reddish brown, reddish yellow + yellow (in XPL)	<700		Oxidised	Oxidised	Oxidised	
		5	Vughs	Weak-none				<900		Oxidised	Oxidised	Oxidised	

ID	Fabric	Microstructure	Microstructure – note	Sorting	Calcareous matrix	Grain size distribution	Aplastics (vol. %)	Aplastics size (µm)	Avg. aplastics size (µm)	Spacing	Aplastics shape	Shape 2	Mineral temper (vol. %)	Mineral temper size (µm)	Avg. mineral temper size (µm)	Spacing
2	D	Weakly parallel		Very poor	✓	Unimodal	15	<1200	~450	Double	Sub-angular to sub-rounded	Equant to elongated				
3	C	Parallel		Very poor	✓	Bimodal	1	<30		Open	Sub-angular to sub-rounded	Equant	15	~120–1100	~400	Double
4	C	Weakly parallel		Very poor	✓	Bimodal	1	<30		Open	Sub-angular to sub-rounded	Equant	15	~100–2700	~800	Double
5	A	Weakly parallel		Very poor	✓	Unimodal	20	<1800	~300	Single	Sub-angular to sub-rounded	Equant to elongated				
6	A	Weakly parallel		Very poor	✓	Unimodal	20	<1200	~300	Single	Sub-angular to sub-rounded	Equant to elongated				
7	A	Weakly parallel	Coiling	Very poor	✓	Unimodal	15	<1900	~300	Double	Sub-angular to sub-rounded	Equant to elongated				
8	A	Weakly parallel		Very poor	✓	Unimodal	20	<1200	~200	Single	Sub-angular to sub-rounded	Equant to elongated				
9	B	Unpar-allel	Coiling	Very poor	✓	Unimodal – tempered	30	<650	~150	Close	Sub-angular to sub-rounded	Elongated to equant		Graphitic temper ~70–1500	~350	
10	B	Weakly parallel		Poor	✓	Unimodal – tempered	35	<500	~150	Close	Sub-angular to sub-rounded	Elongated to equant		Graphitic temper ~60–1000	~300	
11	B	Weakly parallel		Very poor	✓	Unimodal – tempered	25	<600	~200	Close	Sub-angular to sub-rounded	Elongated to equant		Graphitic temper ~50–1500	~350	
12	Pottery fragment	Parallel		Very poor	✓	Unimodal	15	<1600	~300	Double	Sub-angular to sub-rounded	Elongated to equant				

Appendix 2-B. Jihlava – Křížová Street, kiln 927. Description of structural and technological characteristics.

	Mineral temper shape	Mineral temper shape 2	Voids (vol. %)	Voids shape	Biotite pleochroism	Green amphibole pleochroism	Matrix optical activity	Matrix colour	Firing temperature (°c)	Outer surface	Outer layer	Core	Inner layer	Inner surface smoked
			5	Vughs, planar	Weak-none	✓	Slightly, none in core	Grey, dark grey (in core)	<1000	Glaze	Reduced	Reduced	Reduced	Galze
	Angular to subangular	Elon-gated	<5	Vughs	Medium	✓	Highly	Brownish yellow, reddish yellow + yellow (in XPL)	<800	Locally mica	Oxidised	Oxidised	Oxidised	Locally mica
	Angular to subangular	Elon-gated	<5	Vughs	Medium	✓	Moderately	Brownish yellow, reddish, brown + yellow (in XPL)	<800		Oxidised	Oxidised	Oxidised	
			5	Vughs, planar	None	✓	Moderately, none in core	Red, dark red, reddish brown, reddish black	<950		Oxidised	Weakly reduced	Oxidised	
			5	Vughs, planar	Medium-none	✓	Highly	Reddish yellow, red + yellow (in XPL)	<850		Oxidised	Oxidised	Oxidised	
			15	Cham-bers, vughs, planar	Weak-none	✓	Moderately, none in core	Bands of red, grey, black in core, reddish brown	<900		Weakly oxidised	Reduced	Oxidised	
			5	Vughs, planar	Medium-none	✓	None	Grey, reddish grey, black, brown	<950		Weakly reduced	Weakly reduced	Weakly reduced	
			1	Vughs	Medium	✓	Moderately	Red, reddish yel-low, reddish brown + yellow (in XPL)	<800		Oxidised	Oxidised	Oxidised	
			5	Vughs, planar	Medium	✓	Highly, none in core	Light brown, grey, black in core + yellowish brown (in XPL)	<900		Weakly oxidised	Reduced	Weakly oxidised	
			10	Vughs, planar	Medium	✓	Slightly	Red, dark red, reddish brown	<850		Oxidised	Oxidised	Oxidised	
			20	Planar, vughs	Medium	✓	None	Black	<950		Reduced	Reduced	Reduced	

ID	Microstructure	Microstructure – note	Sorting	Calcareous matrix	Grain size distribution	Aplastics (vol. %)	Aplastics size (µm)	Avg. aplastics size (µm)	Spacing	Aplastics shape	Shape 2	Mineral temper (vol. %)	Mineral temper size (µm)	Avg. mineral temper size (µm)	Spacing	Mineral temper shape	
1	Weakly parallel		Poor		Unimodal	20	<1200	~150	Single spaced	Sub-angular	Equant to elongated						
2	Weakly parallel		Very poor		Unimodal	15	<1600	~150	Double spaced	Sub-angular to sub-rounded	Equant to elongated						
3	Weakly parallel	Coiling	Very poor		Unimodal	20	<1200	~150	Single spaced	Sub-angular	Equant to elongated						
4	Weakly parallel		Very poor		Unimodal	15	<1200	~150	Double spaced	Sub-angular	Equant to elongated						
5	Parallel		Very poor		Unimodal	20	<1200	~150	Single spaced	Sub-angular	Equant to elongated						
6	Weakly parallel		Very poor		Unimodal	15	<3000	~200	Double spaced	Sub-angular to sub-rounded	Equant to elongated						
7	Weakly parallel		Very poor		Unimodal	15	<2200	~150	Double spaced	Sub-angular	Equant to elongated						
8	Weakly parallel	Coiling	Very poor		Weakly bimodal	<5	<80		Open spaced	Sub-angular	Equant to elongated	20	<1600	~320	Single spaced	Sub-angular to sub-rounded	
9	Weakly parallel	Coiling	Very poor		Unimodal	10	<1800	~150	Open spaced	Sub-angular to sub-rounded	Equant to elongated						
10	Weakly parallel		Very poor		Unimodal	10	<1900	~220	Open spaced	Sub-angular to sub-rounded	Equant to elongated						
11	Weakly parallel		Very poor		Weakly bimodal	<5	<40		Open spaced	Sub-angular to sub-rounded	Equant to elongated	15	<1400	~280	Double spaced	Sub-angular to sub-rounded	
12	Weakly parallel		Poor		Unimodal	15	<1400	~300	Double spaced	Sub-angular to rounded	Equant to elongated						
13	Weakly parallel		Very poor		Unimodal	15	<1400	~220	Double spaced	Sub-angular to rounded	Equant to elongated						
14	Weakly parallel		Very poor		Unimodal	15	<1100	~150	Double spaced	Sub-angular to sub-rounded	Equant to elongated						
15	Weakly parallel		Poor		Unimodal	15	<1200	~280	Double spaced	Sub-angular to sub-rounded	Equant to elongated						
16	Weakly parallel		Very poor		Unimodal	20	<2000	~200	Single spaced	Sub-angular to sub-rounded	Equant to elongated						
17	Weakly parallel	Coiling	Very poor		Unimodal	15	<1600	~200	Double spaced	Sub-angular to sub-rounded	Equant to elongated						
18	Weakly parallel		Very poor		Unimodal	20	<1300	~150	Single spaced	Sub-angular to sub-rounded	Equant to elongated						
19	Weakly parallel		Very poor		Unimodal	20	<1400	~200	Single spaced	Sub-angular to sub-rounded	Equant to elongated						
20	Weakly parallel		Very poor		Unimodal	20	<1500	~160	Single spaced	Sub-angular to sub-rounded	Equant to elongated						

Appendix 2-C. Kostelec near Jihlava. Description of structural and technological characteristics.

	Mineral temper shape 2	Voids (vol. %)	Voids shape	Biotite pleochroism	Green amphibole pleochroism	Matrix optical activity	Matrix colour	Firing temperature (°c)	Outer surface smoked	Outer layer	Core	Inner layer	Inner surface smoked
		5	Vughs, planar	Medium to none	Transparent to green/ green-brown	Slight, none in core	Very pale brown, dark greyish brown, brown in core	<850		Weakly reduced	Reduced	Weakly reduced	
		5	Vughs, planar	Strong to medium	Transparent to green	Slight, none in core	Dark greyish brown, pale brown, very dark brown in core	<750	✓	Weakly reduced	Reduced	Weakly reduced	✓
		5	Vughs, planar	Strong		High/moderate	Reddish yellow (+ yellow in XPL), dark brown in core	<700		Weakly oxidised	Reduced	Weakly oxidised	
		5	Vughs, planar	Strong		High, slight in core	Brown, light yellowish brown (+ yellow in XPL), black in core	<700	✓	Weakly oxidised	Reduced	Weakly oxidised	✓
		5	Vughs, planar	Strong		High, slight in core	Brown, light yellowish brown (+ yellow in XPL), black in core	<700	✓	Weakly oxidised	Reduced	Weakly oxidised	✓
		5	Vughs, planar	Medium to strong	Transparent to green	Moderate, none in core	Brown, reddish yellow (+ yellow in XPL), light yellowish brown, black core	<750	✓	Weakly oxidised	Reduced	Weakly oxidised	✓
		5	Vughs, planar	Medium	Transparent to green-brown	Moderate, slight in core	Very pale brown, greyish brown, very dark brown in core	<850	✓	Weakly reduced	Reduced	Weakly reduced	✓
	Equant to elongated	5	Vughs, planar	Strong	Transparent to green	High, none in core	Dark brown, very pale brown (+ yellow in XPL), black in core	<700	✓	Weakly oxidised	Reduced	Weakly oxidised	✓
		5	Vughs, planar	None to medium	Transparent to green	Slight/moderate, none in core	Brown, very pale brown, brownish yellow (+ yellow in XPL), black core	<800	✓	Weakly oxidised	Reduced	Weakly oxidised	
		10	Vughs, planar	Medium	Light green to green, yellow-green to brown-red	High/medium, none in core	Yellow, very pale brown, very dark brown, black in core	<800	✓	Weakly oxidised	Reduced	Weakly oxidised	✓
	Equant to elongated	5	Vughs, planar	Strong		High, none in core	Yellowish brown, black in core	<700		Weakly reduced	Reduced	Weakly reduced	
		5	Vughs, planar	Medium	Yellow-green to dark brown	Moderate, none in core	Dark yellowish brown, very pale brown (+ yellow in XPL), black core	<800	✓	Weakly reduced	Reduced	Weakly reduced	✓
		10	Vughs, planar	None to weak	Yellow-green to dark brown	High, weak/none in core	Yellow, bery pale brown, very dark greyish brown in core	<850		Weakly oxidised	Reduced	Weakly oxidised	
		5	Vughs, planar	None to medium	Yellow-green to brown-green	High, none in core	Very pale brown, pale brown, very dark brown in core	<850	✓	Weakly reduced	Reduced	Weakly reduced	✓
		1	Vughs, planar	Strong	Yellow to green	High, none in core	Yellow, very dark brown in core	<700	✓	Weakly oxidised	Reduced	Weakly oxidised	✓
		5	Vughs, planar	Strong	Green to brown-green	High/slight, none in core	Very pale brown, very dark brown in core	<700	✓	Weakly reduced	Reduced	Weakly reduced	✓
		5	Vughs, planar	None to medium		High/slight, none in core	Brown, very pale brown, black in core	<850	✓	Weakly reduced	Reduced	Weakly reduced	✓
		5	Vughs, planar	Medium	Transparent to green	Brown to dark brown	Slight, none in core,very pale brown, black in core	<850		Weakly reduced	Reduced	Weakly reduced	
		5	Vughs, planar	Strong		Moderate, none in core	Brown, brownish yellow, black in core	<750	✓	Weakly reduced	Reduced	Reduced	✓
		5	Vughs, planar	Medium strong		High, slight in core	Very pale brown, very dark brown in core	<750	✓	Weakly reduced	Reduced	Reduced	✓

ID	Fabric	Microstructure	Sorting	Calcareous matrix	Grain size distribution	Aplastics (vol. %)	Aplastics size (µm)	Avg. aplastics size (µm)	Spacing	Aplastics shape	Shape 2	Mineral temper (vol. %)	Mineral temper size (µm)	Avg. mineral temper size (µm)	Spacing	Mineral temper shape	
1	B3	Unparallel	Poor		Uni-modal	25	<2000	~100	Single spaced	Angular to sub-rounded	Elongated to equant						
3	A1	Weakly parallel	Very poor		Uni-modal	20	<3000	~300	Single spaced	Sub-angular to sub-rounded	Equant to elongated						
4	A2	Weakly parallel	Very poor		Uni-modal	30	<2200	~200	Close spaced	Sub-rounded to rounded	Elongated to equant						
5	A2	Weakly parallel	Very poor		Uni-modal	30	<3400	~250	Close spaced	Sub-rounded to rounded	Elongated to equant						
6	C1	Parallel	Poor		Uni-modal	15	<2600	~300	Double spaced	Sub-angular to sub-rounded	Elongated to equant						
7	A1	Weakly parallel	Very poor		Uni-modal	25	<2600	~400	Single spaced	Sub-angular to sub-rounded	Equant to elongated						
8	A2	Weakly parallel	Very poor		Uni-modal	30	<1300	~180	Close spaced	Sub-rounded to rounded	Elongated to equant						
9	B1	Weakly parallel	Very poor		Bimodal	1	<20		Open spaced	Sub-rounded to rounded	Elongated to equant	25	<2800	~300	Single spaced	Sub-angular to sub-rounded	
10	A1	Weakly parallel	Very poor		Uni-modal	15	<2800	~150	Double spaced	Sub-angular to sub-rounded	Equant to elongated						
11	A1	Weakly parallel	Very poor		Uni-modal	20	<3200	~300	Single spaced	Sub-angular	Equant to elongated						
12	A2	Weakly parallel	Very poor		Uni-modal	30	<2300	~300	Close spaced	Sub-rounded to rounded	Elongated to equant						
13	A1	Weakly parallel	Poor		Uni-modal	15	<1800	~150	Double spaced	Sub-rounded	Elongated to equant						
14	C1	Parallel	Poor		Uni-modal	15	<1500	~200	Double spaced	Sub-angular	Elongated to equant						
15	A1	Weakly parallel	Very poor		Uni-modal	25	<2000	~300	Single spaced	Sub-angular to sub-rounded	Elongated to equant						
16	B2	Weakly parallel	Very poor		Uni-modal	25	<1500	~100	Single spaced	Sub-angular to sub-rounded	Equant to elongated						
17	A1	Parallel	Very poor		Uni-modal	20	<2200	~350	Single spaced	Sub-angular to rounded	Elongated to equant						
18	A1	Weakly parallel	Very poor		Uni-modal	20	<1600	~200	Single spaced	Sub-angular to sub-rounded	Elongated to equant						
19	C2	Weakly parallel	Poor		Uni-modal	30	<2500	~200	Close spaced	Sub-angular to rounded	Elongated to equant						
20	A1	Weakly parallel	Poor		Uni-modal	15	<1500	~220	Double spaced	Sub-rounded	Elongated to equant						
21	B4	Parallel	Very poor		Bimodal	5	<80		Open spaced	Sub-angular to sub-rounded	Equant to elongated	15	<2600	~600	Double spaced	Angular to sub-angular	
22	A1	Weakly parallel	Very poor		Uni-modal	25	<3000	~300	Single spaced	Sub-angular to sub-rounded	Elongated to equant						
23	D	Weakly parallel	Poor	✓	Uni-modal	15	<900	~200	Double spaced	Sub-angular to sub-rounded	Equant to elongated						

Appendix 2-D. Mstěnice – both kilns. Description of structural and technological characteristics.

	Mineral temper shape 2	Voids (vol. %)	Voids shape	Biotite pleochroism	Green amphibole pleochroism	Matrix optical activity	Matrix colour	Firing temperature (°c)	Outer surface smoked	Outer layer	Core	Inner layer	Inner surface smoked
		1	Vughs, planar	Strong		High	Very pale brown, yellowish red, black	<700		Mixed	Reduced	Oxidised	
		1	Vughs, planar	Medium		Moderate	Reddish yellow (+ yellow in XPL)	<700	✓	Weakly oxidised	Weakly oxidised	Weakly oxidised	✓
		5	Vughs, planar	Weak		Moderate	Brown, dark greyish brown, yellowish brown	<800	✓	Reduced	Reduced	Weakly reduced	✓
		5	Vughs, planar	Weak		Moderate	Very pale brown, brown, dark brown	<800	✓	Reduced	Reduced	Weakly reduced	✓
		1	Vughs	None to medium	Gray-green to light brown	Moderate	Strong brown, reddish yellow	<800		Weakly oxidised	Weakly oxidised	Weakly oxidised	
		1	Vughs	Weak		Slight/ none in core	Brown, reddish yellow	~950		Weakly oxidised	Reduced	Reduced	
		5	Vughs, planar	Weak		High	Brown, reddish yellow	<800	✓	Weakly oxidised	Weakly oxidised	Weakly oxidised	✓
	Equant to elongated	1	Vughs	Medium to strong		High	Very pale yellow, reddish yellow, strong brown (+ yellow in XPL)	<700		Weakly oxidised	Weakly oxidised	Weakly oxidised	
		1	Vughs	Medium		High	Yellowish red, strong brown	<800	✓	Weakly oxidised	Weakly oxidised	Weakly oxidised	
		1	Vughs	Medium	Transparent to light orange-green	High	Yellowish red, brown, very pale brown	<700	✓	Reduced	Weakly reduced	Weakly oxidised	
		5	Vughs, planar	Weak		Moderate	Very pale brown, greyish brown (+ yellow in XPL)	<800	✓	Reduced	Reduced	Weakly reduced	✓
		1	Vughs	Weak to none	Light yellow-green to red-brown	Slighte/ none in core	Dark brown, strong brown, brown	850-900	✓	Reduced	Reduced	Weakly reduced	✓
		1	Vughs	None to medium		Modreate	Reddish yellow	<800		Weakly oxidised	Weakly oxidised	Weakly oxidised	
		1	Vughs	Medium	Transparent to green	Slight	Dark brown under surface, reddish yellow, brown	<700	✓	Weakly oxidised	Weakly oxidised	Weakly oxidised	✓
		<5	Vughs	Medium	Light yellow-green to red-brown	High-moderate	Yellowish red, strong brown, reddish brown	<750		Reduced	Weakly oxidised	Weakly oxidised	
		5	Vughs, planar	None to medium		Moderate	Reddish yellow	<800	✓	Weakly oxidised	Weakly oxidised	Weakly oxidised	✓
		5	Vughs	Strong		Moderate	Reddish yellow	<700		Weakly oxidised	Weakly oxidised	Weakly oxidised	
		1	Vughs, planar	Strong	Light gray to light red	Moderate	Yellowish red, greyish brown, red	<700	✓	Weakly oxidised	Weakly reduced	Weakly oxidised	✓
		1	Vughs	None to weak		Moderate	Dark brown under surface, greyish brown, yellowish red	<850	✓	Reduced	Weakly oxidised	Weakly reduced	✓
	Elongated to equant	5	Planar	Very strong		High	Reddish yellow, very pale brown, strong brown	<700		Weakly oxidised	Weakly oxidised	Weakly oxidised	
		5	Vughs	Weak		Moderate	Reddish yellow, brown	<800	✓	Reduced	Weakly oxidised	Weakly reduced	
		<5	Vughs, planar	Strong	Yellow-green to red-brown	Moderate	Very dark greyish brown below surface, pale brown, reddish yellow core (+ yellow in XPL)	<750	✓	Reduced	Weakly oxidised	Weakly reduced	✓

ID	Fabric	Microstructure	Sorting	Calcareous matrix	Grain size distribution	Aplastics (vol. %)	Aplastics size (µm)	Avg. aplastics size (µm)	Spacing	Aplastics shape	Shape 2	Mineral temper (vol. %)	Mineral temper size (µm)	Avg. mineral temper size (µm)
1	A1	Moderately parallel	Poorly sorted	✓	Moderately bimodal	5	<500 (Biotite), <40 (other)	~160 (Biotite)	Open spaced	Subangular-rounded	Elongated-equant	10	<1600	~340
2	A1	Weakly parallel	Poorly sorted	✓	Bimodal	5	<200 (Biotite), <30 (other)	~60 (Biotite)	Open spaced	Subangular	Elongated-equant	5	<850	~250
3	A1	Weakly parallel	Poorly sorted	✓	Bimodal	5	<360 (Biotite), <40 (other)	~80 (Biotite)	Open spaced	Subangular	Elongated-equant	10	<1600	~400
4	A1	Weakly parallel	Poorly sorted	✓	Strongly bimodal	1	<320 (Biotite), <60 (other)	~100 (Biotite)	Open spaced	Subangular	Elongated-equant	5	<1000	~300
5	A2	Unparallel	Poorly sorted	✓	Unimodal/ weakly bimodal	30	<1300	~300	Close spaced	Subangular-subrounded	Equant			
6	A1	Weakly parallel	Very poorly sorted	✓	Strongly bimodal	5	<250 (Biotite), <60 (other)	~80 (Biotite)	Open spaced	Subangular	Elongated-equant	10	<2000	~500
7	A1	Unparallel	Poorly sorted	✓	Bimodal	5	<200 (Biotite), <40 (other)	~100 (Biotite)	Open spaced	Subangular	Elongated-equant	10	<1600	~400
8	B	Weakly parallel	Very poorly sorted	✓	Strongly bimodal	5	<80		Open spaced	Subangular-subrounded	Elongated-equant	20	<3500	~300
9	A1	Weakly parallel	Poorly sorted	✓	Weakly bimodal	5	<500 (Biotite), <50 (other)	~100 (Biotite)	Open spaced	Subrounded	Elongated-equant	5	<1100	~500
10	A1	Parallel	Poorly sorted	✓	Bimodal	5	<350 (Biotite), <80 (other)	~100 (Biotite)	Open spaced	Subrounded	Elongated-equant	5	<1000	~550
11	A1	Parallel	Poorly sorted	✓	Bimodal	5	<250 (Biotite), <80 (other)	~80 (Biotite)	Open spaced	Subrounded	Elongated-equant	5	<2000	~500
12	A1	Weakly parallel	Poorly sorted	✓	Weakly bimodal	5	<350 (Biotite), <80 (other)	~100 (Biotite)	Open spaced	Subangular	Elongated-equant	5	<1200	~400
13	A1	Weakly parallel	Very poorly sorted	✓	Strongly bimodal	5	<300 (Biotite), <40 (other)	~150 (Biotite)	Open spaced	Subangular	Elongated-equant	15	<1200	~600
14	A1	Weakly parallel	Poorly sorted	✓	Bimodal	5	<200 (Biotite), <60 (other)	~100 (Biotite)	Open spaced	Subangular	Elongated-equant	5	<1600	~550
15	Brick – ref. Sample	Unparallel	Very poorly sorted	✓	Weakly bimodal	20	<4500	~450	Single spaced	Subangular-subrounded	Elongated-equant	10		

Appendix 2-E. Žďár nad Sázavou – 'Staré Město'. Description of structural and technological characteristics.

	Spacing	Mineral temper shape	Mineral temper shape 2	Voids (vol. %)	Voids shape	Biotite pleochroism	Matrix optical activity	Matrix colour	Temperature	Outside surface	Core	Inside surface	Surface
	Double-spaced	Subangular	Elongated	<5	Vughs, planar	Strong	High/slight in core	Very pale brown, very dark brown in core (+ yellow in XPL)	<700	Oxidised	Reduced	Oxidised	
	Open-spaced	Subangular-subrouded	Elonated-equant	1	Vughs	Medium	Medium	Very pale brown, dark brown in core (+ yellow in XPL)	<800	Oxidised	Reduced	Oxidised	
	Double-spaced	Subangular-subrouded	Elonated-equant	10	Planar, vughs	Medium	Slight	Dark-very dark brown	<800	Reduced	Reduced	Reduced	
	Double-spaced	Subangular	Elonated-equant	1	Planar, vughs	Medium	Medium	Yellowish brown, dark brown in core	<800	Oxidised	Reduced	Oxidised	Smoked
				5	Vughs	Strong	Medium	Very pale brown below surface, brown, dark brown (+ yellow in XPL)	<700	Oxidised	Reduced	Reduced	
	Double-spaced	Subangular	Elonated-equant	10	Planar, vughs, chambers	Medium	High	Pale brown (+ yellow in XPL)	<800	Oxidised	Reduced	Reduced	
	Double-spaced	Subangular-subrounded	Elonated-equant	1	Vughs	Medium	Medium	Yellowish brown, dark brown in core	<800	Oxidised	Reduced	Oxidised	Smoked
	Single-spaced	Subrounded	Elonated-equant	1	Vughs	Weak	Medium	Very pale brown below surface, reddish brown	<850	Oxidised	Reduced	Oxidised	
	Open-spaced	Subangular	Equant	1	Vughs, planar	Medium	Slight	Dark-very dark brown	<800	Oxidised	Reduced	Reduced	
	Open-spaced	Subangular	Equant	5	Planar, vughs	Medium	Medium	Yellowish brown, dark brown in core	<800	Oxidised	Reduced	Oxidised	Smoked
	Open-spaced	Subangular	Equant	5	Planar, vughs	Medium-strong	Medium	Yellowish brown, dark brown in core	<750	Oxidised	Reduced	Oxidised	Smoked
	Open-spaced	Subangular-subrouded	Elonated-equant	1	Vughs	Weak	Medium	Yellowish brown, dark brown in core	<850	Oxidised	Oxidised	Oxidised	
	Double-spaced	Subangular-subrouded	Elonated-equant	5	Planar, vughs	Medium-strong	High/slight in core	Very pale brown below surface, very dark brown in core (+ yellow in XPL)	<750	Oxidised	Reduced	Oxidised	
	Open-spaced	Subangular-subrouded	Elonated-equant	1	Vughs, planar	Medium	High/slight in core	Very pale brown below surface, very dark brown in core (+ yellow in XPL)	<800	Oxidised	Reduced	Oxidised	
	Open-spaced	Angular-subangular	Elongated	1	Planar, vughs	Weak	High-medium	Reddish yellow, yellowish red (+ yellow in XPL)	<850	Oxidised	Oxidised	Oxidised	

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ID	Kiln/hoard	Fabric	Microstructure	Sorting	Grain size distribution	Aplastics (vol. %)	Aplastics size (µm)	Avg. aplastics size (µm)	Spacing	Aplastics shape	Aplastics shape 2	Mineral temper (vol. %)	Mineral temper size (µm)	Avg. mineral temper size (µm)	Spacing	Mineral temper shape	
1	Feature 11	A	Unparallel	Very poor	Uni-modal	40	<2200	~200	Close spaced	Sub-angular to rounded	Equant to elongated						
2	Feature 11	A	Weakly parallel	Very poor	Uni-modal	35	<1200	~150	Close spaced	Sub-angular to sub-rounded	Equant to elongated						
3	Feature 11	B2	Weakly parallel	Very poor	Bimodal	1	<60		Open spaced	Sub-angular to sub-rounded	Equant to elongated	20	<1800	~550	Single spaced	Sub-angular to sub-rounded	
4	Feature 11	A	Weakly parallel	Very poor	Uni-modal	20	<1400	~250	Single spaced	Sub-angular to rounded	Equant to elongated						
5	Feature 11	Sm4	Weakly parallel	Very poor	Bimodal	<5	<40		Open spaced	Sub-angular to sub-rounded	Elongated	35	<3000	~500	Close spaced	Sub-angular	
6	Feature 11	A	Weakly parallel	Very poor	Uni-modal	15	<2000	~150	Double spaced	Sub-angular to sub-rounded	Equant to elongated						
7	Feature 11	B2	Weakly parallel	Very poor	Bimodal	1	<60		Open spaced	Sub-angular to sub-rounded	Equant to elongated	20	<1800	~300	Single spaced	Sub-angular to sub-rounded	
8	Feature 11	B2	Weakly parallel	Very poor	Bimodal	1	<40		Open spaced	Sub-angular to sub-rounded	Equant to elongated	20	<1000	~300	Single spaced	Sub-angular to sub-rounded	
9	Feature 11	B2	Weakly parallel	Very poor	Bimodal	15	<100		Double spaced	Sub-angular to sub-rounded	Equant to elongated	10	<2600	~450	Open spaced	Sub-angular to sub-rounded	
10	Feature 11	A	Unparallel	Very poor	Uni-modal	20	<1300	~100	Single-double spaced	Sub-angular to sub-rounded	Equant to elongated						
11	Feature 11	Sm3	Weakly parallel	Poor	Bimodal	<5	<100		Open spaced	Sub-angular to sub-rounded	Equant to elongated	10	<1500	~600	Open spaced	Sub-angular to sub-rounded	
12	Feature 11	Sm3	Weakly parallel	Very poor	Bimodal	1	<80		Open spaced	Sub-angular to sub-rounded	Equant to elongated	25	<4000	~1200	Single spaced	Sub-angular to sub-rounded	
13	Feature 11	A	Weakly parallel	Very poor	Uni-modal	35	<1600	~100	Close spaced	Sub-angular to rounded	Equant to elongated						
14	Feature 11	B3	Weakly parallel	Poor	Bimodal	15	<80		Double spaced	Sub-angular to sub-rounded	Equant to elongated	15	<2000	~450	Double spaced	Sub-angular to sub-rounded	
15	Feature 11	B1	Unparallel	Very poor	Bimodal	5	<60		Open spaced	Sub-angular to sub-rounded	Equant to elongated	30	<2600	~350	Close spaced	Sub-angular to sub-rounded	
16	Feature 11	B1	Parallel	Very poor	Bimodal	<5	<60		Open spaced	Sub-angular to sub-rounded	Equant to elongated	20	<2200	~400	Single spaced	Sub-angular to sub-rounded	
17	Feature 11	B3	Weakly parallel	Very poor	Bimodal	15	<80		Double spaced	Sub-angular to sub-rounded	Equant to elongated	15	<1800	~400	Double spaced	Sub-angular to sub-rounded	
18	Feature 11	B3	Weakly parallel	Very poor	Bimodal	15	<80		Double spaced	Sub-angular to sub-rounded	Equant to elongated	15	<1800	~500	Double spaced	Sub-angular to sub-rounded	
19	Feature III/98	A	Weakly parallel	Poor	Uni-modal	40	<1000	~140	Close spaced	Sub-angular to sub-rounded	Rounded						
20	Feature III/98	A	Weakly parallel	Poor	Uni-modal	30	<1300	~100	Close spaced	Sub-angular to sub-rounded	Rounded						
21	Feature III/98	B2	Weakly parallel	Very poor	Bimodal	5	<60		Open spaced	Sub-angular to sub-rounded	Equant to elongated	25	<1800	~300	Single spaced	Sub-angular to sub-rounded	

	Mineral temper shape 2	Voids (vol. %)	Voids shape	Biotite pleochroism	Green amphibole pleochroism	Matrix optical activity	Matrix colour	Firing temperature (°c)	Outer layer	Core	Inner layer
		<5	Vughs	Weak	Green-brown to brown	Medium	Reddish yellow, yellowish red (+ yellow in XPL)	750–900	Oxidised	Oxidised	Oxidised
		5	Planar; vughs	Weak	Yellow-brown	Medium, locally inactive	Yellowish brown	800–900	Weakly oxidised	Weakly oxidised	Weakly oxidised
	Equant to elongated	30	Vughs; planar		Light brown-green	Slight-none	Reddish yellow, yellowish red, grey	800–900	Oxidised	Oxidised	Weakly oxidised
		15	Vughs; planar	Medium	Green-brown to red-brown	Medium	Yellowish red, light brown	750–900	Oxidised	Oxidised	Reduced
	Elongated	5	Vughs	Medium to weak		High, none in core	Brown below surface, black	800–900	Oxidised	Reduced	Reduced
		5	Vughs; planar	Medium	Light green-brown	High	Reddish yellow (+ yellow in XPL)	750–900	Oxidised; black-smoked	Oxidised	Weakly oxidised
	Equant to elongated	5	Planar; vughs	Weak	Green-brown to green	Medium	Reddish-dark reddish brown	800–900	Reduced	Oxidised	Oxidised
	Equant to elongated	15	Planar; vughs		Light green-yellow to brown-green	High, locally inactive	Yellowish red, grey (+ yellow in XPL)	800–900	Oxidised	Reduced	Reduced
	Equant to elongated	10	Chambers; vughs; planar	Weak		High	Reddish yellow, yellowish red (+ yellow in XPL)	800–900	Oxidised	Weakly oxidised	Oxidised
		<5	Vughs	Weak	Light green	Medium	Reddish yellow, yellowish red	<850	Oxidised	Oxidised	Oxidised
	Equant to elongated	10	Planar; vughs	None		None in core	Light-dark grey, reddish yellow below surface	950–1000	Weakly oxidised	Reduced	Weakly oxidised
	Equant to elongated	20	Planar; vughs	Weak		Locally inactive	Light-dark grey	1000–1050	Weakly oxidised	Reduced	Weakly oxidised
		15	Planar	None	Yellow-brown-green to red-brown	Medium	Brown, reddish yellow	800–900	Weakly oxidised	Weakly oxidised	Weakly oxidised
	Equant to elongated	10	Planar; vughs	None		None	Grey	850–950	Reduced	Reduced	Reduced
	Equant to elongated	5	Vughs; planar	Medium	Light brown-green to red-brown	Medium	Yellowish red (+ yellow in XPL)	750–900	Oxidised	Oxidised	Oxidised
	Equant to elongated	15	Planar; vughs	Weak	Light green	High	Very pale brown, grey (+ yellow in XPL)	<850	Oxidised, black-smoked	Reduced	Oxidised
	Equant to elongated	10	Planar; vughs	Medium to none	Light green-yellow to dark red-brown	Slight	Yellowish red, brown, dark reddish brown	750–900	Weakly oxidised	Weakly oxidised	Weakly oxidised
	Equant to elongated	25	Planar; vughs; bubbles	None		None, locally melted	Greyish brown	1000–1050/1100	Reduced	Reduced	Reduced
		20	Planar; vughs	None		Slight, locally inactive	Greyish brown, very dark grey in XPL	1000–1050/1100	Reduced	Reduced	Reduced
		15	Planar	None		Medium	Dark yellowish brown	700–900	Weakly oxidised	Weakly oxidised	Weakly oxidised
	Rounded	5	Planar; vughs	Weak	Green-brown to black	Medium	Reddish yellow (+ yellow in XPL)	750–900	Oxidised	Oxidised	Oxidised

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ID	Kiln/hoard	Fabric	Microstructure	Sorting	Grain size distribution	Aplastics (vol. %)	Aplastics size (µm)	Avg. aplastics size (µm)	Spacing	Aplastics shape	Aplastics shape 2	Mineral temper (vol. %)	Mineral temper size (µm)	Avg. mineral temper size (µm)	Spacing	Mineral temper shape	
22	Feature III/98	A	Weakly parallel	Poor	Uni-modal	20	<1000	~150	Single spaced	Sub-angular to sub-rounded	Rounded						
23	Feature III/98	A	Weakly parallel	Poor	Uni-modal	20	<1100	~140	Single spaced	Sub-angular to sub-rounded	Rounded						
24	Feature III/98	B2	Weakly parallel	Very poor	Bimodal	1	<60		Open spaced	Sub-angular to sub-rounded	Equant to elongated	20	<900	~250	Single spaced	Sub-rounded to rounded	
25	Feature III/98	A	Weakly parallel	Poor	Uni-modal	30	<1100	~100	Close spaced	Sub-rounded to rounded	Equant to elongated						
26	Feature III/98	A	Weakly parallel	Poor	Uni-modal	30	<900	~120	Close spaced	Sub-angular to sub-rounded	Rounded						
27	Feature III/98	A	Weakly parallel	Very poor	Uni-modal	25	<1600	~140	Single spaced	Sub-angular to rounded	Rounded						
28	Feature III/98	A	Weakly parallel	Poor	Uni-modal	30	<1500	~120	Close spaced	Sub-angular to sub-rounded	Equant to elongated						
29	Feature III/98	A	Weakly parallel	Poor	Uni-modal	20	<800	~150	Single spaced	Sub-angular to sub-rounded	Equant to elongated						
30	Feature III/98	A	Weakly parallel	Poor	Uni-modal	30	<1300	~180	Close spaced	Sub-rounded to rounded	Rounded						
31	Feature III/98	A	Weakly parallel	Poor	Uni-modal	20	<1200	~130	Single spaced	Sub-angular to sub-rounded	Rounded						
32	Feature III/98	A	Weakly parallel	Very poor	Uni-modal	20	<1500	~180	Single spaced	Sub-angular to sub-rounded	Equant to elongated						
33	Feature III/98	B1	Parallel	Very poor	Bimodal	1	<100		Open spaced	Sub-rounded to rounded	Equant to elongated	20	<2200	~700	Single spaced	Sub-angular to sub-rounded	
34	Feature III/98	A	Weakly parallel	Poor	Uni-modal	30	<900	~150	Close spaced	Sub-angular to sub-rounded	Rounded						
35	Feature III/98	A	Weakly parallel	Poor	Uni-modal	20	<1400	~140	Single spaced	Sub-angular to sub-rounded	Rounded						
36	Feature III/98	B2	Weakly parallel	Very poor	Bimodal	5	<100		Open spaced	Sub-angular to sub-rounded	Equant to elongated	30	<1400	~300	Close spaced	Sub-angular to rounded	
37	Feature III/98	A	Weakly parallel	Poor	Uni-modal	20	<1200	~80	Single spaced	Sub-angular to sub-rounded	Rounded						
38	Feature III/98	A	Weakly parallel	Poor	Uni-modal	30	<1300	~120	Close spaced	Sub-angular to sub-rounded	Equant to elongated						
39	Feature III/98	A	Weakly parallel	Poor	Uni-modal	20	<1600	~140	Single spaced	Sub-angular to sub-rounded	Equant to elongated						
40	Feature III/98	A	Weakly parallel	Poor	Uni-modal	20	<1300	~120	Single spaced	Sub-angular to sub-rounded	Equant to elongated						
41	Feature 62	A	Weakly parallel	Very poor	Uni-modal	15	<1400	~140	Double spaced	Sub-angular to sub-rounded	Equant to elongated						
42	Feature 62	A	Weakly parallel	Very poor	Uni-modal	20	<1800	~200	Single spaced	Sub-angular to rounded	Equant to elongated						

	Mineral temper shape 2	Voids (vol. %)	Voids shape	Biotite pleochroism	Green amphibole pleochroism	Matrix optical activity	Matrix colour	Firing temperature (°c)	Outer layer	Core	Inner layer
		10	Planar; vughs	None		Medium	Reddish yellow, light brown, light grey (+ yellow in XPL)	800–900	Oxidised	Oxidised	Weakly oxidised
		10	Planar; vughs	Weak	Brown-green to brown	High	Yellowish red	750–900	Black-smoked	Oxidised	Oxidised
	Equant to elongated	5	Planar; vughs	None	Green-brown to dark brown	High	Reddish yellow	800–900	Oxidised	Oxidised	Oxidised
		1	Planar	None		Slight	Light brown, dark grey in XPL	~900–950	Reduced	Reduced	Reduced
		10	Planar; vughs	None		Medium	Reddish brown	750–900	Weakly oxidised	Weakly oxidised	Weakly oxidised
		20	Planar; vughs	Weak	Light green-yellow to red-brown	Medium	Reddish brown	750–900	Weakly oxidised	Weakly oxidised	Weakly oxidised
		<5	Planar; vughs	Weak to none	Light green-yellow to red-brown	High-medium, slight in core	Reddish-light brown (+ reddish yellow in XPL)	850–900	Weakly oxidised	Reduced	Weakly oxidised
		10	Planar; vughs	None		Slight-none	Light grey, dark grey in XPL	1000–1050	Reduced	Reduced	Reduced
		10	Planar; vughs	Weak	Light green-yellow to red-brown	Medium	Reddish brown	750–900	Weakly oxidised	Weakly oxidised	Weakly oxidised
		<5	Planar; vughs	Weak	Light green-yellow to red-brown	High, locally inactive	Reddish yellow, yellowish red (+ yellow in XPL)	850–900	Oxidised	Oxidised	Oxidised
		10	Planar; vughs	None	Light green-yellow to red-brown	High	Light-yellowish brown, dark greyish brown below surface	750–900	Weakly oxidised; black-smoked	Weakly oxidised	Weakly oxidised
	Rounded	20	Planar; vughs	None		High, locally inactive	Yellowish-dark yellowish brown (+ brownish yellow in XPL)	800–900	Weakly oxidised	Oxidised	Oxidised
		10	Planar; vughs	None	Light green-yellow to red-brown	Medium-slight	Yellowish-greyish brown	700–800	Weakly oxidised	Weakly oxidised	Weakly oxidised
		10	Planar; vughs	Weak	Brown-green	Medium-slight, locally inactive	Yellowish-dark yellowish brown	850–900	Weakly oxidised	Weakly oxidised	Weakly oxidised
	Rounded	5	Planar; vughs	Weak	Orange-green to dark brown	Medium	Brownish-reddish yellow (+ yellow in XPL)	750–900	Oxidised	Oxidised	Oxidised
		<5	Planar; vughs	Weak	Light green-yellow to brown-green	High	Reddish yellow	750–900	Oxidised	Oxidised	Oxidised
		5	Vughs; planar	Weak	Light green-brown	Medium	Light brown, reddish yellow	750–900	Oxidised	Oxidised	Oxidised
		1	Vughs	Weak	Light greenyellow to red-brown	Medium	Reddish yellow	750–900	Black-smoked	Oxidised	Oxidised
		10	Planar; vughs	Weak		Slight-none	Grey	1000–1050	Reduced	Reduced	Reduced
		5	Planar; vughs	Medium	Transparent to green-brown	High, medium	Pale brown, grey	850–900	Weakly reduced	Reduced	Weakly oxidised
		5	Planar; vughs	Medium	Transparent/ light green to brown-red	High	Brown below surface, reddish yellow, yellowish red	750–900	Oxidised	Oxidised	Oxidised

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ID	Kiln/hoard	Fabric	Microstructure	Sorting	Grain size distribution	Aplastics (vol. %)	Aplastics size (µm)	Avg. aplastics size (µm)	Spacing	Aplastics shape	Aplastics shape 2	Mineral temper (vol. %)	Mineral temper size (µm)	Avg. mineral temper size (µm)	Spacing	Mineral temper shape	
43	Feature 62	A	Weakly parallel	Very poor	Uni-modal	15	<2000	~120	Double spaced	Sub-angular to rounded	Equant to elongated						
44	Feature 62	A	Weakly parallel	Very poor	Uni-modal	20	<1000	~200	Single spaced	Sub-angular to rounded	Equant to elongated						
45	Feature 62	A	Weakly parallel	Very poor	Weakly bimodal	5	<100		Open spaced	Sub-angular to sub-rounded	Equant to elongated	15	<1400	~500	Double spaced	Sub-angular to rounded	
46	Feature 62	A	Weakly parallel	Very poor	Uni-modal	15	<1600	~160	Double spaced	Sub-angular to rounded	Equant to elongated						
47	Feature 62	A	Weakly parallel	Very poor	Weakly bimodal	5	<100		Open spaced	Sub-angular to sub-rounded	Equant to elongated	20	<2200	~500	Single spaced	Sub-angular to well rounded	
48	Feature 62	A	Weakly parallel	Very poor	Uni-modal	15	<1200	~160	Double spaced	Poloostro-hranná- dobře zaoblená	Equant to elongated						
49	Feature 62	A	Weakly parallel	Very poor	Uni-modal	20	<1600	~150	Single spaced	Sub-angular to rounded	Equant to elongated						
50	Feature 62	A	Weakly parallel	Very poor	Uni-modal	15	<1800	~200	Double spaced	Sub-angular to rounded	Equant to elongated						
51	Feature 62	A	Weakly parallel	Very poor	Uni-modal	15	<1400	~200	Double spaced	Sub-angular to rounded	Equant to elongated						
52	Feature 62	A	Weakly parallel	Very poor	Uni-modal	15	<1400	~180	Double spaced	Sub-angular to sub-rounded	Equant to elongated						
53	Feature 62	A	Weakly parallel	Very poor	Weakly bimodal	5	<80		Open spaced	Sub-angular to sub-rounded	Equant to elongated	15	<1400	~400	Double spaced	Sub-angular to well rounded	

Appendix 2-F. Staré Město near Uherské Hradiště – kiln 11, III/98 and hoard f. 62. Description of structural and technological characteristics.

	Mineral temper shape 2	Voids (vol. %)	Voids shape	Biotite pleochroism	Green amphibole pleochroism	Matrix optical activity	Matrix colour	Firing temperature (°c)	Outer layer	Core	Inner layer
		10	Planar; vughs	None	Green-orange to brown-green	High, slight in core	Greyish brown, reddish brown, grey core	850–900	Weakly reduced	Ox-red-ox (multi-layered)	Weakly reduced
		5	Planar; vughs	None	Green-orange to brown-red	High	Light grey, light brown, dark grey below surface (+ reddish yellow in XPL)	750–900	Weakly reduced	Weakly oxidised	Weakly reduced
	Predominantly equant	10	Planar; vughs	None	Green-orange to dark brown	High, none in core	Reddish yellow, yellowish red, light grey core	850–900	Weakly oxidised	Reduced	Oxidised
		<5	Planar; vughs	Weak	Green-orange to dark brown	High	Light brown, reddish yellow	750–900	Weakly reduced	Oxidised	Oxidised
	Predominantly equant	5	Planar; vughs	Medium to none	Transparent to blue-green	Medium, locally inactive	Reddish yellow, dark grey core	850–900	Weakly reduced	Oxidised (localy reduced)	Oxidised
		<5	Planar; vughs	None	Green-orange to dark brown-red	Medium	Reddish yellow, yellowish red	750–900	Oxidised	Oxidised	Oxidised
		5	Planar; vughs	None	Grey-green to dark brown (in reduced zone) and light green-orange (in oxidised zone)	Medlim, slight, none in core	Light brown, brown, grey, yellowish red, reddish yellow	850–900	Oxidised	Reduced	Weakly reduced
		10	Planar; vughs	None	Brown-green to brown-orange	Slight, none in core	Yellowish red, light grey, grey in XPL	850–900	Oxidised	Reduced	Oxidised
		<5	Planar; vughs	None	Transparent to bledě brown-green	Medium	Reddish yellow, light grey (+ yellow in XPL)	750–900	Weakly oxidised	Weakly reduced	Weakly oxidised
		5	Planar; vughs	None	Light green-orange to dark brown-red	High	Light grey, very pale brown (+ yellow in XPL)	750–900	Weakly reduced	Weakly oxidised	Weakly oxidised
	Predominantly equant	<5	Planar; vughs	Weak	Light green-orange to dark brown-red	High	Reddish yellow (+ yellow in XPL)	750–900	Weakly reduced	Oxidised	Weakly oxidised

Characterization of matrix, natural inclusions and matrix.

ID	Fabric	Microstructure	Sorting	Matrix	Grain size distribution	Aplastics (vol. %)	Aplastics size (µm)	Avg. aplastics size (µm)	Spacing	Aplastics shape	Shape 2	Mineral temper (vol. %)	Mineral temper size (µm)	Avg. mineral temper size (µm)	Spacing	Mineral temper shape	
1	A	Unparallel	Poor	Kaolinitic clay with significant amount of silt and sand	Unimodal	30	<3000	~140	Close	Sub-angular	Elongated to equant						
2	A	Slightly parallel	Poor	Kaolinitic clay with significant amount of silt and sand	Unimodal	15	<1200	~150	Double	Sub-angular	Elongated to equant						
3	A	Unparallel	Poor	Kaolinitic clay with significant amount of silt and sand	Unimodal	30	<700	~130	Close	Sub-angular to sub-rounded	Elongated to equant						
4	A	Unparallel	Poor	Kaolinitic clay with significant amount of silt and sand	Unimodal	40	<650	~160	Close	Sub-angular to sub-rounded	Elongated to equant						
5	A	Unparallel	Poor	Kaolinitic clay with significant amount of silt and sand	Unimodal	30	<1200	~160	Close	Sub-angular to sub-rounded	Elongated to equant						
6	A	Unparallel	Poor	Kaolinitic clay with significant amount of silt and sand	Unimodal	30	<1100	~130	Close	Sub-angular to sub-rounded	Elongated to equant						
7	A	Unparallel	Poor	Kaolinitic clay with significant amount of silt and sand	Unimodal	30	<1800	~120	Close	Sub-angular to sub-rounded	Elongated to equant						
8	B	Slightly parallel	Poor	Kaolinitic clay with silt content	Bimodal	10	<30		Open	Sub-rounded	Equant	20	<800	~200	Single	Sub-angular to sub-rounded	
9	B	Slightly parallel	Poor	Kaolinitic clay with silt content	Bimodal	10	<30		Open	Sub-rounded	Equant	20	<1400	~200	Single	Sub-angular to sub-rounded	
10	A	Unparallel	Poor	Kaolinitic clay with significant amount of silt and sand	Unimodal	20	<950	~180	Single	Sub-rounded	Elongated to equant						
11	A	Unparallel	Poor	Kaolinitic clay with significant amount of silt and sand	Unimodal	30	<1000	~250	Close	Sub-angular to sub-rounded	Elongated to equant						
12	A	Unparallel	Poor	Kaolinitic clay with significant amount of silt and sand	Unimodal	15	<800	~140	Double	Sub-rounded	Elongated to equant						
13	A	Slightly parallel	Poor	Kaolinitic clay with significant amount of silt and sand	Unimodal	30	<1000	~140	Close	Sub-rounded	Elongated to equant						
14	A	Unparallel	Poor	Kaolinitic clay with significant amount of silt and sand	Unimodal	20	<600	~180	Single	Sub-angular to sub-rounded	Elongated to equant						

Appendix 2-G. St. Pölten. Description of structural and technological characteristics.

	Mineral temper shape 2	Voids (vol. %)	Voids shape	Optical inactive matrix	Matrix optical activity	Matrix colour	Firing temperature (°c)	Outer surface	Outer layer	Core	Inner layer	Inner surface
		<5	Vughs	Locally	Medium, locally none	White, grey in XPL	~1000		Reduced	Reduced	Reduced	
		5	Vughs, planar	Vitrified or optically inactive	Slight-vitrified	Grey, greyish brown	1000–1100		Reduced	Reduced	Reduced	
		<5	Vughs		Medium	White, light grey, grey in XPL	800–900		Reduced	Reduced	Reduced	
		5	Vughs		Medium	Very dark brown below surface, white, grey in XPL	800–900	Smoked	Reduced	Reduced	Reduced	
		5	Vughs		Medium	Very pale brown, pale brown in XPL	800–900		Slightly oxidised	Slightly oxidised	Slightly oxidised	
		5	Vughs		Medium	Very dark brown below surface, very paly brown, grey in XPL	800–900	Smoked	Reduced	Reduced	Reduced	
		5	Vughs		Medium	Brown below surface, very pale brown, grey in XPL	800–900	Smoked	Reduced	Reduced	Reduced	
	Elongated to equant	5	Vughs, planar	Slightly vitrified	Slight-vitrified	Reddish grey	1000–1100		Oxidised	Oxidised	Oxidised	
	Elongated to equant	5	Vughs, planar	Slightly vitrified	Slight-vitrified	Reddish grey	1000–1100		Oxidised	Oxidised	Oxidised	
		5	Vughs		Medium	Light grey	800–900		Oxidised	Oxidised	Oxidised	
		5	Vughs		Medium	Very pale brown, grey in XPL	800–900		Oxidised	Oxidised	Oxidised	
		5	Vughs	Locally	High/slight, locally none	Very pale brown, grey (+ yellow in XPL)	~1000		Oxidised	Oxidised	Oxidised	
		5	Vughs, planar		Medium	White, light grey, grey in XPL	800–900	Smoked	Reduced	Reduced	Reduced	Smoked
		<5	Vughs		High	Reddish yellow, light grey (+ yellow in XPL)	800–900		Oxidised	Oxidised	Oxidised	

Appendix 3: 3D data statistics

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Pot inventory No.	Vessel part	Mean WT (mm)	SD WT (mm)	CV WT (%)	Mean Y (mm)	SD Y (mm)	CV Y (%)
JiA40_2020_003	Bottom	5.42	0.56	10.35			
JiA40_2020_003	V3	6.61	1.16	17.57	57.13	2.34	4.10
JiA40_2020_003	V4	3.80	0.58	15.20	62.28	1.07	1.72
JiA40_2020_003	V6	5.35	1.19	22.17	59.13	1.31	2.21
JiA40_2020_004	Bottom	6.89	0.83	11.98			
JiA40_2020_004	V3	5.63	1.10	19.47	61.18	3.89	6.36
JiA40_2020_004	V4	3.76	0.58	15.44	69.31	3.08	4.45
JiA40_2020_004	V6	6.47	1.55	23.94	65.49	2.35	3.59
JiA40_2020_012	Bottom	7.04	1.38	19.57			
JiA40_2020_012	V3	5.50	1.13	20.47	57.72	1.48	2.56
JiA40_2020_012	V4	4.27	0.40	9.44	65.28	2.98	4.56
JiA40_2020_012	V6	5.46	1.12	20.45	63.50	2.26	3.56
JiA40_2020_013	Bottom	7.02	1.60	22.77			
JiA40_2020_013	V3	4.72	0.77	16.36	73.98	1.53	2.06
JiA40_2020_013	V4	4.42	0.54	12.16	82.45	2.41	2.92
JiA40_2020_013	V6	6.27	1.53	24.36	79.21	2.60	3.28
JiA40_2020_015	Bottom	5.83	1.13	19.31			
JiA40_2020_015	V3	5.67	1.26	22.25	55.25	2.84	5.13
JiA40_2020_015	V4	3.48	0.51	14.51	63.69	2.27	3.57
JiA40_2020_015	V6	4.92	1.20	24.46	61.25	2.21	3.61
JiA40_2020_016	Bottom	6.12	0.74	12.06			
JiA40_2020_016	V3	5.17	0.88	16.93	64.44	1.93	3.00
JiA40_2020_016	V4	4.94	0.85	17.24	69.30	3.04	4.38
JiA40_2020_016	V6	5.63	1.33	23.69	64.39	1.87	2.90
JiA40_2020_018	Bottom	6.85	1.34	19.52			
JiA40_2020_018	V3	5.45	1.37	25.14	69.61	2.70	3.88
JiA40_2020_018	V4	4.49	0.51	11.26	83.93	1.78	2.12
JiA40_2020_018	V6	6.00	1.69	28.12	78.08	1.59	2.03
JiA40_2020_022	Bottom	4.31	0.83	19.20			
JiA40_2020_022	V3	8.47	2.82	33.30	67.14	2.25	3.36
JiA40_2020_022	V4	4.08	0.45	10.93	74.75	2.58	3.45
JiA40_2020_022	V6	6.18	1.54	24.94	70.06	1.51	2.16
JiA40_2020_023	Bottom	6.79	1.01	14.84			
JiA40_2020_023	V3	6.69	0.79	11.85	90.70	2.35	2.59
JiA40_2020_023	V4	5.56	0.81	14.62	102.75	1.99	1.94
JiA40_2020_023	V6	6.47	1.60	24.75	92.43	1.75	1.89
JiA40_2020_025	Bottom	7.89	1.04	13.14			
JiA40_2020_025	V3	6.09	1.40	22.93	65.31	10.39	15.91
JiA40_2020_025	V4	4.28	0.73	16.95	77.44	7.33	9.47
JiA40_2020_025	V6	5.84	1.68	28.68	73.13	5.90	8.07
JiA40_2020_026	Bottom	5.07	0.71	14.01			
JiA40_2020_026	V3	6.50	1.17	18.00	61.88	1.12	1.80
JiA40_2020_026	V4	4.81	0.64	13.31	67.07	1.45	2.17
JiA40_2020_026	V6	6.13	1.54	25.06	61.59	1.43	2.32
JiA40_2020_030	Bottom	7.06	0.91	12.93			
JiA40_2020_030	V3	8.96	1.81	20.23	88.20	1.94	2.20

Appendix 3-A. Jihlava – U Skály Street. Descriptive statistics for wall thickness (WT) and symmetry along rotational axis (Y) for each vessel part (v6 – bottom to maximum bulge; v4 – maximum bulge to neck; v3 – neck to rim). The table shows the mean, standard deviation (SD), and coefficient of variation (CV).

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Pot inventory No.	Vessel part	Mean WT (mm)	SD WT (mm)	CV WT (%)	Mean Y (mm)	SD Y (mm)	CV Y (%)
JiA40_2020_030	V4	6.34	0.68	10.73	100.41	1.66	1.65
JiA40_2020_030	V6	7.61	1.03	13.59	91.40	0.99	1.08
JiA40_2020_033	Bottom	4.23	0.59	13.88			
JiA40_2020_033	V3	5.36	1.06	19.84	51.45	1.55	3.00
JiA40_2020_033	V4	3.93	0.77	19.51	58.54	1.23	2.11
JiA40_2020_033	V6	4.69	0.99	21.03	52.75	1.46	2.77
JiA40_2020_034	Bottom	4.38	1.08	24.74			
JiA40_2020_034	V3	5.62	1.26	22.38	58.33	1.52	2.60
JiA40_2020_034	V4	4.42	0.88	19.84	67.16	1.89	2.81
JiA40_2020_034	V6	4.73	1.04	22.04	64.35	1.83	2.85
JiA40_2020_045	Bottom	5.97	0.77	12.88			
JiA40_2020_045	V3	3.47	0.48	13.77	79.21	1.14	1.44
JiA40_2020_045	V4	3.16	0.29	9.24	77.08	0.73	0.95
JiA40_2020_045	V6	4.97	1.18	23.68	66.14	1.27	1.91
JiA40_2020_047	Bottom	6.88	2.08	30.19			
JiA40_2020_047	V3	5.37	1.46	27.20	74.99	2.66	3.54
JiA40_2020_047	V4	4.40	0.66	14.93	83.33	2.03	2.44
JiA40_2020_047	V6	6.42	1.76	27.40	79.11	3.12	3.94
JiA40_2020_048	Bottom	7.71	1.27	16.45			
JiA40_2020_048	V3	5.48	1.00	18.29	71.78	1.49	2.08
JiA40_2020_048	V4	4.47	0.58	12.99	83.43	2.67	3.20
JiA40_2020_048	V6	6.69	1.72	25.70	78.95	2.43	3.08
JiA40_2020_049	Bottom	7.57	1.62	21.35			
JiA40_2020_049	V3	6.78	2.02	29.77	75.25	2.48	3.29
JiA40_2020_049	V4	4.39	0.78	17.76	83.43	2.47	2.96
JiA40_2020_049	V6	6.19	1.49	24.04	77.88	2.76	3.54
JiA40_2020_050	Bottom	6.70	1.71	25.59			
JiA40_2020_050	V3	5.60	1.75	31.20	71.64	4.45	6.21
JiA40_2020_050	V4	4.50	0.82	18.21	85.12	3.64	4.28
JiA40_2020_050	V6	5.90	1.59	26.92	81.15	2.91	3.59
JiA40_2020_060	Bottom	4.51	1.28	28.29			
JiA40_2020_060	V3	6.69	1.46	21.90	48.97	3.95	8.06
JiA40_2020_060	V4	4.50	0.85	18.91	49.45	3.39	6.86
JiA40_2020_060	V6	6.14	1.01	16.43	46.54	3.63	7.80
JiA40_2020_062	Bottom	4.04	0.80	19.73			
JiA40_2020_062	V3	5.80	0.66	11.44	57.72	0.84	1.45
JiA40_2020_062	V4	4.22	0.62	14.57	69.51	0.86	1.24
JiA40_2020_062	V6	5.40	1.31	24.29	65.24	1.03	1.58
JiA40_2020_097	Bottom	4.91	0.96	19.45			
JiA40_2020_097	V3	5.94	1.26	21.28	53.63	2.75	5.12
JiA40_2020_097	V4	3.72	0.33	8.82	57.97	1.44	2.49
JiA40_2020_097	V6	4.95	1.32	26.67	54.59	1.21	2.21
JiA40_2020_100	Bottom	5.92	0.89	14.95			
JiA40_2020_100	V3	5.96	1.32	22.08	84.90	4.08	4.80
JiA40_2020_100	V4	4.51	0.56	12.51	101.11	4.41	4.37
JiA40_2020_100	V6	5.90	1.18	20.00	94.12	3.90	4.14

Pot Inventory No.	Vessel part	Mean WT (mm)	SD WT (mm)	CV WT (%)	Mean Y (mm)	SD Y (mm)	CV Y (%)
7_93_233-1	Bottom	6.01	1.55	25.85			
7_93_233-1	V3	6.98	2.14	30.66	100.31	6.24	6.22
7_93_233-1	V4	5.33	0.55	10.27	103.85	5.28	5.09
7_93_233-1	V6	6.77	1.45	21.42	91.44	2.51	2.74
7_93_233-25	Bottom	9.20	2.00	21.76			
7_93_233-25	V3	7.44	1.94	26.08	76.66	2.90	3.78
7_93_233-25	V4	4.34	0.66	15.14	85.10	5.63	6.62
7_93_233-25	V6	7.14	1.95	27.38	77.59	4.78	6.16
7_93_233-5	Bottom	9.12	0.83	9.05			
7_93_233-5	V3	7.56	1.40	18.51	82.00	4.50	5.48
7_93_233-5	V4	4.87	0.45	9.30	89.84	2.92	3.25
7_93_233-5	V6	6.11	1.62	26.52	84.77	1.89	2.23
7_93_233-6	Bottom	6.95	0.75	10.85			
7_93_233-6	V3	6.15	1.61	26.23	68.17	2.61	3.83
7_93_233-6	V4	5.04	0.90	17.85	78.30	1.48	1.89
7_93_233-6	V6	6.45	1.67	25.92	72.68	1.38	1.89
7_93_233-7	Bottom	6.44	1.14	17.70			
7_93_233-7	V3	7.03	1.82	25.84	62.47	1.21	1.94
7_93_233-7	V4	4.35	1.24	28.46	68.11	1.04	1.52
7_93_233-7	V6	5.39	0.72	13.42	62.65	1.22	1.95
7_93_233-9	Bottom	8.72	1.56	17.87			
7_93_233-9	V3	7.25	0.82	11.31	55.88	5.83	10.44
7_93_233-9	V4	4.16	0.90	21.70	65.79	4.74	7.21
7_93_233-9	V6	5.58	1.72	30.91	61.19	3.45	5.64

Appendix 3-B. Jihlava – Křížová Street, kiln 927. Descriptive statistics for wall thickness (WT) and symmetry along rotational axis (Y) for each vessel part (v6 – bottom to maximum bulge; v4 – maximum bulge to neck; v3 – neck to rim). The table shows the mean, standard deviation (SD), and coefficient of variation (CV).

Pot Inventory No.	Vessel part	Mean WT (mm)	SD WT (mm)	CV WT (%)	Mean Y (mm)	SD Y (mm)	CV Y (%)
7_93_233-1	Bottom	6.01	1.55	25.85			
7_93_233-1	V3	6.98	2.14	30.66	100.31	6.24	6.22
7_93_233-1	V4	5.33	0.55	10.27	103.85	5.28	5.09
7_93_233-1	V6	6.77	1.45	21.42	91.44	2.51	2.74
7_93_233-25	Bottom	9.20	2.00	21.76			
7_93_233-25	V3	7.44	1.94	26.08	76.66	2.90	3.78
7_93_233-25	V4	4.34	0.66	15.14	85.10	5.63	6.62
7_93_233-25	V6	7.14	1.95	27.38	77.59	4.78	6.16
7_93_233-5	Bottom	9.12	0.83	9.05			
7_93_233-5	V3	7.56	1.40	18.51	82.00	4.50	5.48
7_93_233-5	V4	4.87	0.45	9.30	89.84	2.92	3.25
7_93_233-5	V6	6.11	1.62	26.52	84.77	1.89	2.23
7_93_233-6	Bottom	6.95	0.75	10.85			
7_93_233-6	V3	6.15	1.61	26.23	68.17	2.61	3.83
7_93_233-6	V4	5.04	0.90	17.85	78.30	1.48	1.89
7_93_233-6	V6	6.45	1.67	25.92	72.68	1.38	1.89
7_93_233-7	Bottom	6.44	1.14	17.70			
7_93_233-7	V3	7.03	1.82	25.84	62.47	1.21	1.94
7_93_233-7	V4	4.35	1.24	28.46	68.11	1.04	1.52
7_93_233-7	V6	5.39	0.72	13.42	62.65	1.22	1.95
7_93_233-9	Bottom	8.72	1.56	17.87			
7_93_233-9	V3	7.25	0.82	11.31	55.88	5.83	10.44
7_93_233-9	V4	4.16	0.90	21.70	65.79	4.74	7.21
7_93_233-9	V6	5.58	1.72	30.91	61.19	3.45	5.64

Appendix 3-C. Kostelec near Jihlava. Descriptive statistics for wall thickness (WT) and symmetry along rotational axis (Y) for each vessel part (v6 – bottom to maximum bulge; v4 – maximum bulge to neck; v3 – neck to rim). The table shows the mean, standard deviation (SD), and coefficient of variation (CV).

Pot inventory No.	Vessel part	Mean WT (mm)	SD WT (mm)	CV WT (%)	Mean Y (mm)	SD Y (mm)
5060 (kiln 1)	Bottom	5.34	0.89	16.60		
5060 (kiln 1)	V3	6.29	1.14	18.04	62.56	4.25
5060 (kiln 1)	V4	3.78	0.93	24.57	72.21	2.90
5060 (kiln 1)	V6	4.47	0.97	21.58	66.32	1.79
5310 (kiln 2)	Bottom	7.03	0.58	8.18		
5310 (kiln 2)	V3	7.46	1.33	17.83	63.04	2.22
5310 (kiln 2)	V4	4.29	0.90	20.92	70.07	1.97
5310 (kiln 2)	V6	4.19	0.53	12.57	65.38	1.54
5311 (kiln 2)	Bottom	4.68	1.34	28.58		
5311 (kiln 2)	V3	7.29	2.54	34.89	69.86	3.94
5311 (kiln 2)	V4	4.15	0.52	12.43	76.22	3.01
5311 (kiln 2)	V6	4.58	1.20	26.14	70.65	1.76

Appendix 3-D. Mstěnice – both kilns. Descriptive statistics for wall thickness (WT) and symmetry along rotational axis (Y) for each vessel part (v6 – bottom to maximum bulge; v4 – maximum bulge to neck; v3 – neck to rim). The table shows the mean, standard deviation (SD), and coefficient of variation (CV).

Pot inventory No.	Vessel part	Mean WT (mm)	SD WT (mm)	CV WT (%)	Mean Y (mm)	SD Y (mm)	CV Y (%)
66_06_349_1	Bottom	8.19	1.44	17.55			
66_06_349_1	V3	5.59	1.25	22.42	62.05	2.95	4.76
66_06_349_1	V4	3.72	0.33	8.75	67.51	1.66	2.47
66_06_349_1	V6	4.93	0.94	19.11	62.23	1.65	2.65
66_06_349_2	Bottom	5.61	1.06	18.86			
66_06_349_2	V3	8.74	1.70	19.42	62.51	4.77	7.62
66_06_349_2	V4	5.17	1.01	19.59	70.57	3.52	4.99
66_06_349_2	V6	4.80	0.78	16.34	66.31	2.83	4.27
66_06_349_3	Bottom	8.37	1.15	13.78			
66_06_349_3	V3	5.42	1.36	25.19	62.44	2.59	4.15
66_06_349_3	V4	4.18	0.52	12.40	69.59	0.88	1.26
66_06_349_3	V6	5.14	0.97	18.79	64.02	1.19	1.85
66_06_349_4	Bottom	5.33	0.65	12.29			
66_06_349_4	V3	5.40	0.92	17.09	59.80	2.43	4.06
66_06_349_4	V4	4.81	0.64	13.22	67.71	1.87	2.77
66_06_349_4	V6	5.11	0.80	15.68	59.49	1.45	2.44
66_06_349_5	Bottom	9.22	0.55	5.93			
66_06_349_5	V3	4.33	1.67	38.50	63.36	0.75	1.19
66_06_349_5	V4	3.05	0.47	15.55	68.25	1.77	2.60
66_06_349_5	V6	5.24	1.44	27.40	64.49	1.50	2.33
66_06_349_6	Bottom	5.35	1.09	20.31			
66_06_349_6	V3	4.33	1.13	26.00	65.61	5.53	8.43
66_06_349_6	V4	4.42	1.72	38.99	72.11	2.30	3.19
66_06_349_6	V6	5.56	1.27	22.83	64.65	2.15	3.33
66_06_349_7	Bottom	6.57	1.37	20.87			
66_06_349_7	V3	4.94	1.51	30.62	67.93	1.66	2.45
66_06_349_7	V4	3.69	0.96	25.94	81.23	2.07	2.55
66_06_349_7	V6	5.42	1.19	22.03	75.59	1.55	2.05

Appendix 3-E. Žďár nad Sázavou – 'Staré Město'. Descriptive statistics for wall thickness (WT) and symmetry along rotational axis (Y) for each vessel part (v6 – bottom to maximum bulge; v4 – maximum bulge to neck; v3 – neck to rim). The table shows the mean, standard deviation (SD), and coefficient of variation (CV).

Pot inventory No.	Vessel part	Mean WT (mm)	SD WT (mm)	CV WT (%)	Mean Y (mm)	SD Y (mm)	CV Y (%)
12393 (kiln III/98)	Bottom	8.56	0.84	9.83			
12393 (kiln III/98)	V3	6.80	1.71	25.13	61.39	3.34	5.44
12393 (kiln III/98)	V4	3.73	0.64	17.26	73.37	1.89	2.57
12393 (kiln III/98)	V6	4.36	0.99	22.78	66.74	1.84	2.76
12394 (kiln III/98)	Bottom	3.99	1.02	25.52			
12394 (kiln III/98)	V3	6.44	1.13	17.59	59.10	2.51	4.25
12394 (kiln III/98)	V4	3.87	0.56	14.42	67.00	1.72	2.57
12394 (kiln III/98)	V6	5.01	0.99	19.86	61.35	1.44	2.35
12395 (kiln III/98)	Bottom	5.54	0.88	15.88			
12395 (kiln III/98)	V3	8.63	2.16	25.00	76.40	5.30	6.94
12395 (kiln III/98)	V4	4.36	0.56	12.91	87.38	3.78	4.33
12395 (kiln III/98)	V6	5.36	1.14	21.33	78.59	2.82	3.59
12396 (kiln III/98)	Bottom	5.85	0.89	15.18			
12396 (kiln III/98)	V3	7.33	0.59	8.07	61.67	4.34	7.04
12396 (kiln III/98)	V4	4.25	0.71	16.63	66.56	2.14	3.22
12396 (kiln III/98)	V6	5.50	1.30	23.56	59.96	2.08	3.48
A31299 (kiln 11)	Bottom	8.34	0.87	10.44			
A31299 (kiln 11)	V3	9.21	1.50	16.32	80.62	3.32	4.11
A31299 (kiln 11)	V4	7.55	1.25	16.61	87.46	2.76	3.15
A31299 (kiln 11)	V6	9.20	2.48	26.98	81.03	2.12	2.62
A31301 (kiln 11)	Bottom	10.66	1.17	11.00			
A31301 (kiln 11)	V3	11.65	2.07	17.74	93.51	1.98	2.11
A31301 (kiln 11)	V4	11.34	3.46	30.50	95.48	2.67	2.80
A31301 (kiln 11)	V6	11.81	2.43	20.61	85.35	2.22	2.60
4 (depot 62)	Bottom	7.36	1.35	18.30			
4 (depot 62)	V3	8.19	3.49	42.67	87.02	5.96	6.85
4 (depot 62)	V4	3.82	0.49	12.95	98.20	3.57	3.64
4 (depot 62)	V6	5.96	1.78	29.86	87.32	1.91	2.19
6 (depot 62)	Bottom	6.47	1.08	16.69			
6 (depot 62)	V3	5.95	1.77	29.79	70.35	2.69	3.82
6 (depot 62)	V4	3.74	0.73	19.61	79.23	2.84	3.59
6 (depot 62)	V6	5.00	1.30	25.92	67.48	1.46	2.17
7 (depot 62)	Bottom	4.62	1.14	24.73			
7 (depot 62)	V3	6.61	1.76	26.68	55.09	4.00	7.26
7 (depot 62)	V4	3.77	0.94	24.87	61.34	1.91	3.11
7 (depot 62)	V6	5.30	1.27	23.90	53.52	1.78	3.32
8 (depot 62)	Bottom	5.62	0.65	11.54			
8 (depot 62)	V3	5.83	1.12	19.21	51.01	0.96	1.88
8 (depot 62)	V4	3.36	0.32	9.58	55.20	0.38	0.69
8 (depot 62)	V6	4.30	0.72	16.82	49.02	0.64	1.30

Appendix 3-F. Staré Město near Uherské Hradiště – kiln 11, III/98 and hoard f. 62. Descriptive statistics for wall thickness (WT) and symmetry along rotational axis (Y) for each vessel part (v6 – bottom to maximum bulge; v4 – maximum bulge to neck; v3 – neck to rim). The table shows the mean, standard deviation (SD), and coefficient of variation (CV).

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Videos

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From clay to kiln

Medieval pottery production in the Bohemian-Moravian Highlands, eastern Moravia and Lower Austria

Rudolf Procházka, Kateřina Těsnohlídková, Karel Slavíček, Gabriele Scharrer-Liška, Eva Nová, Martin Košťál, Dalibor Všianský

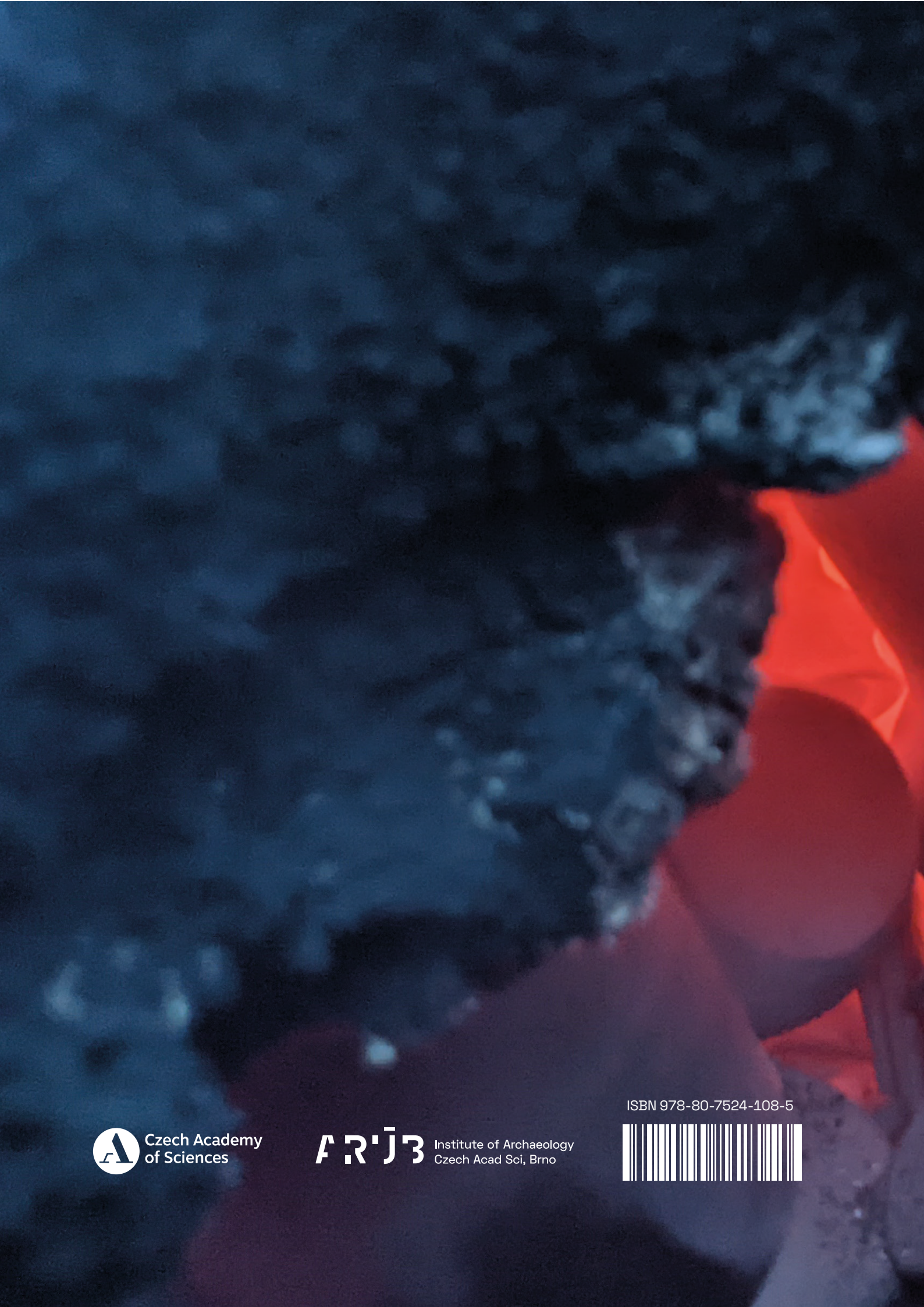
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